

Geothermal vegetation of the Waikato Region, 2023

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GEOHERMAL VEGETATION OF THE WAIKATO REGION, 2023



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EXECUTIVE SUMMARY

Geothermal activity is associated with the surface release of geothermal heat. This heat release is associated with elevated subsurface soil temperatures, boiling groundwater and surface water, and the emission of steam and gas, including carbon dioxide and hydrogen sulphide. These all constitute significant environmental stressors, that limit the survivorship and growth of most plants and animals. As a result, geothermal environments are occupied by a unique assemblage of plants and animals that are tolerant of the heat and chemically-induced stress, particularly subsurface soil temperature. These assemblages include species normally found in tropical and subtropical climates, lower altitude habitats, and species capable of surviving elevated soil temperatures or hydrothermally altered soils, often with unusual soil chemistry. The geothermal vegetation of the Waikato Region includes populations of several plant species that have been classified as Threatened or At Risk at a national level.

This study provides an updated inventory of the current distribution, condition, extent and ecological values of geothermal vegetation and habitats in the Waikato Region, where almost 75% of New Zealand's geothermal systems occur. Waikato Regional Council has significant responsibilities for the management of geothermal systems and associated habitats.

This report presents findings from the 2022-2023 update to the inventory of geothermal habitats in the Waikato Region. Forty-six sites with geothermal vegetation, located within 14 geothermal systems and 17 geothermal systems have been identified, mapped, described, and assessed for significance in this report. For each site the vegetation types, site boundaries, and location relative to other sites are mapped. A history of ecological assessment of geothermal habitat provides context for the current inventory, which is complemented with a section on the ecological context. Changes in site conditions, management actions, and threats are all considered.

Since the last inventory study in 2014, an additional 142.8 hectares of geothermal vegetation has been mapped, however most of this area is the result of discovery of additional areas of existing habitat as the quality and resolution of aerial photography continues to improve. Real increase in vegetation extent was noted for two sites covering only relatively small areas. Overall, the extent of geothermal vegetation across the Waikato Region has been relatively stable in the last ten years. Minor real reductions have occurred at some sites due to increases in pest plant cover and, in some cases, from herbicide use on site margins. However, real decreases in extent large enough to be seen have not occurred. Real increase in vegetation extent was noted for two sites. Te Maari Craters increased in size after eruptions, and Waikite Valley where restoration effort has expanded the wetland area.

The condition of many sites has changed positively as a result of ecological restoration effort. However, some sites are in poorer condition since the last survey, mainly as a result of pest plant expansion. Many geothermal areas have been fenced in the past 10 or more years, but in many cases where no other restoration effort has taken place, this has resulted in a significant increase in blackberry.

Future surveys should be undertaken in five years' time or, for sites where land access permission was not obtained for this study, as soon as possible. Restoration effort should focus on fencing, weed control, pest animal control (especially of pigs), and buffer planting.

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1. INTRODUCTION

Arc-related volcanic activity in the Te Ika-a-Māui/North Island commenced around 25-23 million years ago, and was characterised by andesite-dominant eruptions (Pittari *et al.* 2021). At around four million years ago the nature of volcanic activity began to change, with rhyolite-dominated eruptions commencing and becoming more frequent (Briggs *et al.* 1995). From 3.0 to 0.9 million years ago there was a south-east migration of the volcanic arc in response to the changes in tectonic rifting that have formed the Havre Trough (Pittari *et al.* 2021). The current centre of the volcanic arc is the Taupō Volcanic Zone (Briggs *et al.* 1995; Pittari *et al.* 2021).

Volcanic activity is associated with intrusion of magma into the earth's crust to shallow depths. These intrusions heat surrounding host rocks, which in turn heat and cause to convectively circulate meteoric groundwaters¹. Where these heated ground waters circulate to the earth's surface, geothermal features occur, including hot springs, and fumaroles. Hot springs often deposit large volumes of silica and other dissolved salts, forming silicified deposits characteristic of geothermal activity including sinter.

Widespread remnants of silicified deposits within the Whitianga Volcanic Centre, which was active during the Late Miocene (Hamilton *et al.* 2019), suggest that geothermal surface features have a long history of association with centres of volcanic activity in the North Island.

Like the volcanic systems associated with them, geothermal surface features form, are active, and senesce on geological time scales.

The Taupō Volcanic Zone is an 18,000 square kilometre zone of crustal extension characterised by high heat flow (2600 MW/100 km) along the rift axis (Bibby *et al.* 1995; Drake *et al.* 2014). There are more than 20 geothermal systems within the Taupō Volcanic Zone whose hot reservoir temperatures are greater than 250 degrees Celsius (Drake *et al.* 2014).

The current phase of active volcanism within the Taupō Volcanic Zone is relatively young, having commenced during the Quaternary, some 1.6 Ma years ago (Wilson *et al.* 1995). The geothermal surface features associated with this volcanic activity are also relatively young. For example, hydrothermal activity at Mangatete commenced around 36 thousand years ago, and ceased around two thousand years ago, with activity spikes and intervening periods of quiescence related to local fault movement (Drake *et al.* 2014).

1.1 Geothermal habitats

Geothermal activity is associated with the surface release of geothermal heat. This heat release constitutes a significant environmental stress, as it is associated with elevated subsurface soil temperatures, with boiling groundwater and surface water, and the emission of steam and gas, including carbon dioxide and hydrogen sulphide. These environmental stressors limit the survivorship and growth of most plants and animals. As a result, geothermal habitats are occupied by a unique assemblage of plants and animals that are tolerant of the heat and chemically-induced stress, particularly the

¹ Groundwater that is derived from precipitation.

subsurface soil temperature. These assemblages include species normally found in tropical and subtropical climates and lower altitudes, and species capable of surviving elevated soil temperatures or hydrothermally altered soils (Given 1980).

1.2 Waikato Region

The Waikato Region covers nearly 24 thousand square kilometres from Coromandel-Colville in the north to Mount Ruapehu in the south, to Mokau in the west, and onto the Kāingaroa Plains and Kāingaroa Forest in the east (Figure 1). A significant proportion of the Taupō Volcanic Zone is part of the Waikato Region.

Almost 75% of New Zealand's geothermal systems occur within the Waikato Region. Areas of surface activity associated with most of these are outside public conservation land. Waikato Regional Council therefore has significant responsibilities for the management of geothermal systems and associated habitats.

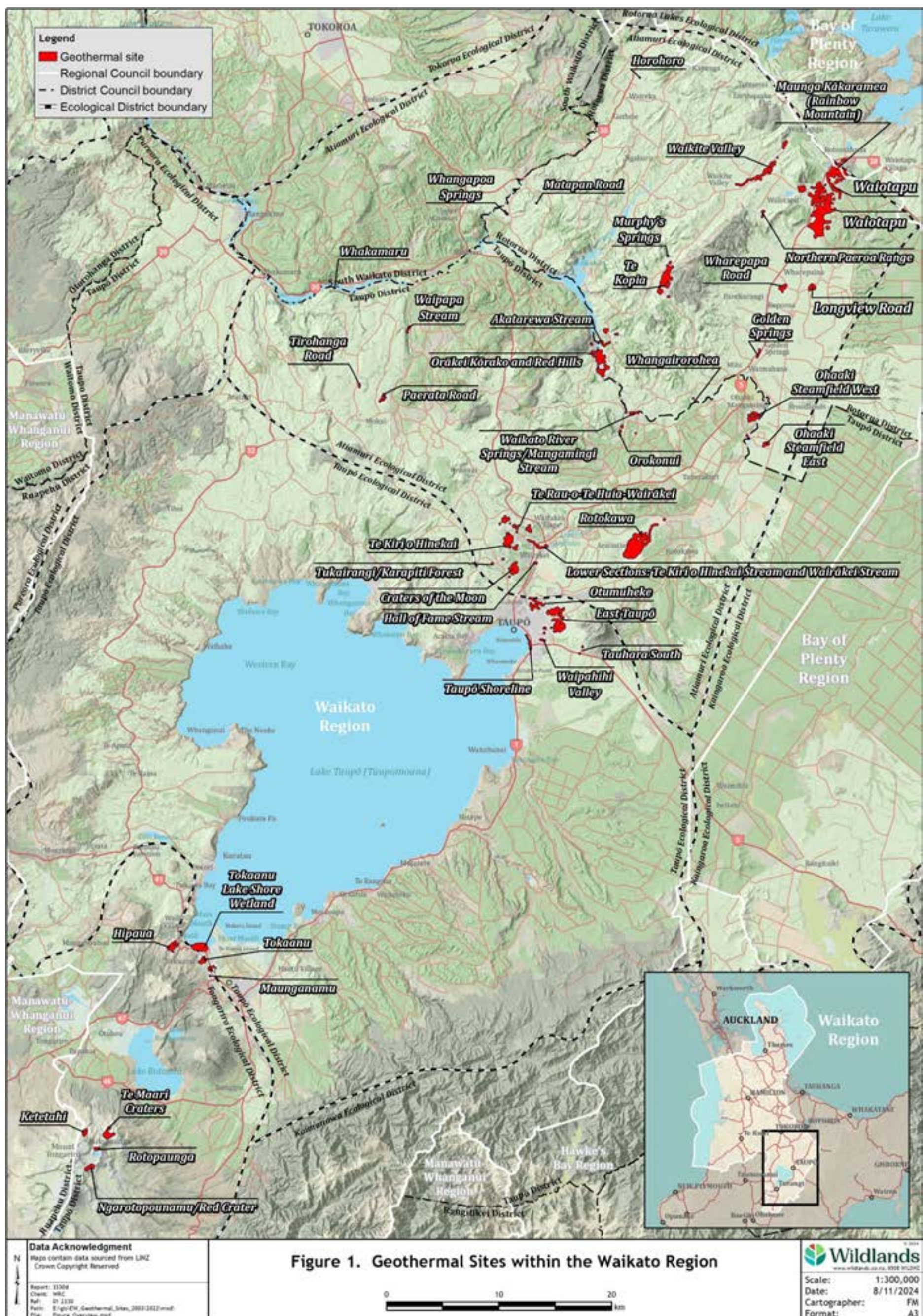
1.3 Purpose

This study provides an inventory of the current distribution, extent, and character of geothermal vegetation in the Waikato Region, and includes an assessment of the relative significance of each site based on criteria defined in the Waikato Regional Policy Statement (2016). This study updates the 2014 geothermal inventory report (Wildland Consultants 2014a), and will enable management of the varied characteristics of the geothermal resource, as required by the Waikato Regional Policy Statement.

Geothermal areas are appreciated for their historical, amenity, cultural, spiritual, conservation, tourism, and scientific values (Waikato Regional Council 2007; Merrett & Clarkson 1999, Luketina 2010). Threats to these values include geothermal energy extraction, the utilisation of mineralised fluids, and tourism operations. Other threats include pest animal and plant invasion and spread, insensitive plantation forestry practices, and clearance associated with changes in site use. If these threats are not monitored and controlled, ecological values of sites will decline. Examples of loss at geothermal sites include the loss of features such as geysers, flowing springs, sinter terraces, and geothermally heated ground, and loss of geothermal habitats and threatened plants. The Waikato Regional Council management objectives, which are derived from consideration of these issues, are to maintain the extent and variety of geothermal characteristics within the region, and to achieve protection and efficient take of the regional geothermal resource (Waikato Regional Council 2007). The Waikato Regional Council aims to do this by¹:

- Researching and identifying geothermal systems and their features.
- Classifying geothermal systems to determine the best management approaches.
- Encouraging the reuse and reinjection of used geothermal energy and fluid.
- Promoting sustainable management of Development Systems through stepped production and System Management Plans.

¹ <https://www.waikatoregion.govt.nz/environment/geothermal/resources>: Accessed 12 April 2023.



1.4 Structure

This report presents findings from the 2022-2023 update to the inventory of geothermal habitats in the Waikato Region. A history of ecological assessment of geothermal habitat provides context for the current inventory, which we complement with a section on the ecological context. The methods employed to complete this inventory are then described in detail, including an explanation of the arrangement of site descriptions, and the assessment of significance. Changes in extent of geothermal vegetation and habitats are a central outcome of this inventory survey, and detailed discussion of these is provided in a dedicated section. The report also considers threats to geothermal vegetation and habitats, and opportunities for ecological restoration.

2. HISTORY OF ECOLOGICAL ASSESSMENT

The earliest descriptions and assessments of geothermal vegetation and flora in the Waikato Region were compiled on a site-by-site basis. Vegetation and flora at Karapiti (Craters of the Moon) was described by Given (1980). Assessments of geothermal areas at Maungaongaonga, Maunga Kākaramaea (Rainbow Mountain), Waiotapu, and Te Kopia were provided by Clarkson (1981a, 1981b, 1982, 1984, 1987). The first description of botanical values across multiple geothermal sites, being those then administered by the Waikato Catchment Board, was completed by Given (1989a). The first assessments of relative botanical values of geothermal sites were completed by Given (1995, 1996).

Merrett and Clarkson (1999) compiled an annotated bibliography of reports relevant to geothermal vegetation occurring within the boundaries of the Waikato Region.

The first comprehensive inventory and assessment of geothermal sites in the Waikato Region was produced by Wildland Consultants (2000). This inventory was progressively updated in 2003 and 2004, and from additional field surveys and assessment of 2002 aerial photographs that were not available in 2003 (Wildland Consultants 2003, 2004c). Several sites were resurveyed between 2006 and 2007 and their information updated (Wildland Consultants 2006, 2007a, and 2007b).

A full update of the Waikato Region geothermal vegetation inventory was undertaken in 2012 based on field survey of 37 sites completed between June 2010 and June 2011, and assessment of 2007 aerial photographs (Wildland Consultants 2012).

Field surveys of 25 sites were undertaken in 2014, and the vegetation types updated based on both field observation and assessment of 2012 WRAPS aerial photographs (Wildland Consultants 2014a). In total, 64 geothermal sites were included in the 2014 inventory (Wildland Consultants 2014a).

Since 2014 one new site has been identified at Tongariro (Wildland Consultants 2018), and sites within the Wairākei-Tauhara Geothermal System, as well as Orakonui and Waipapa Stream were field surveyed and updated by Wildland Consultants (2021b).

3. ECOLOGICAL CONTEXT

Geothermal vegetation (as defined in Section 4) is naturally rare in Aotearoa New Zealand (Williams *et al.* 2007) and internationally. Approximately 75% of the total extent of Aotearoa New Zealand's geothermal vegetation occurs within the Waikato Region, with almost all of the remainder in the Bay of Plenty Region (Fitzgerald and Smale 2010) all within the Taupō Volcanic Zone. A few geothermal features are also present in the part of the Taupō Volcanic Zone within the Manawatū-Whanganui (Horizons) Region on the upper slopes and summit of Ngāuruhoe, Te Wai-ā-Moe/Crater Lake on Ruapehu and possibly elsewhere in Tongariro National Park. Few other examples of geothermal vegetation are known from elsewhere in Aotearoa New Zealand. The Ngāwhā Geothermal System in Northland (near Kaikohe) is the only high temperature geothermal system in New Zealand outside of the Taupō Volcanic Zone, but has only a relatively small area of geothermal vegetation (Cox & Browne 1991 and 1992). Other geothermal features occur in the Hauraki Gulf and in scattered hot springs in the North Island and South Island (Mongillo & Clelland 1984), but there is little to no associated geothermal vegetation at these sites. There is also geothermal vegetation present on the Kermadec Islands, but this has not been formally mapped and described (Sykes 1977).

The varied nature of geothermal surface manifestations, due to varying combinations of temperature, chemistry, hydrology, and local protection from frosts, produces rare and unusual habitats for plants (Burns 1997b, Given 1980 & 1989, Merrett & Clarkson 1999). These habitats include plants capable of surviving elevated soil temperatures, disjunct populations found a considerable distance from other sites of the same species which are usually confined to warmer climates, and local endemic species and distinct genetic forms arising where ground temperatures are sufficiently stable (Given 1989). Many geothermal sites are dynamic and unstable and changes in surface geothermal activity are reflected in relatively rapid changes in the extent and composition of geothermal vegetation. Species present in geothermal habitats can be divided into three groups:

- (i) Relatively common indigenous plant species able to tolerate conditions within geothermal habitats, and which may also occur in neighbouring non-geothermal vegetation. Examples of such species include mānuka (*Leptospermum scoparium*), mingimingi (*Leucopogon fasciculatus*), monoao (*Dracophyllum subulatum*), and tūrutu (*Dianella nigra*).
- (ii) Plant species that are relatively uncommon, either at other sites in New Zealand or outside of New Zealand. Geothermal sites mimic aspects of these species' usual habitats outside of their normal latitudinal and/or altitudinal ranges (Given 1995). These include taxa that occur in warmer climates outside New Zealand, but within New Zealand only occur at geothermal sites. Examples are the ferns *Nephrolepis flexuosa*, *Dicranopteris linearis*, and *Christella* aff. *dentata* ("thermal"). Other species occur in geothermal areas at higher altitudes than in their normal range, including the ferns *Cyclosorus interruptus*, *Hypolepis dicksonioides*, *Schizaea dichotoma*, and *Thelypteris confluens* and the fern allies *Lycopodiella cernua* and *Psilotum nudum*. Many of these species are frost-intolerant and conditions such as steam and heated soils protect them from these cold events.

- (iii) Species endemic to New Zealand geothermal habitats. One of the most interesting is the shrub, geothermal kānuka (*Kunzea tenuicaulis*)¹, which is endemic to New Zealand and only occurs in geothermal habitats. Its form varies in relation to soil temperatures, becoming shorter as soil temperatures increase. Geothermal kānuka has an ectomycorrhizal association with the fungus *Pisolithus* (Moyersoen & Beever 2004). Recent taxonomy indicates that there is more diversity in this genus than previously understood, with at least four species of *Pisolithus* present at geothermal sites in Aotearoa New Zealand. *P. thermalis* and an undescribed species have only been recorded from geothermal sites within Aotearoa New Zealand (Lebel *et al.* 2018).

Twenty-one nationally ‘Threatened’, ‘At Risk’ or ‘Data Deficient’ vascular plant species (as per de Lange *et al.* 2018) are known from geothermal sites in New Zealand (Table 1). Fifteen of these occur in geothermal habitats in the Waikato Region, which contains the largest populations of geothermal kānuka in New Zealand, and key populations of six other ‘At Risk’ species. Some populations of some species are presumed to have become extinct, for example *Cyclosorus interruptus* is thought to have become extinct at two geothermal sites (Te Rau-o-Te Huia-Wairākei and Tokaanu) in the last 50 years, and *Christella* aff. *dentata* (“thermal”) is now presumed extinct at three sites in the Taupō Volcanic Zone for which historic records are available (Te Kiri o Hinekai, Tokaanu, and Te Rau-o-Te Huia-Wairākei). *Nephrolepis flexuosa* has become extinct at three sites (Rotokawa, Horohoro, and Tokaanu) (Bycroft & Beadel 2007). The cause of extinction at most of these sites is due to changes in the character of the sites where these species occurred; these species require specialised habitat and changes to conditions caused by any factor or a combination of factors, including hydrological processes (including energy development and wetland drainage), pest plant competition and pest animal impacts, vegetation clearance, and other land development can alter the habitat so that it is no longer suitable for *C. interruptus*, *C.* aff. *dentata* (“thermal”) or *N. flexuosa*. Significant declines in the population of these three species at Otumuheke have occurred since 2014 due to the decline in geothermal springs and steamy habitats here. Some extinctions (particularly of very small populations) may be as a result of natural changes in population size, as well as natural changes to the characteristics of surface geothermal features (e.g. extent of geothermal activity and changes in chemical characteristics of the feature) and volcanic eruption.

Vegetation and habitats present at geothermal sites include scrub, shrubland, fernland, lichenfield, mossfield, rushland, sedgeland, reedland, herbfield, forest, treeland tussockland, open water, and geothermally-influenced bare ground. The vegetation is highly variable, reflecting soil temperatures, the presence of permanent water and ephemeral wetlands, acidity and other chemical aspects of soil and water, altitude, and the age of the geothermal activity at a particular site. Within the Taupō Volcanic Zone, geothermal vegetation occurs over a wide range of altitudes, from sea level to the summits of the central North Island volcanoes. Soil chemistry and temperature (environmental gradients) strongly influence vegetation at geothermal sites (c.f. Given 1980, Burns and Leathwick 1995).

¹ See Section 6.12 of this report for a discussion of the 2014 revision of *Kunzea* taxonomy (de Lange 2014).

Isolated surface geothermal expressions occur elsewhere in the Waikato Region, but they are generally very small (usually small surface springs) and are not known to contain any geothermal vegetation of ecological significance. Many of these small geothermal expressions have been converted into bathing pools, while others are hot springs (e.g. springs at Kawhia in western Waikato and Hot Water Beach in the Coromandel) amongst sand on the ocean edge and do not support any vegetation. They do not fall within the scope of this study.

Table 1: Nationally 'Threatened' and 'At Risk' vascular plant taxa¹ of geothermal habitats in the Waikato Region².

Scientific Name	Threat Ranking
<i>Korthalsella salicornioides</i> ⁺	Threatened-Nationally Critical
<i>Christella</i> aff. <i>dentata</i> ("thermal") ⁺	Threatened-Nationally Endangered
<i>Dicranopteris linearis</i> ⁺	Threatened-Nationally Endangered
<i>Kunzea tenuicaulis</i> ⁺	Threatened-Nationally Endangered
<i>Anogramma leptophylla</i>	Threatened-Nationally Vulnerable
<i>Kunzea serotina</i>	Threatened-Nationally Vulnerable
<i>Kunzea robusta</i> [*]	Threatened-Nationally Vulnerable
<i>Metrosideros excelsa</i> [*]	Threatened-Nationally Vulnerable
<i>Cyclosorus interruptus</i> ⁺	At Risk-Declining
<i>Leptospermum scoparium</i> [*]	At Risk-Declining
<i>Caladenia alata</i> ⁺	At Risk-Naturally Uncommon
<i>Caladenia atradenia</i>	At Risk-Naturally Uncommon
<i>Calochilus paludosus</i> ⁺	At Risk-Naturally Uncommon
<i>Calochilus robertsonii</i> ⁺	At Risk-Naturally Uncommon
<i>Corunastylis pumila</i>	At Risk-Naturally Uncommon
<i>Fimbristylis velata</i>	At Risk-Naturally Uncommon
<i>Hypolepis dicksonioides</i> ⁺	At Risk-Naturally Uncommon
<i>Nephrolepis flexuosa</i> ⁺	At Risk-Naturally Uncommon
<i>Schizaea dichotoma</i> ⁺	At Risk-Naturally Uncommon
<i>Thelypteris confluens</i> ⁺	At Risk-Naturally Uncommon
<i>Thelymitra colensoi</i>	Data Deficient

+ Key populations of these species are present at geothermal sites within the Waikato Region and thus survival of these populations at geothermal sites is very important for conservation of the species in Aotearoa New Zealand.

* These species threat rankings are influenced by the risk of myrtle rust; see Section 6.11 for more detail.

4. GEOTHERMALLY INFLUENCED VEGETATION

Geothermally influenced terrestrial and emergent wetland vegetation are plant communities that have compositional, structural, and/or growth rate characteristics determined by current or former inputs of geothermally-derived energy (heat) or material (solid, fluid, or gas).

Merrett & Clarkson 1999

¹ As per de Lange *et al.* (2018).

² Two other species – flying duck orchid (*Caleana minor*) (Threatened-Nationally Critical) and *Machaerina complanata* (Threatened-Nationally Vulnerable) - have been recorded in geothermal habitats in the Bay of Plenty and Northland regions, respectively.

Compositional, structural, and/or growth rate characteristics of geothermally influenced terrestrial and emergent wetland vegetation include the unexpected presence of species usually found in warmer climates or at lower altitudes or southerly latitudes (disjunct populations), prostrate or stunted growth forms, and reduced growth rates. Merrett & Clarkson (1999) classified geothermal habitats into four broad categories:

- heated ground.
- geothermal wetlands.
- cooled hydrothermally altered soils.
- atmospheric influence from regular toxic gas emissions, or warm micro-climates created by hot-springs discharge.

In this report, the ‘cooled hydrothermally altered soils’ and ‘heated ground’ categories of Merrett and Clarkson (1999) have been included in the category ‘geothermally-influenced bare ground’. Explanations of these categories are provided below.

4.1 Geothermally-influenced bare ground

Geothermally-influenced bare ground includes Merrett and Clarkson’s (1999) ‘heated ground’ and ‘cooled hydrothermally altered soils’ geothermal habitats. Merrett and Clarkson used the term ‘nonvegetated raw-soilfield’ for what in this assessment is termed geothermally-influenced bare ground.

Merrett and Clarkson (1999) defined nonvegetated raw-soilfield as areas that are bare of vegetation and that are either too hot to support plant life, are cooled by hydrothermally altered sinter pavements, or are subjected to regular mud ejection or gas emission that prevent colonisation and established plants. These areas are often small, and may not be visible on aerial photographs.

Heated ground comprises geothermally heated soils that generally have temperatures above 20 °C at 10 cm depth and increasing temperature with depth. Vegetation growing on heated ground comprises terrestrial geothermal vegetation.

Very hot soils are often associated with steam vents and/or boiling mud craters, and soil temperatures at 10 cm depth are usually >90 °C.

Vigorously boiling mud pools and craters that regularly eject hot mud around margins effectively prevent plant colonisation. Where toxic gas is emitted, vegetation is either absent, or if present, killed.

Hydrothermally altered soils often occur where geothermal expression has ceased, e.g. dried mud craters, which result in soils with unusual chemical composition. Cooled hydrothermally altered soils comprise habitats where geothermal heating has ceased, but the chemically altered soils restrict plant colonization and diversity. These habitats include inactive craters and solfataras, old sinter pavements, and dried mud pools.

4.2 Atmospheric influence

Habitats subject to (a) regular toxic gas emissions to the extent that vegetation growth is negatively influenced (e.g. Whakaari/White Island), or (b) a warm micro-climate

created by hot-springs discharge (e.g. the fern *Christella* aff. *dentata* (“thermal”) occurs along the margins of hot streams where the atmosphere is influenced by steam) (Merrett and Clarkson 1999).

5. GEOTHERMAL ECOSYSTEMS

5.1 Overview

In studies delimiting 72 Naturally Uncommon Ecosystems in Aotearoa New Zealand, Williams *et al.* (2007), Holdaway *et al.* (2012) and Wiser *et al.* (2013) identified five naturally uncommon geothermal ecosystems. These are described below, and a sixth ecosystem type, geothermal wetland, which was not recognised is described and justified below. Table 2 explains the relationship between these ecosystem types and those used in this report.

Table 2: Relationship between ecosystem types and habitat definitions used in this report.

Uncommon Ecosystems (Williams <i>et al.</i> 2001; Holdaway <i>et al.</i> 2012; Wiser <i>et al.</i> 2013)	Merret & Clarkson (1999) Habitats	Geothermal Ecosystems (this report)
Acid rain	Atmospheric influence (a)	Acid rain systems
Hydrothermally altered ground (now cool)	Cooled hydrothermally altered soils	Geothermally influenced bare ground
Heated ground (dry)	Heated ground Nonvegetated raw-soil field	
Geothermal streamsides	Atmospheric influence (b)	Geothermal streamsides (steamy habitats)
Fumaroles	Atmospheric influence (b)	Fumaroles (steamy habitats)
	Geothermal wetland	Geothermal wetlands
		Open geothermal water

5.2 Acid rain systems

“Acid rain is derived from craters and fumaroles associated with volcanoes or other forms of geothermal activity, such as those on White Island (Whakaari), which can continually omit gases at rates of several hundred to several thousand tonnes per day. These gases are mostly steam, carbon dioxide and sulphur dioxide, with small quantities of halogen gases (chlorine and fluorine). The acidic gases combine with water in the steam/gas clouds to form acidic liquid droplets. Volcanic gases at White Island are discharged at high temperatures (100-800 °C). Fallout of this material is highly toxic and corrosive so that plant life is very limited”¹

Acid rain systems are challenging to delimit in the field, and may be difficult to distinguish from fumaroles. In the Waikato Region acid rain systems may occur around Ketetahi and the Te Maari Craters, especially following the 2012 eruptions. Small areas of acid rain systems may be present at Waitapu, Te Kopia, Te Kiri o Hinekai, and other geothermal sites.

¹ <https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/geothermal>: Accessed 18 April 2023)

5.3 Hydrothermally-altered ground (now cool)

“Hydrothermally altered soils have been changed by geothermal steam and are highly infertile, being strongly acidic, with low amounts of organic matter and phosphorus, and sometimes high concentrations of metals and trace elements (Given 1980). This ecosystem is dominated by scrub, mostly of geothermal kānuka”¹

This type is widespread at geothermal sites across the Waikato Region, where it occurs both as a result of natural temporal changes in geothermal manifestations and as a result of induced declines in surface activity levels associated with geothermal energy generation. An example of the latter is presented by the Wairākei-Tauhara Geothermal System where hydrothermally-altered bare ground (now cool) is becoming more abundant as the site cools following the heat pulse induced by extraction draw-down. Through time these features slowly lose their geothermal character as the traces of past geothermal influence decline.

5.4 Heated ground (dry)

“Geothermally heated soils result from heat flow through the ground in contrast to heat losses from water sources or fumaroles, overflow from geysers and springs, or seepages to nearby lakes or rivers). The heat flowing through the heated ground is released at the surface as steam.”²

This habitat is one of the most widespread habitat types at geothermal sites and is present at almost all of the larger geothermal sites in the Waikato Region. Most sites in the montane bioclimatic zone are dominated by shrubs, particularly geothermal kānuka, but also mingimingi, mānuka, monoao, prickly mingimingi (*Leptecophylla juniperina* subsp. *juniperina*) and ferns. The warmest temperature soils are devoid of vegetation, with mosses and *Lycopodiella cernua* appearing as soils cool, with other shrub species and ferns becoming more abundant the cooler the soil gets. Of the woody species geothermal kānuka is most tolerant of soils with elevated temperatures. The most extensive areas of geothermal kānuka associated with this ecosystem are present at sites in the Waikite-Waiotapu-Waimangu, Orākei Kōrako, Te Kopia, Wairākei-Tauhara, Rotokawa and Ohaaki Geothermal Systems. Many of the Threatened and At Risk fern species are associated with this ecosystem, particularly *Dicranopteris linearis* at sites such as Orākei Kōrako and Red Hills, Te Kopia and Te Kiri o Hinekai. *Nephrolepis flexuosa* often utilises this habitat at sites such as Te Rau-o-Te Huia-Wairākei, Te Kiri o Hinekai, Te Kopia and Maunga Kākarama (Rainbow Mountain), with the orchid *Calochilus paludosa* also present at Maunga Kākarama. *Thelymitra* and *Caladenia* species are present such as *T. colensoi* at Orākei Kōrako and *C. alata*, and *C. atradenia* at Maunga Kākarama (Rainbow Mountain). *Korthalsella salicornioides* is occasionally present on the branches of geothermal kānuka and mānuka, e.g. Te Kopia. In this habitat type at Rotokawa, one of the largest populations of *Calochilus robertsonii* occurs in the Waikato Region. Small pockets of this type within forest on Maunga Kākarama (Rainbow Mountain), Orākei Kōrako, and Te Kopia include populations of *Schizaea dichotoma*. This ecosystem type is one of

¹ <https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/geothermal>: Accessed 18 April 2023)

² <https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/geothermal>: Accessed 18 April 2023)

the most important geothermal habitat types for Threatened and At Risk vascular plant species.

5.5 Geothermal streamsides

Geothermal streamsides are steam-influenced microhabitats created by hot springs and streams that allow species (particularly those with tropical origins) to exist in areas that would otherwise be too cold. For example, harakeke (*Phormium tenax*) and pukio (*Carex secta*) grow beside the hot pools in the Copland Valley at 450 m, a higher altitude than elsewhere in Westland.¹

This term would be better defined as steamy habitats, as it is often found near large and small hot springs, steaming ground and alongside heated streams downstream of geothermal springs, as well as geothermal streams and alongside the edges of geothermal pools, mudpools, geysers, and margins of geothermal wetlands. This matches more with most of the habitats (excluding acid rain systems) under the definition for ‘atmospheric influence’ type b of Merrett and Clarkson (1999) – see Table 2. Geothermal streams and other steamy habitats often support important populations of key Threatened and At Risk vascular plants including *Nephrolepis flexuosa*, *Christella* aff. *dentata* (“thermal”), and *Hypolepis dicksonioides*. Streamsides in the Waikite Valley support key populations of *Christella* aff. *dentata* (“thermal”), *Hypolepis dicksonioides* and *Nephrolepis flexuosa*. Other important geothermal streamside sites for *Christella* aff. *dentata* (“thermal”) include Waipapa Steam, Akatarewa Stream, Orākei Kōrako, Otumuheke Stream and Lower Te Kiri o Hinekai Stream. Important streamside sites for *N. flexuosa* include Waikite Valley, Akatarewa Stream and a small population at Otumuheke Stream. *Hypolepis dicksonioides* is also present on streamsides in the Wairākei-Tauhara Geothermal System. A recent finding in this ecosystem type in lower parts of Te Kiri o Hinekai Stream in 2022 was a population of annual fern (*Anogramma leptophylla*), a new record for geothermal sites in the Waikato Region.

5.6 Fumaroles

“Fumaroles are vents or openings that issue steam and hydrogen sulphide and other gases, and are usually associated with past or current magmatic activity. Constant steam allows frost-sensitive species to survive on fumarole margins, including otherwise tropical ferns (listed below; Given 1980). The moss *Campylopus pyriformis* can be important close to fumaroles where soil temperatures are too hot for vascular plants. Low soil pH also limits the species that can survive in these areas.”²

Fumaroles are abundant at most large geothermal sites in the Waikato Region with extensive areas of the heated ground (dry) ecosystems, e.g. sites in the Waikite-Waiotapu-Waimangu Geothermal System, Orākei Kōrako and Red Hills, Te Kopia, sites in Wairākei-Tauhara Geothermal System, Rotokawa, and geothermal sites on Tongariro. There are few species specifically associated uniquely with fumaroles, although species that are abundant in heated ground (dry) are often more abundant

¹ <https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/geothermal>: Accessed 18 April 2023)

² <https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/geothermal>: Accessed 18 April 2023)

around fumaroles including *Dicranopteris linearis*, *Lycopodiella cernua*, and *Campylopus pellidus*.

5.7 Geothermal wetlands

In no published scheme are geothermal wetlands recognised as a naturally uncommon ecosystem, however due to the presence of many of the threatened and at risk species of geothermal habitat in this type, we think this is warranted. We have therefore included geothermally influenced wetlands as a key geothermal ecosystem in this study (see Section 4) alongside the other naturally rare geothermal ecosystems recognised.

The definition of geothermal wetland for this study follows Clarkson *et al.* (2004) and Johnson and Gerbeaux (2004), and is here adapted from Wildland Consultants (2005).

“A wetland hydrosystem where the dominant function is **geothermally heated water**. The Resource Management Act (1991) defines geothermal waters as those heated by natural phenomena to 30 degrees Celsius or above. Geothermal wetlands may have water temperatures below this, but must be considered geothermal due to the chemical composition of the water. Geothermal wetlands are permanently or intermittently wet areas, shallow water, or land water margins that support a natural ecosystem of plants that have compositional, structural, and/or growth rate characteristics determined by current or former inputs of geothermally derived water.” (Clarkson *et al.* 2004)

“A hydrosystem where volcanic activity produces hot surface waters, or heated soils (30 °C or more) or where geothermal chemistry affects wetland habitats.” (Johnson and Gerbeaux 2004).

Geothermal wetlands have provided habitat for threatened fern species such as *Thelypteris confluens* at Waikite Valley and *Cyclosorus interruptus* at Otumuheke, Waiotapu, Orākei Kōrako, and Orakonui.

Some species, such as arrow grass (*Triglochin striata*), sea rush (*Juncus kraussii* var. *australiensis*), and oioi (*Apodasmia similis*) that usually grow in northern regions or close to the coast have unusual inland and higher elevation within geothermal wetlands of the Taupō Volcanic Zone.

6. METHODS

6.1 Existing information

Existing information on the distribution and botanical values of geothermal areas in the Waikato Region was compiled from published and unpublished sources (see Bibliography). Geothermal sites containing, or likely to contain, geothermal vegetation were identified from Cave *et al.* (1993), Mongillo and Clelland (1984), Leathwick *et al.* (1995), Given (1989a & 1995), Spring-Rice (1996), Department of Conservation (1997), Waikato Regional Council reports, Wildland Consultants (2014) discussion with various people with knowledge of geothermal sites, including DOC and Regional Council staff and landowners, and subsequent studies. Information was incorporated from 17 sites where surveys had been undertaken by the authors since 2014.

For each geothermal site, the following variables were extracted from existing information: grid references, site names, local authority, ecological district, geothermal system, bioclimatic zone (from Leathwick *et al.* 1995), altitude, notable indigenous flora, fauna, threats/modification/vulnerability, management requirements, botanical rank from Given 1996, and ecological significance from Wildland Consultants 2003, 2004c, 2006, 2007a&b, 2012, 2014a.

6.2 Ecological districts

Three ecological districts in the Waikato Region contain sites with geothermal vegetation: Atiamuri Ecological District, Taupō Ecological District (both of which occur within the Central Volcanic Plateau Ecological Region), Tongariro Ecological District (within the Tongariro Ecological Region). From an ecological perspective, geothermal vegetation and habitats are best assessed by geothermal systems rather than ecological district, due to these areas being naturally rare and widely scattered. Some geothermal systems also occur in more than one ecological district.

6.3 Geothermal systems

Within the Waikato Region, there are 18 Geothermal Systems, along with 29 small geothermal systems. The small systems are mostly in the form of hot springs and have none to very little indigenous geothermal vegetation associated with them. Of the larger geothermal systems, Mangakino and Horomatangi Reef both have no associated geothermal vegetation. The geothermal systems and their associated geothermal vegetation are described in more detail in Section 9.

6.4 Bioclimatic zones

Bioclimatic zones refer to the broad distribution of vegetation zones along both altitudinal and coastal to inland gradients where a particular climatic regime dictates the character of the natural ecosystem (Leathwick *et al.* 1995). Bioclimatic zones used were based on the published definitions of Meurk (1984), but with one further subdivision, and with the addition of a coastal zone to delineate those environments that are typified by frequent windblown salt and a marked reduction in the severity of frost.

The coastal bioclimatic zone includes areas less than 1 km from the coast, and with an altitude of less than 300 metres. The lowland bioclimatic zone extends from the coastal zone up to an altitude of 300 metres. The submontane bioclimatic zone extends from 300 m to 800 m and the montane bioclimatic zone from 800 metres to 1,300 metres. The subalpine bioclimatic zone includes all land between 1,300 metres and 1,800 metres altitude. The alpine bioclimatic zone includes all areas above 1,800 metres.

6.5 Geophysical properties

In 2007 and 2010, geophysical assessments were undertaken for all or parts of the following geothermal sites within the Waikato Region (see Table 3).

Table 3: Geothermal sites where geophysical assessments have been undertaken.

Site Name	Date of Assessment
Northern Paeora Range	29 and 30 June 2010
Waiotapu (Waiotapu North part)	26 and 29 July 2010
Waiotapu (Waiotapu South part)	27, 29, and 31 July 2010 (c.30% of site)
Maunga Kākaramēa (Rainbow Mountain)	26 July 2010 (about 1/2 of site)
Tirohanga Road	5 February 2007
Whangapoa Springs (including Upper Atiamuri West part)	5 February 2007
Te Kopia (Western Te Kopia part)	29 June 2010
Te Kopia (Mangamingi Station part)	28 June 2010
Murphy's Springs	29 June 2010
Orākei Kōrako	1 August 2010 (c.30% of site)
Wharepapa Road	30 July 2010
Maunganamu (including Maunganamu East, Maunganamu West and Tokaanu Tailrace Canal parts)	7 and 13 February 2007
Tokaanu	7 February 2007 (c.50% of site)

Specific methods for those assessments varied slightly between the geophysical consultants, but generally the following methods were used:

- Locations of each feature were recorded using a GPS.
- Direct temperature measurements were made with a thermocouple on a four metre long wire, or a 100 mm long rigid probe, connected to a Fluke multimeter. If the surface to be measured was not accessible, a Fluke infrared (IR) thermometer was used; however, this has limited accuracy, particularly where steam blocks a clear view of the feature.
- The pH was measured with a Hanna Instruments pH meter with a maximum operating temperature of 50 °C; if the spring temperature was >50 °C the water was cooled to less than 50 °C before the pH measurement was taken or a pH paper strip was used. Further details are provided on each site sheet.

Details of the assessments are presented in Appendix 4.

6.6 Field survey

Prior to fieldwork, each site and its immediate surrounds was checked on the latest high quality aerial photographs (see Section 6.7) at a scale of 1:1,000 for geothermal habitat that had not been mapped previously. These areas were included in the field survey where landowner permission allowed.

Field survey of sites (or parts of sites) with geothermal vegetation were carried out at 28 sites in 2022 and 2023 by teams of two or more people (Appendix 2). Site data sheets were also updated for 10 sites visited by the authors from field visits in 2017 and 2018. Two sites have never been visited in the field in any capacity as part of this inventory study: Hipaua, and Ketetahi Springs, because access permission was withheld. For more details on digitisation including sites not visited, see Section 6.10 and Appendix 3.

Field assessments addressed the following components: the extent and types of vegetation and habitats; indigenous flora and fauna (including threatened species); current condition of vegetation and habitats; key geothermal ecosystems present;

invasive exotic plants; human impacts; grazing; adjoining land use, and management requirements.

6.7 Geothermal vegetation and habitat mapping

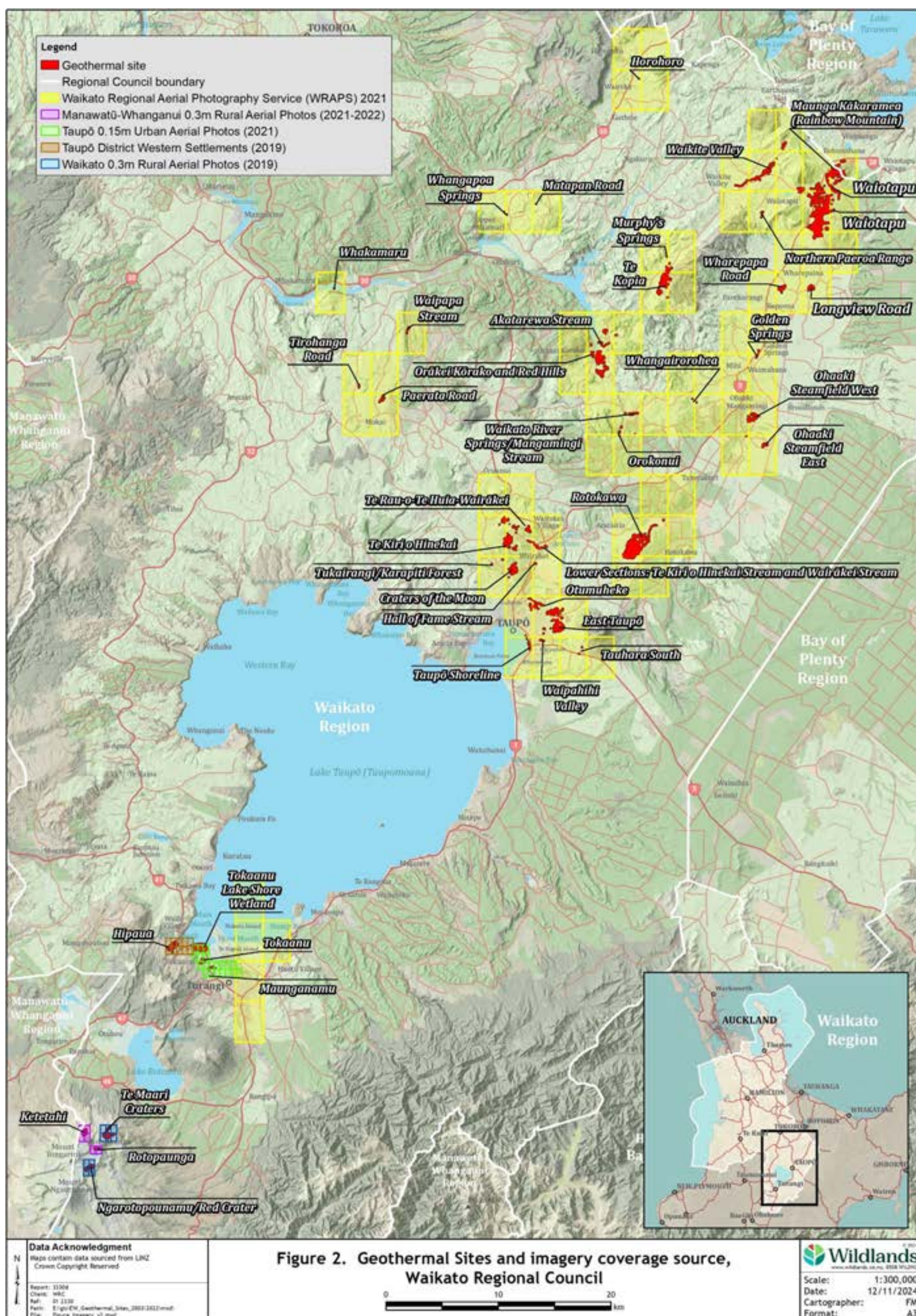
For all sites, vegetation types were mapped onto the most recent available aerial photography. Most of the Waikato Region north of Lake Taupō is covered by 2021 WRAPS photography, but sites to the south were mapped on a combination of 2021 WRAPS, 2021 Urban, 2019 Western Settlements and 2019 Waikato 0.3 m Rural aerial photographic series (Figure 2). Geothermal vegetation types were described for each site, and the extent of each type was mapped onto colour printouts of digital aerial photographs at A3 size and scale of 1:1,000. Vegetation structural class definitions used in this report are provided in Appendix 7, and common abbreviations are provided in Appendix 8.

Geothermal vegetation and habitats includes terrestrial and wetland habitats. Terrestrial habitats include geothermal vegetation dominated by vascular and non-vascular plants, and geothermally-influenced bare ground (referred to as nonvegetated raw-soilfield in earlier versions of this report) that often contains scattered patches of non-vascular and vascular plants. Notes on the vascular flora of geothermal areas can be found in Appendix 5. Wetland habitats include emergent wetland vegetation and open geothermal water. Geothermal water was only mapped if it was an integral part of a geothermal site; geothermal streams flowing from a site without associated geothermal vegetation are not usually mapped as part of sites. In the site descriptions (Appendix 1), open geothermal water is included in “extent of geothermal habitat”, but not in “extent of geothermal vegetation”.

6.7.1 Mapping geothermal wetland habitat

Wetland habitat boundaries have been mapped as accurately as possible given the time limitations, issues with safe access, and difficulties of mapping very small areas. Examples of difficulties that may be encountered when mapping geothermal wetland include:

- Heated wet air (steam) from fumaroles, hot pools, and geothermal streams can extend for a considerable distance from the surface geothermal activity, making geothermal vegetation and habitats generally difficult to map. Steamy habitats such as banks alongside streams have not been identified as a wetland type in the background metadata in this study.
- Heated water flowing over waterfalls produces graduations of habitats affected by water flow, splash, and spray (Johnson and Gerbeaux 2004), and seepages and associated increased air and soil temperatures provide habitat for plant species typical of geothermal activity. These types were too small to map separately.
- The presence of surface geothermal activity can fluctuate at a particular location and across a landscape making access and mapping difficult.



Access to all parts of a geothermally active area is difficult in some locations, particularly in geothermal wetlands where isolated geothermal seepages and immediate geothermal plants can be surrounded by cold water species (e.g. raupō (*Typha orientalis*) wetland). In this situation the vegetation is mapped as one broad class. Generally the water present will have geothermal derived chemical inputs.

6.7.2 Mapping of geothermally-influenced bare ground

Occasional scattered vascular and non-vascular plants are often included in mapping of geothermally-influenced bare ground, particularly in areas that appear as bare ground on aerial photographs, and in areas that could not be viewed during the field survey, or where the pockets of vegetation or individual plants are too small to map separately. Small mud pools amongst bare ground have also been mapped as geothermally-influenced bare ground (large areas with open water and abundant mud pools were mapped as open geothermal water). On this basis, geothermally-influenced bare ground was included in calculations of the area covered by terrestrial geothermal habitats.

6.8 Site and geothermal vegetation extent

The extent (in hectares) of each geothermal vegetation and habitat type in each site was calculated using mapped polygon size. The extent of geothermal vegetation (but not geothermal water) was also calculated for each ecological district, geothermal system, and administrative district. The extent of geothermal water and terrestrial and emergent geothermal wetland habitats is provided for each site (Section 7.1, Table 8).

Changes in historic vegetation extent are presented in Appendix 6.

6.9 Threats modification and vulnerability assessment

For each site, current threats, modification, and vulnerability were evaluated under four categories:

- Invasive exotic plant species.
- Human threats.
- Grazing.
- Adjoining land use.

Invasive exotic plant species were assessed in terms of their absolute cover abundance.

6.10 Digitisation of vegetation and habitat type boundaries

Vegetation and habitat type boundaries for each site were digitised onto the most recently available aerial photographs (2017 or 2021 WRAPs) in ArcGIS (V.10.8) at a scale of 1:1,000 with the following data fields:

- Site Name
- NZTM Eastings and Northings
- Geothermal System
- Geothermal System (if more than one recognised in the Geothermal System)
- Ecological District
- Territorial Local Authority

- Area (ha)
- Ecological Significance Ranking
- Broad Vegetation Code
- Detailed Vegetation Code
- Vegetation Description
- Structural Class Code

For each geothermal site a separate site information sheet and map are presented.

Site information sheets include information on the extent and composition of vegetation and habitat types present, the presence of threatened plant or animal species within a site, threats to the vegetation and habitats at the site, and an assessment of the significance of the site. The extent of each vegetation class, geothermal vegetation/habitat type and their codes are represented in Appendix 11. A list of all common plant and fauna names used in the text are presented in Appendices 9 and 10.

Maps include a topographic map showing the location of each geothermal site and a vegetation map of sites overlain on aerial photographs (vegetation maps have been prepared at three scales depending on the size of the site: 1:2,500 for small sites to 1:5,000 and 1:7,500 for large sites).

Representative site photographs are provided for each site. Note that some photographs have been provided from our archive for sites which were not recently visited, and these photographs may not include GPS coordinates.

Vascular plant species lists are also provided for each site that has been surveyed recently.

Definitions of data fields are presented in Appendix 13.

6.11 Threat rankings

A list of the relevant publications for each taxonomic group, ecosystem, or other habitat type which were utilised for this review are presented in Table 4 below. Subsequent assessments or reviews of sites should use the most up-to-date publications available at the time of the assessment. Since 2014 two new categories: Threatened-Nationally Increasing and At Risk-Recovering have been added to the Threat Classification System.

Table 4: Threat ranking documents for indigenous species, vegetation types, habitat types, ecosystem types, and land systems used in this report.

Taxonomic Group, Habitat Type, Ecosystem Type	Relevant Ranking Document(s)
Bats	O'Donnell <i>et al.</i> 2018
Birds	Robertson <i>et al.</i> 2021
Freshwater fish	Dunn <i>et al.</i> 2018
Mosses	Rolfe <i>et al.</i> 2016
Plants	de Lange <i>et al.</i> 2018a
Historically rare ecosystems	Williams <i>et al.</i> 2007
Naturally uncommon ecosystems	Holdaway <i>et al.</i> 2012
Vegetation extent by Ecological District	Leathwick <i>et al.</i> 1995; Wildland Consultants 2009c

The conservation status of species within the Myrtaceae family were elevated due to the potential threat posed by myrtle rust (*Austropuccinia psidii*) which arrived in New Zealand in May 2017. Myrtle rust is a fungal disease which infects plants from the Myrtaceae family and has potentially devastating effects. There is currently no known cure for myrtle rust. These changes to the conservation status were made as a precautionary measure based on the potential threat of myrtle rust to the New Zealand Myrtaceae and associated species.

For the purposes of the significance assessment two Myrtaceae species were included geothermal kānuka (*Kunzea tenuicaulis*) (now classed as Threatened-Nationally Endangered and previously classified as At Risk-Naturally Uncommon in 2013 (de Lange *et al.* 2013)) and pōhutukawa (*Metrosideros excelsa*) (now classed as Threatened-Nationally Vulnerable and which is regionally uncommon in Taupō District - see DOC 1997 & 1998) were considered to meet Criterion 3 of the Waikato Regional Council's significance criteria (Waikato Regional Council 2016). Other species in the Myrtaceae family including mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea robusta* and *K. serotina*) have wide distributions and are common within a range of habitats within the Taupō and Rotorua Districts. These species were therefore not considered to meet Criteria 3.

6.12 Kānuka identification and taxonomy

Recent revision of *Kunzea* in Aotearoa New Zealand recognised ten species, seven of which were newly described (de Lange 2014). Following this revision, seven species of *Kunzea* occur in the North Island, with three (*Kunzea robusta*, *Kunzea serotina*, and geothermal kānuka (*Kunzea tenuicaulis*))¹ present within the Waikato Region. Geothermal kānuka is confined to geothermal habitats. Hybrids of *K. robusta* × *K. tenuicaulis*, *K. serotina* × *K. tenuicaulis*, and potentially *K. robusta* × *K. serotina*² may also be present in geothermal habitats of the Waikato Region.

There is ongoing debate around both the circumscription of *Kunzea* taxa and the rank at which those taxa are most appropriately recognised in New Zealand. Two recent studies, informed by microsatellite and single nucleotide polymorphism (SNP) genetic data (Heenan *et al.* 2022, in press) have concluded that all New Zealand *Kunzea* taxa should be regarded as ecotypes of a single ecologically and morphologically variable species, *Kunzea ericoides*, and have proposed formal synonymy for the other species recognised in New Zealand. However, analyses of genetic similarity, such as the extensive and data-rich analyses completed by Heenan *et al.* (in press), informs population genetic structure, which does not necessarily achieve species delimitation (see for example Sukumaran and Knowles 2017). Interpretation of the results with respect to species circumscription is still required, and different interpretations of the same data are possible. The different interpretations of morphological, ecological, and genetic variation in New Zealand *Kunzea* by de Lange (2014) on the one hand and Heenan *et al.* (2022, in press) on the other both accept that there are morphologically, ecologically, and genetically distinct variants that warrant recognition. While Heenan

¹ *Kunzea salterae* has only been recorded from Moutohora (Whale Island) in the Bay of Plenty Region.

² Hybrids of *Kunzea robusta* × *K. serotina* also occur (see de Lange 2014), but it is not known whether any occur in geothermal vegetation/habitats.

et al. (in press) demonstrated that the distinction between *K. robusta* and *K. serotina* cannot be maintained, their substantive objection to the remaining taxa was the rank morphological and ecological variants were accorded, rather than their reality. Aotearoa New Zealand presents a challenging ecological and evolutionary context to species circumscription in many lineages, not just *Kunzea*, because of the challenges to genetic species circumscription presented by processes such as hybridisation and gene flow, processes that are known to occur in *Kunzea*. The microsatellite data presented by Heenan *et al.* (2022) can be interpreted as supporting the recognition of *K. linearis* and *K. sinclairii*, two taxa that were not included in the subsequent SNP study of Heenan *et al.* (in press). Therefore, we prefer to continue using the species circumscription for New Zealand *Kunzea* proposed by de Lange (2014), while acknowledging the deficiencies in that classification demonstrated by Heenan *et al.* (in press), until further studies are completed.

Kunzea tenuicaulis has been called prostrate kānuka, however it is often not prostrate, and may form a small tree up to eight metres tall (de Lange 2014). Therefore, we prefer to use a common name that references its association with geothermal habitats: geothermal kānuka, rather than the potentially misleading ‘prostrate kānuka’.

6.13 Ecological evaluation

The relative significance of each geothermal site was assessed as part of the current study using the criteria specified in Waikato Regional Council Regional Policy Statement (2016). Using these criteria, each site was assigned to one of four levels of relative significance: Internationally Significant, Nationally Significant, Regionally Significant, or Locally Significant. Threats, modifications, vulnerabilities, and the relative significance of each site have been assessed in a regional context.

7. GEOTHERMAL VEGETATION OF THE WAIKATO REGION – AN OVERVIEW

7.1 Overview

Forty-six sites with geothermal vegetation, within 14 geothermal systems and 17 geothermal systems are identified, mapped, and described, and their significance assessed in this report (Table 5). For each site, the vegetation and its condition are described, the significance assessed, and the vegetation types, site boundaries, and location relative to other sites mapped (see Section 14).

Table 5: List of geothermal sites mapped and described in the Waikato Region.

Geothermal System	Geothermal System	Site Name
Atiamuri	Atiamuri	Matapan Road Whangapoa Springs
Horohoro	Horohoro	Horohoro
Mokai	Mokai	Paerata Road Tirohanga Road Waipapa Stream Whakamaru
Ngā Tamariki	Ngā Tamariki	Orakonui Waikato River Springs/Mangamingi Stream
Ohaaki	Ohaaki	Ohaaki Steamfield East Ohaaki Steamfield West
Orākei Kōrako	Orākei Kōrako	Akatarewa East Akatarewa Stream Orākei Kōrako and Red Hills Waihunuhunu
Reporoa	Reporoa	Golden Springs Longview Road Wharepapa Road
Rotokawa	Rotokawa	Rotokawa
Te Kopia	Te Kopia	Murphy's Springs Te Kopia
Tokaanu-Waihi-Hipaua	Hipaua	Hipaua
	Tokaanu	Maunganamu Tokaanu Tokaanu Lake Shore Wetland
Tongariro	Tongariro	Ketetahi Ngarotopounamu/Red Crater Rotopaunga Te Maari Craters
Waikite-Waiotapu-Waimangu	Waikite	Northern Paeroa Range Waikite Valley
	Waiotapu	Maunga Kākamea (Rainbow Mountain) Maungaongaonga Waiotapu
Wairākei-Tauhara	Tauhara	East Taupō Otumuheke Stream Tauhara South Taupō Shoreline Waipahihi Valley
	Wairākei	Craters of the Moon Hall of Fame Stream Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream Te Kiri o Hinekai Te Rau-o-Te Huia-Wairākei Tukairangi/Karapiti Forest
Whangairorohea	Whangairorohea	Whangairorohea

These 46 sites contain *c.*1,016 hectares of geothermal habitat, which comprises *c.*894 hectares of geothermal vegetation (including geothermally-influenced bare ground) and *c.*123 hectares of geothermal water. Broad groupings of geothermal vegetation and habitats within the Waikato Region include geothermally-influenced bare ground (*c.*97 ha), emergent wetland vegetation (*c.*114 ha), and terrestrial vegetation (*c.*683 ha) (see Table 6). Terrestrial vegetation includes all vegetation that was not mapped as geothermal wetland and geothermally-influenced bare ground; this category includes (but is not limited to) forest, scrub, shrubland, fernland, and mossfield.

Each of the 46 sites meets one or more of the criteria for ecological significance in the Waikato Regional Policy Statement 2016 (refer to Appendix 14). Six entire sites, and part of three other sites encompassing *c.*446 hectares or 44% of geothermal habitat in the Waikato Region (see Table 7), were identified as being of International significance. Ten entire sites, and part of three other sites encompassing *c.*434 hectares or 43% of geothermal habitat in the Waikato Region, were identified as being of National significance. Eight entire sites, and part of seven other sites encompassing *c.*122.2 hectares or 12% of geothermal habitat in the Waikato Region, were identified as being of Regional significance. The remainder of the sites (12 entire sites, and parts of nine other sites encompassing *c.*17 hectares, or *c.*2% of geothermal habitat in the Waikato Region) were identified as being of Local significance.

Table 6: Area (ha) of each habitat type within geothermal sites in the Waikato Region.

Site Name	Geothermal Habitats (ha)					Total Site Area (ha) ¹
	Geothermal Water (ha)	Geothermal Vegetation (ha)			Total Geothermal Vegetation	
		Terrestrial Vegetation (including bare ground)	Geothermally-Influenced Bare Ground	Emergent Wetland		
Atiamuri Geothermal System						
Matapan Road		<0.1			<0.1	<0.1
Whangapoa Springs	<0.1	0.2	0.1		0.2	0.2
Total	<0.1	0.2	0.1		0.2	0.2
Horohoro Geothermal System						
Horohoro	<0.1	<0.1	<0.1	<0.1	0.1	0.1
Total	<0.1	<0.1	<0.1	<0.1	0.1	0.1
Mokai Geothermal System						
Paerata Road	0.2	1.3	0.5		1.3	1.5
Tirohanga Road	0.1	0.4	0.1		0.4	0.6
Waipapa Stream		1.0		0.2	1.2	1.2
Whakamaru				<0.1	<0.1	<0.1
Total	0.4	2.7	0.5	0.3	3.0	3.3
Ngā Tamariki Geothermal System						
Orakonui	0.2	1.0	0.2	0.1	1.1	1.3
Waikato River Springs/Mangamingi Stream	0.7	0.3	<0.1	3.7	4.0	4.6
Total	0.9	1.4	0.2	3.7	5.1	5.9
Ohaaki Geothermal System						
Ohaaki Steamfield East	<0.1	5.3	1.1		5.3	5.3
Ohaaki Steamfield West	1.8	11.9	1.1	1.2	13.1	15.0
Total	1.9	17.2	2.3	1.2	18.4	20.3
Orākei Kōrako Geothermal System						
Akatārewa East		0.1			0.1	0.1
Akatārewa Stream	0.3	1.8			1.8	2.1
Orākei Kōrako and Red Hills	0.5	68.4	2.4	2.1	70.5	71.0
Waihunuhunu	3.6	0.6		1.7	2.3	5.9
Total	4.4	70.9	2.4	3.8	74.7	79.1

¹ Includes geothermal vegetation and geothermal water.

Site Name	Geothermal Habitats (ha)					Total Site Area (ha) ¹
	Geothermal Water (ha)	Geothermal Vegetation (ha)				
		Terrestrial Vegetation (including bare ground)	Geothermally-Influenced Bare Ground	Emergent Wetland	Total Geothermal Vegetation	
Reporoa Geothermal System						
Golden Springs	0.1	0.6		0.2	0.8	0.9
Longview Road	0.4	5.1	1.1	0.8	6.0	6.3
Wharepapa Road	0.1	3.3	1.0	1.0	4.3	4.4
Total	0.5	8.97	2.1	2.1	11.1	11.54
Rotokawa Geothermal System						
Rotokawa	72.9	135.2	11.0	9.7	144.8	217.8
Total	72.9	135.2	11.0	9.7	144.8	217.8
Te Kopia Geothermal System						
Murphy's Springs		0.1			0.1	0.1
Te Kopia	0.9	66.1	4.7	2.4	68.5	69.3
Total	0.9	66.2	4.7	2.4	68.6	69.5
Tokaanu-Waihi-Hipaua Geothermal System						
Hipaua		12.7	0.7		12.7	12.7
Maunganamu				2.1	2.1	2.1
Tokaanu	0.3	5.8	0.1	1.7	7.5	7.8
Tokaanu Lakeshore Wetland	3.8			43.7	43.7	47.5
Total	4.2	18.5	0.9	47.4	65.9	83.6
Tongariro Geothermal System						
Ketetahi	<0.1	8.5	8.5		8.5	8.5
Ngarotopounamu/Red Crater	1.0	10.9	10.9	0.2	11.1	12.1
Rotopaunga		3.2	3.2		3.2	3.2
Te Maari Craters	1.4	27.1	26.2		27.1	28.5
Total	2.4	49.59	48.7	0.2	49.8	52.2
Waikite-Waiotapu-Waimangu Geothermal System						
Waikite Geothermal System						
Northern Paeroa Range		0.4	0.2	0.1	0.4	0.4
Waikite Valley	2.7	12.1	0.6	10.4	22.4	25.1
Total	2.7	12.4	0.7	10.4	22.8	25.5
Waiotapu Geothermal System						
Maunga Kākaramaea (Rainbow Mountain)	3.0	49.3	1.8	0.3	49.6	52.3
Maungaongaonga	0.1	9.1	0.4		9.1	9.2
Waiotapu	27.8	175.7	9.7	30.9	206.6	234.4
Total	30.9	234.1	11.9	31.2	265.3	296.0

Site Name	Geothermal Habitats (ha)					Total Site Area (ha) ¹
	Geothermal Water (ha)	Geothermal Vegetation (ha)				
		Terrestrial Vegetation (including bare ground)	Geothermally-Influenced Bare Ground	Emergent Wetland	Total Geothermal Vegetation	
Total Waikite-Waiotapu-Waimangu Geothermal System	33.7	246.5	12.7	41.6	288.1	321.6
Wairākei-Tauhara Geothermal System						
Tauhara Geothermal System						
East Taupō		56.8	6.8		56.8	56.8
Otumuheke	0.1	7.4	0.1	1.1	8.5	8.6
Tauhara South		0.1	0.1		0.1	0.1
Taupō Shoreline	0.1	0.3	0.3		0.3	0.5
Waipahihi Valley	0.1	0.3	<0.1	<0.1	0.4	0.4
Total	0.3	65.0	7.3	1.1	66.1	66.4
Wairākei Geothermal System						
Craters of the Moon	<0.1	36.4	1.0		36.4	36.4
Hall of Fame Stream	0.1	0.2	<0.1		0.2	0.3
Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	0.4	2.6	0.2	<0.1	2.6	3.0
Te Kiri o Hinekai	0.1	42.8	1.5		42.8	42.9
Te Rau-o-Te Huia-Wairākei		15.2	1.1		15.2	15.2
Tukairangi/Karapiti Forest		0.6			0.6	0.6
Total	0.5	97.8	3.8	<0.1	97.9	98.4
Total Wairākei-Tauhara Geothermal System	0.8	162.8	11.1	1.2	164.0	164.8
Whakamaru Geothermal System						
Whakamaru				<0.1	<0.1	<0.1
Total				<0.1	<0.1	<0.1
Whangairorohea Geothermal System						
Whangairorohea	0.1	0.1			0.1	0.2
Total	0.1	0.1			0.1	0.2
Grand Total	123.0	780.1	96.7	113.6	893.7	1016.5

Table 7: Area (ha) of geothermal sites of International, National, Regional, and Local significance in the Waikato Region.

Site Name	Ecological District	Ecological Significance Ranking (ha)			
		International	National	Regional	Local
Atiamuri Geothermal System					
Matapan Road	Atiamuri				<0.1
Whangapoa Springs	Atiamuri		0.2		<0.1
	Total		0.2		<0.1
Horohoro Geothermal System					
Horohoro	Atiamuri				<0.1
	Total				<0.1
Mokai Geothermal System					
Paerata Road	Atiamuri				1.5
Tirohanga Road	Atiamuri				0.6
Waipapa Stream	Atiamuri		1.2		
Whakamaru	Atiamuri				<0.1
	Total		1.2		2.2
Ngā Tamariki Geothermal System					
Orakonui	Atiamuri			1.3	
Waikato River Springs/ Mangamingi Stream	Atiamuri			4.6	
	Total			5.9	
Ohaaki Geothermal System					
Ohaaki Steamfield East	Atiamuri			4.7	0.6
Ohaaki Steamfield West	Atiamuri			15.0	
	Total			19.7	0.6
Orākei Kōrako Geothermal System					
Akatarewa East	Atiamuri				0.1
Akatarewa Stream	Atiamuri		2.1		
Orākei Kōrako and Red Hills	Atiamuri		71.0		
Waihunuhunu	Atiamuri		5.9		
	Total		81.1		0.1
Reporoa Geothermal System					
Golden Springs	Atiamuri			0.9	
Longview Road	Atiamuri			5.5	0.8
Wharepapa Road	Atiamuri				4.4
	Total			6.4	5.2
Rotokawa Geothermal System					
Rotokawa	Atiamuri		217.8		
	Total		217.8		
Te Kopia Geothermal System					
Murphy's Springs	Atiamuri			0.1	<0.1
Te Kopia	Atiamuri	68.5			0.8
	Total	68.5		0.1	0.8
Tokaanu-Waihi-Hipaua Geothermal System					
Hipaua Geothermal System					
Hipaua	Tongariro		12.8		
	Total		12.8		
Tokaanu Geothermal System					
Maunganamu	Taupō/Tongariro			2.1	<0.1
Tokaanu			7.8		
Tokaanu Lakeshore Wetland	Taupō/Tongariro	47.5			
	Total	47.5	7.8	2.1	<0.1
Tongariro Geothermal System					
Ketetahi	Tongariro	8.5			
Ngarotopounamu/Red Crater	Tongariro	12.7			
Rotopaunga	Tongariro	3.2			
Te Maari Craters	Tongariro	28.5			

Site Name	Ecological District	Ecological Significance Ranking (ha)			
		International	National	Regional	Local
	Total	52.9			
Waikite-Waiotapu-Waimangu Geothermal System					
Waikite Geothermal System					
Northern Paeroa Range	Atiamuri				0.4
Waikite Valley	Atiamuri		25.1		
	Total		25.1		0.4
Waiotapu Geothermal System					
Maunga Kākaramea (Rainbow Mountain)	Atiamuri/Rotorua Lakes	52.4			
Maungaongaonga	Atiamuri		9.2		
Waiotapu	Atiamuri	224.2		10.2	
	Total	276.6	9.2	10.2	
Wairākei-Tauhara Geothermal System					
Tauhara Geothermal System					
East Taupō	Taupō/ Atiamuri			55.8	0.9
Otumuheke	Atiamuri		3.8		4.9
Tauhara South	Taupō				0.1
Taupō Shoreline	Taupō				0.5
Waipahihi Valley	Taupō			0.4	
	Total		3.8	56.2	6.4
Wairākei Geothermal System					
Craters of the Moon	Atiamuri		36.4		
Hall of Fame Stream	Atiamuri			0.3	
Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	Atiamuri			3.0	
Te Kiri o Hinekai	Atiamuri		39.5	3.4	<0.1
Te Rau-o-Te Huia-Wairākei	Atiamuri			14.9	0.3
Tukairangi/Karapiti Forest	Atiamuri				0.6
	Total		75.9	21.6	0.9
Whangairorohea Geothermal System					
Whangairorohea	Atiamuri				0.2
	Total				0.2
Grand Total		445.5	434.9	122.2	16.8

7.2 Assessment by Local Authority District

Geothermal vegetation in the Waikato Region is distributed relatively evenly between the Rotorua and Taupō Districts with c.47% in the Rotorua Lakes District and 53% in the Taupō District (see Table 8). This is a slight change since 2014, when there was slightly higher percentage of geothermal vegetation mapped in the Rotorua Lakes District. These changes are mostly a result of additional areas of geothermal habitat that have been identified in the Taupō District with the availability of higher quality aerial photography for the most recent survey.

Table 8: Area (ha) of geothermal vegetation for each administrative district in the Waikato Region.

Administrative District	Area (ha)	Area (%)
Rotorua Lakes	480.1	47
Taupō	536.3	53
Total	1,016.5	100

7.3 Assessment by Ecological District

Most (*c.*80%) of geothermal vegetation in the Waikato Region occurs within the Atiamuri Ecological District (see Table 9). The Taupō Ecological District and Tongariro Ecological District contain *c.*12.3% and 8.1% of geothermal vegetation in the Waikato Region respectively. Four sites span more than one ecological district: East Taupō (Atiamuri/Taupō), Maunganamu, Tokaanu, and Tokaanu Lakeshore Wetland (Taupō/Tongariro). Part of the Maunga Kākamea (Rainbow Mountain) site extends into Rotorua Lakes Ecological District, although this part of the site is outside the Waikato Region and so is not assessed in this table. As discussed previously, a greater emphasis is placed on geothermal systems than on ecological districts due to the geographical locations of geothermal habitats.

Table 9: Area (ha) of geothermal vegetation for each Ecological District in the Waikato Region.

Ecological District	No. of Sites	Habitats					Total Geothermal Habitats
		Geothermal Water	Geothermal Vegetation			Total Geothermal Vegetation ¹	
			Geothermally influenced bare ground	Terrestrial	Emergent Wetland		
Atiamuri	34	116.1	39.9	646.9	64.8	711.7	827.8
Taupō	7	3.4	7.3	64.9	44.9	109.8	113.2
Tongariro	8	3.4	49.6	68.1	3.9	72.0	75.4
Grand Total	49	122.9	96.8	780.0	113.6	893.6	1,016.5

7.4 Assessment by Waikato Regional Council Classification for resource use

Waikato Regional Council has classified the geothermal resources of the Region into five categories¹:

- Development
- Limited development
- Research
- Protected
- Small

Classification is based on ranking the character and aims of each system to balance development with protection.

Large scale energy development has been undertaken in the Wairākei-Tauhara, Mokai, Ohaaki, Ngā Tamariki, and Rotokawa geothermal systems. These geothermal systems have been classified as Development Geothermal Systems by Waikato Regional Council. The Waikato Regional Council allows large-scale use of the energy resources within these geothermal systems as long as they are undertaken in a sustainable and environmentally responsible manner. Horohoro and Mangakino geothermal systems

¹ <https://www.waikatoregion.govt.nz/environment/geothermal/classifying-geothermal-systems/> Accessed 14 April 2023.

are also classified as Development Geothermal Systems, but no large scale developments have been undertaken within these systems to date.

A total of *c.*335.3 hectares of geothermal vegetation was mapped in geothermal systems classified as Development Geothermal Systems, comprising *c.*37% of the mapped geothermal in the Waikato Region (Table 10).

Two geothermal systems (Atiamuri and Tokaanu-Waihi-Hipaua) are classified as Limited Development Geothermal Systems. The Waikato Regional Council allows resource take that will not damage surface features within these fields. A total of *c.*66.1 hectares of geothermal vegetation was mapped in Limited Development Geothermal Systems, comprising *c.*7.3% of the geothermal vegetation in the Waikato Region.

The Reporoa Geothermal System is classified as a Research Geothermal System, because the Waikato Regional Council considers that not enough is known about the system to classify it as either Development, Limited Development, or Protected. In these systems, only small resource takes and those undertaken for scientific research into the system are allowed¹. A total of 11.1 ha of geothermal vegetation was mapped in the Reporoa geothermal system, which represents *c.*1.2% of the geothermal vegetation in the Waikato Region.

Five geothermal systems are protected from development and classified as Protected Geothermal Systems by Waikato Regional Council. These are Horomatangi, Orākei Kōrako, Te Kopia, Tongariro, and Waikite-Waiotapu-Waimangu geothermal systems. These geothermal systems contain vulnerable geothermal features valued for their cultural and scientific characteristics. Their protected status ensures that their underground geothermal water source cannot be extracted and that the surface features are not damaged. A total of *c.*481.2 hectares of geothermal vegetation was mapped in Protected Geothermal Systems, representing *c.*54% of the geothermal vegetation in the Waikato Region.

8. NATURAL DYNAMICS

Many geothermal sites are very active and dynamic, and their habitats are therefore somewhat unstable. This dynamic nature is illustrated by the 2012 eruption of the Te Maari Craters and a hydrothermal eruption at Orakonui in 2005. Changes in geothermal activity tend to be reflected in changes in the extent and composition of geothermal vegetation. Local increases in heat, steam production, and eruptions of mud and hot water often damage or kill surrounding vegetation; conversely, cooling ground may lead to increased weed invasion and the decline of heat tolerant species. These changes are an integral part of the natural dynamics of geothermal sites.

Table 10: Extent of geothermal vegetation and habitats in each classification for resource use in the Waikato Region.

Classification for Resource Use	Geothermal System	Geothermal Habitats (ha)					Total Area (ha) ¹
		Geothermal Water (ha)	Geothermal Vegetation (ha)				
			Terrestrial Vegetation (including bare ground)	Geothermally-Influenced Bare Ground	Emergent Wetland	Total Geothermal Vegetation	
Limited Development	Atiamuri Geothermal System	<0.1	0.2	0.1	0.0	0.2	0.2
	Tokaanu-Waihi-Hipaua Geothermal System	4.2	18.5	0.8	47.4	65.9	70.1
	Total	4.2	18.7	0.9	47.4	66.1	70.3
Development	Horohoro Geothermal System	<0.1	<0.1	<0.1	<0.1	0.1	0.1
	Mokai Geothermal System	0.4	2.7	0.5	0.2	2.9	3.2
	Ngā Tamariki Geothermal System	0.9	1.4	0.2	3.7	5.1	5.9
	Ohaaki Geothermal System	1.9	17.2	2.3	1.2	18.4	20.3
	Wairākei-Tauhara Geothermal System	0.8	162.8	11.1	1.1	164	164.8
	Rotokawa Geothermal System	72.9	135.2	11.0	9.7	144.8	217.8
	Total	76.9	319.3	25.1	15.9	335.3	412.1
Protected	Te Kopia Geothermal System	0.9	66.23	4.7	2.4	68.6	69.5
	Orākei Kōrako Geothermal System	4.4	70.9	2.4	3.8	74.7	79.1
	Tongariro Geothermal System	2.4	49.59	48.7	0.2	49.8	52.2
	Waikite-Waiotapu-Waimangu Geothermal System	33.7	246.5	12.7	41.6	288.1	321.6
	Total	41.4	433.2	68.5	48.0	481.2	522.4
Research	Reporoa Geothermal System	0.5	8.97	2.1	2.1	11.1	11.5
	Total						
	Grand Total	123.0	780.1	96.7	113.6	893.7	1,016.5

¹ Includes geothermal vegetation and geothermal water.

9. GEOTHERMAL SYSTEMS¹

9.1 Atiamuri Geothermal System

Several chloride hot springs and pools occur in this geothermal system. Two hot chloride springs are producing sinter at the Whangapoa Springs while in adjacent farmland there is an old explosion crater (20 metres diameter and 10 metres deep¹). Small active features are present including a small tomo in a gully and springs in farmland. There may be additional features in the surrounding farmland. Past records indicate that the area once had hotter temperatures (Cave *et al.* 1993), and several pools were submerged when Lake Atiamuri was formed (Cody 2007). The lake was formed when the Atiamuri Power Station was commissioned in 1958². A small site occurs at Matapan Road and there is an undescribed site that is unlikely to have any significant geothermal vegetation at Atiamuri School. There are similarities between the geothermal characteristics of the Atiamuri and Horohoro Geothermal Systems and the two fields may be connected (Cave *et al.* 1993). A small population of *Nephrolepis flexuosa* and arrow grass is present by one hot pool at Whangapoa Springs. This and the neighbouring pool at Whangapoa Springs have been fenced, and considerable weed control and planting of indigenous tree species has been undertaken at this site since 2004. The other two sites in this system are located within farmland, or in fenced gullies adjacent to farmland, with no significant ecological values found. This system contains c.0.2 hectares of geothermal habitat and is classified as a 'Limited Development Geothermal System' by Waikato Regional Council.

9.2 Horohoro Geothermal System

This geothermal system has <0.1 hectares of geothermal habitat, comprising of two hot springs that are depositing small areas of sinter. The geothermal system is considered a waning geothermal system with extensive old sinters, dried up spring basins and big explosion craters. The geothermal features an overflowing pool and a seepage (two relatively small features that have been identified located c.370 metres apart) and is mapped as one site – Horohoro. The Horohoro Geothermal System has extensive other hydrothermal eruption craters and old sinters with no existing geothermal vegetation. The Horohoro site has been fenced to exclude stock since 2014. The larger pool was previously mostly surrounded by pasture but is now a more diverse range of habitats including a small area of geothermal wetland including areas of harakeke, *Machaerina rubiginosa*, *Lepidosperma australe*, *Eleocharis acuta*, and *Gleichenia microphylla* fernland, and blackberry scrub. Both features have extensive areas of blackberry surrounding them. The extensive increase in blackberry (*Rubus fruticosus* agg.) and wilding pines (*Pinus* spp.) around this site since stock exclusion highlights the importance of pest plant management following fencing. The changes to the vegetation may have made the site less suitable for two species recorded in 2014: *Lycopodiella*

¹ Note that all geophysical information is from <https://www.waikatoregion.govt.nz/environment/geothermal/geothermal-systems-map-and-information>: Accessed 25 April 2023.

Classification of geothermal systems is from <https://www.waikatoregion.govt.nz/environment/geothermal/classifying-geothermal-systems>: Accessed 24 April 2023.

² <https://www.engineeringnz.org/programmes/heritage/heritage-records/atiamuri-power-station>: Accessed 25 April 2023.

cernua and *Leucopogon fraseri*. *Nephrolepis flexuosa* (At Risk-Declining) has been recorded from this site in the past (Given 1995), but is presumed extinct at this site (Bycroft and Beadel 2007).

The Horohoro Geothermal System is classified as a ‘Development Geothermal System’ by Waikato Regional Council. The reason for the classification is that it contains few surface outflows vigorously depositing sinter and no evidence of flow of subsurface geothermal fluid to or from a Protected Geothermal System. A commercial glasshouse operation take heat from the system to grow crops.

9.3 Horomatangi Geothermal System

This geothermal system known as the Horomatangi geothermal reef is a pristine geothermal system that occurs on the bed of Lake Taupō. It has two distinct hydrothermal vent areas producing hot water and gases. Hydrothermal chimneys up to 20 cm tall have been built up by thermophilic micro-organisms (de Ronde *et al.* 2002, Gee 1931, Pronzoto and Manconi 2019). There are also thermophilic bacterial mats and sponges. The Horomatangi Geothermal System is classified as a ‘Protected Geothermal System’ by the Waikato Regional Council. As this geothermal system is under Lake Taupō, no terrestrial or emergent wetland geothermal vegetation is present, and no sites are mapped and described in this report.

9.4 Mangakino Geothermal System

Mangakino Geothermal System is a large geothermal system with no remaining surface features above the water level of Lake Maraetai. It is located on the western edge of the Taupō Volcanic Zone. No terrestrial geothermal vegetation is currently known to be present within this geothermal system. At least one boiling spring was previously known at Mangakino, but this was drowned during the formation of Lake Maraetai (Cave *et al.* 1993) and is therefore not included in the current study. The Mangakino Geothermal System is classified as a ‘Development Geothermal System’ by Waikato Regional Council.

9.5 Mokai Geothermal System

Four sites within the Mokai Geothermal System are described in this study: Paerata Road, Tirohanga Road, Waipapa Stream, and Whakamaru. These comprise small areas of geothermal activity and a small (*c.* 3.0 ha) area of associated geothermal vegetation. An additional *c.* 0.4 hectares was mapped as geothermal water. Paerata Road and Tirohanga Road have hot springs, mud pools, and heated ground habitats often with geothermal kānuka dominant vegetation. Whakamaru has several springs on the margin of Lake Whakamaru. Waipapa Stream includes a series of springs alongside the stream that provides steamy habitats. Approximately 0.2 hectares of geothermal wetland occurs at Waipapa Stream. The northern part of the Waipapa Stream site includes a relatively large population of the fern, *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered). Other plant species characteristic of geothermal sites that are present within this system include *Lycopodiella cernua*, and *Campylopus* sp. *Psilotum nudum* was recorded at Paerata Road (Beadel and Clarkson 1986), but has not been recorded in recent surveys. *Psilotum nudum* was also recorded at Waipapa Stream as recently as 2011, and is likely to still be present at this site.

Geothermal electricity production commenced at Mokai in 1999. After evaporative losses, all geothermal fluid used in the power plant is being reinjected up to four kilometres from the site (Stretch 2000 cited in Merrett and Fitzgerald 2004). The Mokai Geothermal System is classified as a 'Development Geothermal System' by Waikato Regional Council.

Other key management issues include:

- Wilding pines and plantation forestry management are an issue at Waipapa Stream and Paerata Road. At Paerata Road, future plantation pine planting adjacent to the site should allow a buffer (at least 10 metres wide) between the plantation and geothermal features, as has been done at Waipapa Stream. Wilding trees should be removed regularly from the sites.
- The *Christella* aff. *dentata* ("thermal") population at Waipapa Stream should be regularly monitored and any threats to its survival managed as required.

9.6 Ngā Tamariki Geothermal System

There is c.5.9 hectares of mapped geothermal habitat in the Ngā Tamariki Geothermal System described in two sites in this report: Orakonui and Waikato River Springs/Mangamingi Stream. Since 2014, additional areas of geothermal vegetation have been identified in a stream to the south of the previously mapped Orakonui site, and additional geothermal wetland and features have been found on the south side of the Waikato River and by Mangamingi Stream. Further geothermal areas are likely to be present in Mangamingi Stream, but obscured by thick vegetation. Other geothermal areas may also be present beneath the Waikato River.

The vegetation present in the system is quite varied ranging from sinter features and hot springs at Orakonui, sinter forming springs, and abundant springs on the north side and south side of the Waikato River and in Mangamingi Stream. At Orakonui, there are examples of alkaline-chloride pools, surrounded by acidic pools and numerous springs and hot pools elsewhere in the geothermal system. A feature of the Ngā Tamariki Geothermal System is its dynamic nature with springs that have both formed and dried up since 1995. There was a hydrothermal eruption in 2005 which formed a new geothermal lake and mud pools, and deposited hydrothermal eruption debris. The vegetation present includes small areas of geothermally influenced bare ground, terrestrial vegetation, and geothermal wetland. Many of the geothermal features at Orakonui are mostly protected in a Department of Conservation managed reserve, although pest plant management is an ongoing concern.

The geothermal system supports c.1.4 hectares of terrestrial geothermal vegetation (including 0.2 hectares of geothermally-influenced bare ground) and c.3.7 hectares of geothermal wetland. An additional c.0.9 hectares was mapped as geothermal water.

A fluctuating, but relatively stable population of *Cyclosorus interruptus* (At Risk-Declining) is present at the Orakonui northern site. This species appeared to be negatively impacted by herbicide drift in 2014, but has since partly recovered. A very small population of *Dicranopteris linearis* (Threatened-Nationally Endangered) was

recorded at this site between 2007 and 2015, but the site does not provide a lot of suitable habitat for this species. Other species characteristic of geothermal sites that are present within the system include geothermal kānuka, *Campylopus* sp, arrow grass, *Lycopodiella cernua*, and *Psilotum nudum*. *Schizaea* (most likely *Schizaea fistulosa*, not threatened) was recorded at this site for the first time in 2020 and was also seen in 2022. This is a very inconspicuous species so is easily missed in botanical surveys. Herbicide drift in 2014 did some damage to the northern Orakonui site with which may have been the cause of the loss of arrow grass at this site; this arrow grass population was one of the larger populations of this species at a geothermal site on sinter in the Waikato Region, although it is widespread in coastal areas in general.

Kārearea/New Zealand bush falcon (Threatened-Nationally Increasing) have been regularly seen during site visits by the authors in the last ten years and in 2002, the birds showed behaviour that may indicate that they were utilising the site for breeding.

The springs alongside the Waikato River at the Waikato River Springs/Mangamingi Stream site support a relatively large area of geothermal wetland. The wetlands have become dominated by exotic species in places, particularly reed sweetgrass and grey willow (*Salix cinerea*), but areas of indigenous wetland habitat remain. A small population of *Christella* aff. *dentata* (“thermal”) (Threatened – Nationally Endangered) has been recorded alongside the northern bank of the Waikato River in 2006, and although not recorded in 2022, is likely to still be present (the Waikato River water levels were very high in 2022 making access difficult).

The Ngā Tamariki Geothermal System is classified as a ‘Development Geothermal System’ by Waikato Regional Council. An 82MW geothermal power plant was commissioned at Ngā Tamariki in 2013. Most of the geothermal fluid used for production is reinjected back into the field, and regular monitoring of the vegetation at this site is undertaken.

Other key management issues in this geothermal system are the monitoring and control of pest plants, and good practice in the management of surrounding pine plantations. Extensive wilding pine control work has been undertaken within the Orakonui site since 2011. There has been occasional control of pines, pampas, and other pest plants since, although further work is required if values are to be maintained. Chinese privet (*Ligustrum sinense*), blackberry, pampas (*Cortaderia selloana*), and Montpellier broom (*Genista monspessulana*) have expanded in extent at the Orakonui site since 2011. While Montpellier broom has declined in cover in recent years, the other species are still of concern. Control of Chinese privet, blackberry, and pampas, and ongoing control of wilding pines should be undertaken within this site. Control of pest plants on the Waikato River margins would also benefit the geothermal vegetation at the Waikato River Springs/Mangamingi Stream site.

9.7 Ohaaki Geothermal System

The Ohaaki Geothermal System has about 18.4 ha of geothermal vegetation which comprises c.2% of the geothermal vegetation in the Waikato Region with an additional c.1.9 hectares mapped as geothermal water. The vegetation comprises c.17.2 ha of terrestrial geothermal vegetation, with c.2.3 hectares of geothermally-influenced bare ground and c.1.2 hectares of geothermal wetland. About 12 hectares is dominated by

geothermal kānuka, which equates to *c.*2% of the geothermal kānuka dominant vegetation in the Waikato Region. The vegetation has been mapped over two sites on either side of the Waikato River.

Small areas of relatively undisturbed geothermal vegetation dominated by geothermal kānuka are present. Scattered areas of monoao are a feature of this geothermal system. Other species typical of geothermal habitat include *Lycopodiella cernua* and *Campylopus pallidus* (a moss). *Dicranopteris linearis* (Threatened-Nationally Endangered), arrow grass (Burns 1997a) and *Psiloum nudum* (Merrett *et al.* 2003) have also been recorded in this geothermal system, although none of these species have been recorded in this geothermal system during regular surveys since 2011.

The Ohaaki Geothermal System is classified as a ‘Development Geothermal System’ by Waikato Regional Council. From 1989, Ohaaki Geothermal Power Station has supplied electricity to the national grid, and this exploitation has affected the geothermal features of both sites described in this report. All geothermally-influenced pools in this area are now dry, unless artificially maintained. Ground temperatures have decreased in places and increased in others, resulting in an overall increase in the extent of geothermal vegetation (Merrett and Burns 1998a). Regular monitoring of the site has shown a reduction in geothermal influence in the vegetation present over time, an increase in pest plant abundance, and an increase in cover and height of geothermal kānuka (Wildland Consultants 2022). Wilding pines are currently having the biggest impact on the site (bigger than any impact from extraction), and require control (Wildland Consultants 2022). Pampas spread is also an issue. An additional threat to geothermal vegetation in this system is any further subsidence of land and subsequent inundation of existing geothermal vegetation by the Waikato River. A restoration plan has been prepared (Wildland Consultants 2012g) and this should be implemented.

9.8 Orākei Kōrako Geothermal System

Geothermal vegetation within Orākei Kōrako Geothermal System comprises *c.*8.3% (*c.*74.7 ha) of the geothermal vegetation of Waikato Region, and is the fourth largest area of geothermal vegetation in the Waikato Region. An additional 4.4 hectares was mapped as geothermal water. The mapped geothermal vegetation comprises 70.9 hectares of terrestrial vegetation (including *c.*2.4 hectares of geothermally-influenced bare ground) and *c.*3.8 hectares of geothermal wetland. In this system, *c.*62.3 hectares has been mapped as geothermal kānuka dominant vegetation (*c.*11% of the geothermal kānuka dominated vegetation in the Waikato Region). The vegetation has been mapped over four sites with the largest areas of geothermal vegetation present at the Orākei Kōrako and Red Hills site (*c.*70.5 ha).

Considerable additional areas of geothermal vegetation and habitats were found in the 2022 field survey of the Orākei Kōrako and Red Hills site compared to what has been mapped previously. A lot of these areas were located between the two areas, and because the sites now have no clear boundary, these sites were combined. This additional geothermal vegetation was likely always present and is thus not considered a real increase in geothermal vegetation extent.

Geothermal features present at Orākei Kōrako include boiling pools, springs, geysers, local steaming ground, occasional mud pools, hydrothermal eruption craters, and silica

sinter terraces. The water types are chloride, mixed chloride bicarbonate and minor acid condensates. Surface rocks and relict sinter between the Orākei Kōrako and Te Kopia Geothermal Systems suggest they once formed a single larger geothermal system (Simpson and Bignall 2016).

Present-day geothermal features and vegetation within the Orākei Kōrako Geothermal System represents only part of what was once a spectacular geyser field (Cave *et al.* 1993). About three quarters of the geothermal features were lost when the Waikato River was dammed and Lake Ōhakuri was created in 1961 (Lloyd 1972, Cave *et al.* 1993). Approximately 200 hot springs and 70 geysers were flooded, with 30 active geysers and 100 hot springs remaining. Abundant hot springs and geothermal features remain present beneath the surface of the hydro reservoir. Orākei Kōrako is classified as a 'Protected Geothermal System' by Waikato Regional Council.

The site 'Orākei Kōrako and Red Hills' is the largest site in the Orākei Kōrako Geothermal System. This site contains large areas of good quality geothermal vegetation, and is nationally significant. The site supports the largest population the Threatened fern *Dicranopteris linearis* (Threatened- Nationally Endangered) in Aotearoa New Zealand. There is also an important and relatively stable population of *Christella* aff. *dentata* ('thermal') (Threatened- Nationally Endangered). A small population of *Cyclosorus interruptus* (At Risk-Declining) is also present at the site. Other "At Risk" species have been recorded at the site previously, but not observed recently. A number of "At Risk" bird species utilise the site, and long-tailed pekapeka/bats (Threatened-Nationally Critical) have been recorded in the past in caves at the site as well as in nearby forest.

Akatarewa Stream supports a stable population of *Christella* aff. *dentata* ('thermal') (Threatened- Nationally Endangered), while Waihunuhunu also supports a number of "At Risk" species and two small populations of *Dicranopteris linearis* (Threatened-Nationally Endangered).

Most of the Orākei Kōrako Geothermal System is in excellent ecological condition, with significant work having been undertaken by iwi and Waikato Regional Council to control wilding pines throughout the Orākei Kōrako-Red Hills area. Follow-up wilding pine control should continue throughout all the sites in the System, along with willow control in wetland areas. Management and monitoring of the impacts of pest animals such as pigs (*Sus scrofa*) and possums is also recommended.

9.9 Reporoa Geothermal System

Reporoa Geothermal System contains c.11.1 hectares of geothermal vegetation spread over three sites (c.1.2% of the geothermal vegetation in the Waikato Region). An additional c.0.5 hectares is mapped as geothermal water. Several areas of surface geothermal features are also present in this field (e.g. Butcher's Pool), but are not known to contain any geothermal vegetation and therefore are not mapped in this report. Mapped vegetation comprises c.9.0 hectares of terrestrial vegetation (including c.2.1 hectares of geothermally-influenced bare ground) and c.2.1 hectares of emergent wetland vegetation. Surface geothermal features present in this system include minor steaming ground, hot pools and peripheral warm springs (Simpson and Bignall 2016).

A moderate, but important population of *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) is present within the Golden Springs site. Management of pest plants along the stream is recommended as the pest plants present may compete with this nationally Threatened fern species.

The best quality geothermal vegetation in the Reporoa Geothermal System occurs at Longview Road and is protected by a QEII Covenant. It contains a relatively large area of mānuka and mingimingi scrub and shrubland associations with large areas of mudpools and geothermally-influenced bare ground. The geothermal vegetation at Wharepapa Road and Golden Springs have been more impacted by farming, recreational use, and planting of exotic species. Geothermal features have been adversely affected by drainage at all sites within this geothermal system and parts are affected by farming. No further drainage of geothermal wetlands and features should be undertaken at any of the sites in the Reporoa Geothermal System. Fencing of geothermal features, with pest plant control and management, is recommended for all geothermal manifestation with stock access e.g. Wharepapa Road.

The Reporoa Geothermal System is classified as a ‘Research Geothermal System’ by Waikato Regional Council. There is some evidence that the Reporoa Geothermal System is linked to the Waikite-Waiotapu-Waimangu System (Kaya *et al.* 2014 & 2015).

9.10 Rotokawa Geothermal System

The Rotokawa Geothermal System contains c.144.8 hectares of geothermal vegetation, (the third largest extent of geothermal vegetation), which comprises c.16% of the mapped geothermal vegetation in the Waikato Region. An additional c.72.9 hectares (most of this comprising Lake Rotokawa) has been mapped as geothermal water. Of the c.144.8 hectares mapped geothermal vegetation in this system, c.11.0 hectares were mapped as geothermally-influenced bare ground; this is a significant reduction in mapped bare ground since the last survey, indicating that the site is recovering from previous disturbance (sulphur mining) as a result of woody species increasing in cover in these areas. A large part of the Rotokawa site is administered by the Department of Conservation as Lake Rotokawa Conservation Area. Approximately 99 hectares was mapped as geothermal kānuka dominant vegetation, which represents 17% of the mapped geothermal kānuka dominant vegetation within the Waikato Region. A further c.9.7 hectares was mapped as geothermal wetland.

This system is characterised by collapse pits and eruption craters, one of which is filled by Lake Rotokawa. Large deposits of sulphur lie under and around the edge of the lake, and the surrounding area has been modified by sulphur mining. Further modification has occurred from harvesting operations in the surrounding pine plantation forest which dominates the northern end of this system. Considerable control of pest plants (particularly wilding pines) has been undertaken by the Department of Conservation in the Lake Rotokawa Conservation Area in recent years. Ongoing control of pest plants in this reserve is recommended both within the Department of Conservation administered areas and other parts of Rotokawa, particularly to the north of the reserve.

The large extent of geothermal kānuka scrub and shrubland is a key feature of this geothermal system. Large areas of mānuka scrub and shrubland are also present. There

is a population of the terrestrial orchid *Calochilus robertsonii* (At Risk-Naturally Uncommon) on the flats on the northern side of Lake Rotokawa; a total of *c.*36 plants were recorded in November 2019 (Wildland Consultants 2020) and *c.*70 plants were recorded in 2006 (Bycroft 2008). Geothermal water in Lake Rotokawa is highly acidic (NIWA 2002) and there have been several surveys of the aquatic biota. *Chironomus zealandicus* is the only chironomid midge to have been recorded from Lake Rotokawa (NIWA 2002). Other invertebrates recorded from the lake include the water boatman bug *Sigara arguta*, mosquito *Culex rotoruae* (Forsyth 1977), the water bug *Saldula stoneri*, fly *Neoscatella* sp. (Duggan and Boothroyd 2002), a diving beetle *Liodessus* sp., a lacewing *Kempynus* sp., and mites (Acari) (James and Kolb 2009). The blue-green alga *Cyanidium caldarum* has been recorded in and around hot springs and their outflows around the lake and the Parariki Stream. Larvae of the thermal mosquito *Culex rotoruae* and the thermal fly *Ephydrella thermarum* have been recorded associated with the blue-green alga (Burns 2007).

The Rotokawa Geothermal System is classified as a Development Geothermal System by Waikato Regional Council. The 29 MW Rotokawa power station was commissioned in 1997 and expanded to 34 MW in 2003. Further development of the Rotokawa Geothermal System has since taken place with commissioning of the 140 MW Ngā Awa Pūrua power station in 2010, which includes the largest single geothermal turbine in the world. The impacts of this energy extraction on the vegetation and features in this geothermal system are being monitored to assist with future management (Wildland Consultants 2021d). The key management issue in this field is the management of wilding pines and other pest plants.

9.11 Te Kopia Geothermal System

Geothermal vegetation mapped within Te Kopia Geothermal System comprises *c.*7.7% (*c.*68.6 ha) of the geothermal vegetation within the Waikato Region, which is the fifth largest area of geothermal vegetation within a geothermal system in the Waikato Region. This vegetation has been mapped over two sites, with almost all of the vegetation being present at Te Kopia (*c.*68.5 ha). Most of the Te Kopia site is located within Te Kopia Scenic Reserve and is contiguous with a much larger area of non-geothermal indigenous vegetation (mainly forest within the Te Kopia Scenic Reserve), but small areas extend into adjoining farmland and onto the west side of Te Kopia Road. The geothermal vegetation of Te Kopia is in excellent condition, and this site is of International significance. The geothermal activity of this area is thought to result from steam boiling off deep chloride water. All the features result from steam heating, although chloride springs are thought to have occurred here in the past (Cave *et al.* 1993). Geothermal features present include steaming ground, acid pools and relict sinter. The water types present are acid sulfate condensates and mixed sulfate chloride. The extent of the system is 11-15 km² (Simpson and Bignall 2016).

The vegetation at Te Kopia Geothermal System is made up of *c.*66.2 hectares of terrestrial geothermal vegetation (including *c.*4.7 hectares of geothermally-influenced bare ground) and *c.*2.4 hectares of emergent wetland vegetation. An additional *c.*0.9 hectares was mapped as geothermal water. The system has *c.*2.4% of the geothermal wetland and 8.5% of the geothermal terrestrial vegetation in the Waikato Region. Approximately *c.*33.5 hectares was mapped as geothermal kānuka dominated vegetation, which is about 6% of the total area of geothermal kānuka dominated

vegetation in the Waikato Region. Additional areas of geothermal vegetation were mapped in the current survey (c.f. Wildland Consultants 2014), mostly within Te Kopia Scenic Reserve. While some small features may be new, and some movement of features were evident on the western side of Te Kopia Road, the overall change in extent of geothermal vegetation is not considered a real change.

The Te Kopia site contains very high quality examples of geothermal vegetation, including habitat for one of the largest populations of the Threatened fern *Dicranopteris linearis* (Threatened-Nationally Endangered) in New Zealand. Murphy's Springs contains a moderate sized population of *Christella* aff. *dentata* ("thermal") (Threatened-Nationally Endangered). *Korthalsella salicornioides* (dwarf mistletoe; Threatened-Nationally Critical) is abundant in the Te Kopia site with at least 100-200 plants present. Two 'At Risk' orchids - *Calochilus paludosus* (At Risk-Naturally Uncommon) and *C. robertsonii* (At Risk-Naturally Uncommon) are well represented at this site. Other 'At Risk' species known from the Te Kopia System include *Schizaea dichotoma*, and *Nephrolepis flexuosa*. The population of *N. flexuosa* appears to have steadily increased in the northern part of the Te Kopia site between 2004, 2014 and 2023 (Chris Bycroft pers. obs.).

Wilding pine control remains a key management issue for the Te Kopia site, although considerable works have been undertaken by the Department of Conservation and the overall number has declined markedly since the early 2000s. Fencing to remove stock from areas of geothermal habitat on farmland should be undertaken, although most areas are well fenced. Management of plantation forest near geothermal habitat should be mindful of the ecological values, particularly as recent plantings are likely to impact some parts of the site in the future through shading and treefall. Dead geothermal kānuka was present in one area at Te Kopia that appeared to have been killed from herbicide overspray from the neighbouring plantation forest. Several areas are vulnerable to management within the surrounding pine plantation, including Murphy's Springs. Herbicide should be used with care, especially near geothermal sites.

The Te Kopia Geothermal System is classified as a 'Protected Geothermal System' by Waikato Regional Council.

9.12 Tokaanu-Waihi-Hipaua Geothermal System

The Tokaanu-Waihi-Hipaua Geothermal System is located at the southern end of Lake Taupō, and lies on the northern flank of Kakaramaea-Tihia andesitic massif. It is part of the greater Tongariro Volcanic Centre. Geothermal activity occurs in three main areas: Tokaanu, Waihi, and Hipaua. Hot springs are also present to about one kilometre to the north on the bed of Lake Taupō (Severne 1999, Risk *et al.* 2002). This geothermal system is >25 km² in size and contains boiling pools, springs, geyser, steaming ground, fumaroles, acid pools, and mud pools. The water types are chloride and enriched chloride, mixed chloride-bicarbonate and acid sulphate condensates (Simpson and Bignall 2016).

The Tokaanu-Waihi-Hipaua Geothermal System contains c.66 hectares of geothermal vegetation, which is c.7.4% of the geothermal vegetation in the Waikato Region. An additional c.4.2 hectares of geothermal water is present. This field contains an estimated 47.4 hectares of geothermal wetland habitat; which equates to about 42% of the

geothermal wetland vegetation in the Waikato Region. The boundaries of geothermal wetlands are difficult to map within the larger wetland complexes in which the sites sit, and are likely to improve with the use of better quality aerial photographs in conjunction with a site inspection. Regardless of the exact size of the geothermal wetland in this field, it is of considerable ecological significance. Most of the area mapped as geothermal wetland was present at Tokaanu Lakeshore Wetland (c.43.7 ha). Tokaanu Lakeshore Wetland contains an extensive area of wetland, with the survey of its margins in 2007 noting that steam was seen rising through raupō at regular intervals throughout much of the mapped site. This is one of the two largest areas of geothermal wetland habitat in Aotearoa New Zealand, and provides habitat for Threatened and At Risk fauna and flora.

About 12 hectares of this system was mapped as geothermal kānuka dominant vegetation, which comprises about 2% of this vegetation type in the Waikato Region.

Geothermal activity at Tokaanu has changed over time and, historically, this site was more extensive and spectacular than it is now. The cause of this decrease in activity is unknown, but may have been related to changes in the water level of Lake Taupō (Cave *et al.* 1993).

None of the sites were field surveyed for this report, and survey information is now twenty years old for some sites. The condition of sites may have changed considerably during this time, including the presence of Threatened and At Risk species. Most of the geothermal kānuka dominant vegetation within this geothermal system occurs at the Hipaua site; however, while it likely to be of high quality, there has been no botanical survey here since 1995 (Given 1995). Hipaua was ranked highly by Given (1995) due to a high diversity of edaphic factors, and for the overall integrity and maintenance of ecological processes. Additional geothermal shrubland and geothermally-influenced bare ground was mapped at Hipaua, based on better quality aerial imagery in 2023, and is unlikely to be real change.

The Tokaanu-Waihi-Hipaua Geothermal System is classified as a 'Limited Development' Geothermal System by Waikato Regional Council.

9.13 Tongariro Geothermal System

The vegetation and habitats in Tongariro Geothermal System have been described in this report in four sites, with an additional relatively small site mapped and described at Rotopaunga. The sites are all on stratovolcano complex of Tongariro, and three of the sites are located in Tongariro National Park. The Ketetahi geothermal site is privately owned and is considered sacred to Tangata Whenua. The System is one of only two high altitude geothermal sites in Aotearoa New Zealand containing geothermal vegetation (the other being a small area on Mt Tarawera in the Bay of Plenty). This system contains the only subalpine and alpine geothermal vegetation in the Waikato Region. The geothermal system is classified as a 'Protected Geothermal System' by Waikato Regional Council.

This geothermal system is >30-60 km² in size and contains steaming ground, fumaroles, minor acid sulfate springs and pools, and recent magmatic hydrothermal eruptions

(Jolly *et al.* 2014, Pardo *et al.* 2014). The water type is acid sulfate condensates (Simpson and Bignall 2016).

Three of the Tongariro sites were visited in 2018 when access permission was granted. The Ketetahi site has never been field surveyed and the site description and assessment are based on the information provided in Given (1995) and aerial photographs.

Geothermal vegetation in the Tongariro System covers *c.*49.8 hectares. This is a big increase in extent since the sites were last mapped. This followed the eruption of the Te Maari Craters in late 2012, which has seen the extent of geothermal habitat at this site almost double. Fumarole activity increased in the vicinity of the crater following the 2012 eruption.

Most of the geothermal sites are bare ground, with scattered *Rytidosperma setifolium* in cooler areas. A small population of *Lycopodiella cernua* was found in Te Maari Crater in 2011 and a population was still present in the wider crater area in the 2018 survey, after the 2012 eruptions. At approximately 1,500 metres a.s.l., this is the highest altitude that this species has been found in Aotearoa New Zealand.

The main issues for management are trampling and damage by people at Ngarotopounamu/Emerald Lakes, and invasive species, including bulbous rush (*Juncus bulbosus*) in the same lakes. Management is underway to control this plant in these lakes.

9.14 Waikite-Waiotapu-Waimangu Geothermal System

The Waikato Regional Council considers Waikite-Waiotapu-Waimangu Geothermal System to be a system with three geothermal systems. This is based on a rigorous analysis by GNS scientists for Waikato Regional Council in 2000. The Waimangu Geothermal System lies within the Bay of Plenty Region. Opinions on what sites should be included in this geothermal system differ, for example, Kaya *et al.* (2014 & 2015) suggested that the connections between the Waimangu and the Waiotapu Geothermal Systems are weak, and also suggest there are lateral flows between the Waiotapu and Reporoa Geothermal System. They refer to the field incorporating the Waikite, Waiotapu and Reporoa Geothermal Systems as being part of the Greater Waiotapu Geothermal System. Further research is needed to confirm the connections among these geothermal systems: Waiotapu, Waimangu, Waikite and Reporoa. In this report, we have analysed the Waikite Geothermal System and Waiotapu Geothermal System sites as part of the Waikite-Waiotapu-Waimangu Geothermal System, and have assessed the Reporoa geothermal sites as a separate Geothermal System.

Features present in the Waimangu-Waikite-Waiotapu Geothermal System include boiling springs and pools, geysers, steaming ground, collapse craters, mud pools, hydrothermal eruption craters and silica sinter terraces. Water types present include chloride, mixed sulphate chloride, mixed chloride bicarbonate, and acid surface condensates. Within the Waiotapu Geothermal System, acid condensate water dominates the north of the site, and chloride sulphate springs are more common in the south. Within the Waikite Geothermal System the springs are near neutral chloride bicarbonate springs (Simpson and Bignall 2016). Geothermal activity has declined at

some parts of the field such as at Maunga Kākaramea with more activity known in the 1870s (Lloyd 1959). The extent of the field is 18-24 km².

The Waikite-Waiotapu-Waimangu Geothermal System comprises the largest area of geothermal vegetation and habitats in the Waikato Region (321.6.1 ha; 32%). Each field is discussed in more detail below.

The Waikite-Waiotapu-Waimangu Geothermal System is classified as a ‘Protected Geothermal System’ by Waikato Regional Council. Sites below are described within the two geotherma. Fields in the Waikite-Waiotapu-Waimangu with the Waikato Region: Waikite and Waiotapu.

9.14.1 Waikite Geothermal Field

The geothermal features of this field are mapped within two sites: Waikite Valley and Northern Paeroa Range.

A total of c.22.8 hectares of geothermal vegetation has been mapped in the Waikite Geothermal Field, which comprises about 2.6% of the geothermal vegetation in the Waikato Region. An additional c.2.7 hectares was mapped as geothermal water. The mapped vegetation in this geothermal field comprises c.12.4 hectares of terrestrial geothermal vegetation (including c.0.7 hectares of geothermally-influenced bare ground) and c.10.4 hectares of geothermal wetland.

Most of the vegetation mapped within the Waikite Geothermal Field is contained within the Waikite Valley site (c.22.4 ha) which includes several disjunct areas of geothermal activity near several small bodies of open water in the north of the site, and hot springs, heated soils, sinter pavements, geothermal wetlands, and plants present on the margins of heated geothermal streams. Surface water draw-off to supply a public swimming pool complex is the only extractive use of the geothermal resource. Since 2011, the wetland areas that were previously farmed on Waikite Pamu Farm to the north of the Waikite Swimming Baths have been fenced to exclude stock, including the entire length of the main stream that passes through the site. Work has been ongoing to restore this relatively large geothermal wetland, including changes to wetland hydrology, planting and weed control. Where stock have been removed from areas, and no planting or weed control has been undertaken, blackberry now dominates. In this survey a few small areas of additional geothermal habitat were located on the Waikite Scarp. These were found as a result of inspection of higher quality aerial photographs and are unlikely to be new areas. The Waikite Valley site contains important habitat for a number of ‘Threatened’ plant species including the second largest population of *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) in Aotearoa New Zealand. Two other Threatened-Nationally Endangered species are also present: geothermal kānuka and *Dicranopteris linearis*. Four other ‘At Risk’ species (as per de Lange *et al.* 2018) are known from this site: *Cyclosorus interruptus* (At Risk-Declining), *Thelypteris confluens* (At Risk-Naturally Uncommon), *Nephrolepis flexuosa* (At Risk-Naturally Uncommon), and *Hypolepis dicksonioides* (At Risk-Naturally Uncommon). It should be noted that *T. confluens* has not been seen at this site in the two most recent surveys (2014, 2022) of the site, so it may no longer be present. The habitat where it occurred previously has changed since 2007. Other species of interest are *Lycopodiella cernua* and *Psilotum nudum*.

Northern Paeroa Range is a relatively small site of c.0.4 hectares and comprises four disjunct relatively small areas of geothermally influenced bare ground. A few plants of geothermal kānuka are present at this site. The site is surrounded by farmland and plantation forest. The site is fenced to exclude cattle, and pest plant cover has increased significantly in this site since the last survey.

9.14.2 Waiotapu Geothermal Field

The Waiotapu Geothermal Field contains the largest area of surface geothermal activity in New Zealand (Cave *et al.* 1993). The geothermal vegetation of this field is mapped over three sites. A total of c.265.3 hectares of geothermal vegetation was mapped, which comprises almost a third (c.29.7%) of the geothermal vegetation of the Waikato Region.

The Waiotapu Geothermal Field comprises c.234.1 hectares of terrestrial vegetation (including c.11.9 hectares of geothermally-influenced bare ground) and c.31.2 hectares of geothermal wetland. The mapped area has increased in size since 2014; this is a result of additional areas being included in this study which were not known about previously, pine harvest which has resulted in additional visibility of geothermal extent, and restoration works improving quality of habitat in places.

The field contains the one of the largest areas of geothermal wetland vegetation in the Waikato Region, which is contiguous with non-geothermal wetland (the entire wetland including geothermal and non-geothermal habitat is known as Orotu Wetland). The geothermal portion of this wetland comprises c.31.2 hectares (27.5%) of the geothermal wetland vegetation mapped in the Waikato Region. The Orotu Wetland contains a varied range of ecological habitats, rare and threatened species, and a diversity of geothermal features.

The field contains indigenous geothermal scrub and shrubland (this includes some extensive areas of geothermal wetland mapped as mānuka scrub). Geothermal kānuka scrub and shrubland covers c.209 hectares (comprising 37% of the area dominated by this species in the Waikato Region), making this the most important field for this species and vegetation type in the Waikato Region. Geothermally-influenced bare ground within the Waiotapu Geothermal Field comprises c.11.9 hectares or 12.3% of this type in the Waikato Region and includes some of the largest areas of sinter terraces remaining in New Zealand, as well as extensive areas of geothermally heated bare ground.

The population of *Cyclosorus interruptus* (At Risk-Declining) in Orotu Wetland is the largest population of this species at any geothermal site in New Zealand. A population of *Korthalsella salicornioides* (Threatened-Nationally Critical), a small hemi-parasitic mistletoe is known to be present at Maungaongaonga, while four orchid species - *Calochilus paludosus*, *C. robertsonii*, *Caladenia alata*¹, and *Caladenia atradenia*² (all At Risk-Naturally Uncommon) have been recorded at Maunga Kākaramaea (Rainbow Mountain).

¹ Previously *Petalochilus alatus*.

² Previously *Stegostyla atradenia*.

Wilding pines remain the key threat to sites in the Waiotapu Geothermal System. Some control has been undertaken, particularly at Maunga Kākaramēa (Rainbow Mountain) and at Waiotapu but this needs to be continued and expanded. Chinese privet is also expanding in extent and should be controlled. Pig damage to the geothermal wetland vegetation remains a threat, with extensive pig tracks still present in 2023 (c.f. extensive pig damage to geothermal wetland vegetation through trampling and making tracks was observed in the Orotu Wetland in 2011).

Some parts of the geothermal vegetation and habitats that are not protected within this field are still subject to grazing, while others are surrounded by plantation forest. Extensive areas are dominated by pest plants. These unprotected areas provide important linkages between the protected areas of geothermal habitat, and regular management of pest plants, particularly wilding pine trees should be undertaken. Managers/owners of adjoining plantation forests should be encouraged to use good practice while harvesting near geothermal sites, and establish buffers when replanting. These areas should be monitored regularly for management issues. Restoration to enhance and/or protect the highly significant ecological values of this field should be encouraged.

9.15 Wairākei-Tauhara Geothermal System

The Wairākei-Tauhara Geothermal System contains *c.*164.0 hectares of geothermal vegetation, which comprises *c.*18.3% of the mapped geothermal vegetation in the Waikato Region (the second largest extent of geothermal vegetation). The vegetation has been mapped over 11 sites, with the largest sites being East Taupō (56.8 ha), Te Kiri o Hinekai (42.8 ha) and Craters of the Moon (36.4 ha). Approximately 62.8 hectares was mapped as terrestrial geothermal vegetation (including *c.*11.1 hectares as geothermally-influenced bare ground) and *c.*1.2 hectares as geothermal wetland. Vegetation dominated by geothermal kānuka covers *c.*133 hectares, which represents 23% of the geothermal kānuka-dominant vegetation within the Waikato Region.

Geothermal features associated with the Wairākei-Tauhara Geothermal System occur in both the Atiamuri and Taupō Ecological Districts. This field is classified as a Development Geothermal System by Waikato Regional Council. Contact Energy Ltd holds resource consents issued by Waikato Regional Council for the take and discharge of geothermal fluid from the Wairākei Geothermal System which is currently used for the generation of electricity in the Wairākei Geothermal Power Plants (collectively Wairākei A and B Power Stations, Wairākei Binary Plant, Poihipi Road Power Station, and Te Mihi Power Station). Geothermal fluid is also provided to a number of ‘cascade’ users, including the Huka Prawn Park and Wairākei Terraces. Contact Energy Ltd also holds separate resource consents for Te Huka Binary Plant and the under-construction Tauhara Power Station on the Tauhara Geothermal System. Independent commissioners granted resource consent in early 2023, for the continued use of the Wairākei Geothermal field for electricity generation for 35 years. This will involve closing Wairākei A&B Power Station by 2031, and further development at Te Mihi.

Present-day surface geothermal expressions in the Wairākei-Tauhara Geothermal System consist of steam vents, weakly steaming ground, steam-heated pools, hydrothermal eruption craters, steam-heated springs, weakly-mineralised springs, and

lake and river edge hot water seeps. Pre-1950, when the Wairākei-Tauhara Geothermal System was considered to be in a natural state, deep chloride fluids reached the surface in the Upper Wairākei Valley (part of Te Rau-o-Te Huia-Wairākei) and on the Waikato River margins near Otumuheke. Elsewhere within the system, reservoir fluids mixed with heated groundwaters before being discharged at the surface. Although the locations of geothermal features within the Wairākei-Tauhara Geothermal System have not changed during recorded history, changes to the nature and levels of activity occurred both before and after extraction of geothermal energy commenced. Some changes pre-1950 that led to some declines in activity of geothermal features included the 1931 Napier earthquake, lowering of the Waikato River associated with construction of the Lake Taupō outlet control gates for the hydroelectric power development scheme in 1941, collection of urban and rural stormwater, and pumped extraction from shallow thermal boreholes (Bromley and Reeves 2021).

Bromley and Reeves (2021) describe how the extraction of deep geothermal fluid at Wairākei since 1958 has had many effects on surface geothermal features. The initial reservoir pressure drawdown at Wairākei had the effect of significantly diminishing surface liquid discharges from deeper reservoirs that contain high-chloride fluid, while increasing discharges from steam-heated features. This also raised the temperature of some shallow ground water aquifers. Furthermore, in the late 1990s there was a cracking of the aquiclude underlying the Waiora Lakes area, causing some small lakes and pools there including Pirorirori (aka Alum Lake) to experience a permanent decline in water level, with most running dry (K. Luketina, Waikato Regional Council, pers. comm). Following this initial phase of enhanced steam heating, resulting from liquid pressure decline and boiling, there has been a subsequent cooling phase, originating in the shallow steam zones. This process has taken place over several decades. Areas of steaming ground have expanded at many sites in the Wairākei-Tauhara Geothermal System during a phase of elevated temperatures (heat pulse), which was followed by a phase of reducing geothermal activity. In terms of vegetation, this earlier heat pulse will have had the effect of increasing the cover of surface geothermal vegetation (most notably vegetation dominated by geothermal kānuka) at many sites (e.g. Te Rau-o-Te Huia-Wairākei, Te Kiri o Hinekai, Craters of the Moon, and East Taupō), followed by a slow decline in thermal ground activity that has resulted in an increase in vegetation height and transition towards species less typical of geothermal habitats.

Overall, the drawdown has caused declines in the pressure of the geothermal reservoir. This resulted in chloride springs such as those at Te Rau-o-Te Huia-Wairākei (in the upper Wairākei Valley Thermal Valley) to cease flowing, new steam vents to appear, several hydrothermal eruptions, and increases in temperature due to subsurface boiling at Craters of the Moon and Otumuheke. Gradual subsidence of more than one metre has accumulated across a large proportion of the area within the System (Bromley *et al.* 2018), and in a few locations, particularly adjacent to Upper Wairākei Valley (part of Te Rau-o-Te Huia-Wairākei), larger subsidence of up to 15.6 metres had accumulated by 2017 (Bromley *et al.* 2018). In 1998, large-scale reinjection of separated brine from the Wairākei Geothermal Power Station was initiated. This led to a slight recovery of pressure within the System, however further declines in pressure have been recorded following the initiation of geothermal fluid extraction at the Te Mihi Power Station in 2012 (Sepulveda *et al.* 2017). Although power production within the Tauhara Geothermal System did not commence until 2006 (Te Huka binary plant), some of the earlier pressure changes originating from extraction in the Wairākei Geothermal System

were transmitted across a wide area of the Tauhara Geothermal System, e.g. early expansion of geothermal vegetation at East Taupō and the loss of geysers alongside the Waikato River near Spa Thermal Park.

Declines in groundwater levels have been recorded throughout the Wairākei Geothermal System since 1955, particularly at Te Kiri o Hinekai. This has reduced the water levels in lakes and hot pools, and the flow rate of some springs. A local hydrothermal eruption occurred at Alum Lakes in 2001, following an anomalous period of groundwater level declines (Bromley *et al.* 2018). There have been no observable effects on nearby springs and fumaroles or changes in groundwater levels following the commissioning of Te Mihi Power Station (Bromley *et al.* 2018).

Long-term declines in groundwater levels were also recorded in the northern part of the Tauhara Geothermal System from 1995-2006 (Bromley 2009). This led to the demise of Kathleen Springs (part of Otumuheke). Conversely, increased flow rates were recorded at the Otumuheke Spring (upper part of Otumuheke Stream; part of Otumuheke) between 1987 and 2009 (Bromley 2009). Activity here has now declined, resulting in large changes to the geothermal vegetation here, with the spring source retreating down the valley (Bromley and Reeves 2021). Despite the ongoing declines in groundwater levels at Wairākei Geothermal System, the levels have remained relatively stable in the Tauhara part of the Wairākei-Tauhara Geothermal System since about 2009 (Bromley *et al.* 2018).

Surface heat discharges in both fields of the Wairākei-Tauhara Geothermal System increased from a pre-development estimate to a peak (heat-pulse in response to development and pressure drawdowns: 750 megawatt in 1964 at Wairākei Geothermal System, 217 megawatt in 1972 at Tauhara Geothermal System), followed by a gradual decrease, with current measurements similar to pre-development values (Bromley *et al.* 2021).

In addition to changes in the vegetation resulting from geothermal development, vegetation has also been significantly affected by a range of other issues, summarised below:

- Loss of vegetation to both road and industrial development, particularly near Taupō township at East Taupō.
- Loss of vegetation due to fire. Geothermal sites dominated by woody species such as geothermal kānuka near Taupō are particularly vulnerable to fire due to recreational use. Fires occurred at both the Upper Wairākei Valley part of Te Rau-o-Te Huia-Wairākei, and Spa Thermal Park part of Otumuheke sites in 2012. A fire occurred in the Broadlands Road part of East Taupō in late 2015. Between 2006 and 2013, a fire burnt about 30% of the geothermal kānuka shrubland and scrub within the Crown Park part of East Taupō. A fire occurred in the southwestern part of the Crown Road part of the East Taupō site in 2002. Some sites recover from fire, but may result in the establishment of a different suite of species, including pest plants.

- Grazing occurs at several sites in the Wairākei-Tauhara Geothermal System (e.g. parts of Te Rau-o-Te Huia-Wairākei, and the Crown Road part of East Taupō), which reduces the extent and condition of geothermal vegetation.
- Exotic plantation forest is present on the margins of many sites in the Wairākei-Tauhara Geothermal System, e.g. Te Kiri o Hinekai. Plantation forests provide an ongoing source of wilding conifers, and mature forests shade and suppress the growth of affected geothermal vegetation (particularly geothermal kānuka which is shade intolerant).
- Other pest plant species that have become increasingly common at cooling geothermal sites include blackberry, pampas, and Chinese privet. Pest plants such as blackberry have also invaded the margins of some sites (e.g. Te Rau-o-Te Huia-Wairākei) when sites have been protected from grazing but without management to address ongoing pest plant issues.

9.15.1 Wairākei Geothermal System

The Wairākei Geothermal System contains *c.*97.9 hectares of geothermal vegetation, which comprises *c.*10.9% of the mapped geothermal vegetation in the Waikato Region. Approximately 97.8 hectares was mapped as terrestrial geothermal vegetation (including *c.*3.8 hectares as geothermally-influenced bare ground) and <0.1 hectares as geothermal wetland.

Past collections of plant specimens indicate that the Upper Wairākei Valley part of Te Rau-o-Te Huia-Wairākei supported populations of nearly all the tropical ferns and fern allies associated with thermal areas in Aotearoa New Zealand (Given 1989, Bycroft and Beadel 2007). Some of these species are now either completely absent or much reduced in abundance and distribution at this site. Cooler ground has also allowed the invasion of pest plants. The Upper Wairākei Valley part of Te Rau-o-Te Huia-Wairākei no longer contains discharging hot springs, geysers or pools, but since the 1950s there has been an increased area of steaming ground (Bromley and Reeves 2021), resulting in a larger area of vegetation dominated by geothermal kānuka. However, in recent decades, the geothermality of this habitat has declined following the initial heat pulse. Measurement of vegetation on two transects on heated ground in the Upper Wairākei Valley between 2013 and 2022 has shown a decline in geothermality, with increased height of vegetation and decreasing surface soil temperatures (at a depth of 10 centimetres) (Wildland Consultants 2017 & 2022f).

Pools and springs have also shown declines in geothermal activity at Te Kiri o Hinekai (e.g. Alum Lakes) and flow has been lost from the upper part of Te Kiri o Hinekai Stream (Bromley and Reeves 2021). New geothermal habitat has been created as a result of the power station on the lower sections of Te Kiri o Hinekai Stream and Wairākei Stream. Te Kiri o Hinekai Stream receives separated brine from a discharge from the power station for cultural purposes and from the Wairākei Terraces Tourism Facility. The lower Wairākei Stream receives brine from the Western Borefield holding pond (Lake Farquhar) and separately from the Wairākei Binary Plant. The lower sections of these streams contain steamy habitats on the margins due to the presence of geothermal water from these inputs. These areas provide habitat for threatened and rare geothermal plant species (e.g. *Christella* aff. *dentata* (“thermal”) and *Hypolepis dicksonioides*) that have been lost from the Upper Wairākei Valley (part of Te Rau-o-

Te Huia-Wairākei) and potentially other sites in the Wairākei Tauhara Geothermal System. The lower section of Te Kiri o Hinekai Stream also supports a small population of annual fern. This is the only known record of this species near Taupō.

Most of the larger sites - Te Rau-o-Te Huia-Wairākei, Te Kiri o Hinekai, and Craters of the Moon - in the Wairākei Geothermal System expanded in the first few decades following the start of deep geothermal extraction at Wairākei in the 1950s. The heat pulse resulted in the increased expanse of geothermal kānuka that is still present at these sites today. At Craters of the Moon, a ten-fold increase in heat output occurred following development of the Wairākei field (Huser 1989). This led to an increase and enhancement of habitat for some species (most notably geothermal kānuka), with considerable development of geothermal vegetation and large populations of plants characteristic of geothermal sites (Given 1989a), including species classified as Threatened or At Risk in Aotearoa New Zealand. As discussed above, the extent and intensity of surface heat at most of these sites has declined in recent decades. Evidence of this has been observed by transect monitoring at Upper Wairākei Valley, Te Kiri o Hinekai, and at Craters of the Moon, with some transects showing clear evidence of a decline in geothermality based on vegetation composition and height (Wildland Consultants 2017a, 2017b, 2019b). The steamy ground habitats at Te Kiri o Hinekai, Te Rau-o-Te Huia- Wairākei and Craters of the Moon support important populations of the Threatened and At Risk ferns *Nephrolepis flexuosa* and *Dicranopteris linearis*.

Other features in the Wairākei Geothermal System occur at Tukairangi/Karapiti Forest, Waipuwera Stream, and alongside the Waikato River at Hall of Fame Stream. The Tukairangi part was historically active but has now cooled (Bromley and Reeves 2021). The vegetation descriptions recorded by Given (1989a), and more recent surveys by Wildland Consultants (2000, 2004, 2012, 2014b, 2021a), indicate that the geothermal character of this part is declining. This is also the case for the Karapiti Forest part of this site. The Waipuwera mud pools and springs, located to the south of Craters of the Moon, were visited for the first time in 2021. Therefore, the history of this site is unknown to the authors. The Hall of Fame Springs are an outflowing of steam-heated groundwater originating from near the Karapiti Thermal Area (Craters of the Moon).

9.15.2 Tauhara Geothermal System

The Tauhara Geothermal System contains c.66.1 hectares of geothermal vegetation, which comprises c.7.3% of the mapped geothermal vegetation in the Waikato Region. Approximately 65.0 hectares was mapped as terrestrial geothermal vegetation (including c.7.3 hectares as geothermally-influenced bare ground) and c.1.1 hectares as geothermal wetland.

The site referred to as Otumuheke in this report contains geothermal springs and streams, thermally heated ground, and geothermal wetland. Some springs in this valley have stopped flowing completely (Kathleen Spring in 1997, AC spring in 2000 and the Otumuheke source spring has been declining since 2000; Bromley and Reeves 2021). The location of the upper spring at Otumuheke Stream has retreated down the valley (Bromley and Reeves 2021), which has resulted in extensive loss of geothermal wetland habitat and sinter in the upper part of the valley. This has led to a marked reduction in the population of *Cyclosorus interruptus* at this site, from an estimated several thousand plants, to currently less than 100 plants (based on a visit in June 2023), with many in

poor health due to the loss of geothermal wetland habitat. The only other site with this species in the Tauhara Geothermal System and near Taupō township is a small population at Waipahihi Valley. Bromley and Reeves (2021) note the historical temperatures in the spring which feeds the stream were naturally lower than they were when last recorded, ostensibly due to geothermal extraction (40 °C in 1964; 83 °C in 2009). Both the upper spring, which is located c.350 metres down the valley from the source spring, and the source spring have a similar temperature (80 °C). The Kathleen Stream that flows into the Otumuheke Stream is fed by thermal bore water from the AC baths thermal bore discharge. Together these two geothermal streams provide habitat for the largest populations of *Christella* aff. *dentata* (“thermal”) and *Hypolepis dicksonioides* in the Tauhara Geothermal System. A small population of *Nephrolepis flexuosa* is also present on the lower section of Otumuheke Stream, but has declined in cover since the early 2000s; it is the only known population in the Tauhara Geothermal System.

The Spa Sights area alongside the Waikato River in Spa Thermal Park historically contained geysers and springs, but these are no longer active (Bromley and Reeves 2021). The thermal areas at Spa Park that are located away from the Waikato River were historically active and were likely dominated by geothermal kānuka and other plant species typical of steam-heated ground. Steam-heated ground at Spa Park reached a maximum in the 1970s, however has since declined and been colonised by wilding pines.

While geothermal vegetation has always been present at East Taupō (Broadlands Road, Crown Road, and Crown Park), the extent of geothermal kānuka and other vegetation associated with steam-heated ground increased markedly to a peak in the 1970s (Bromley and Reeves 2021). The current amount of geothermal vegetation present at this site still exceeds its natural extent, although many hot ground anomalies have cooled since the 1970s.

9.16 Whangairorohea Geothermal System

The Whangairorohea System is classified as one of the small geothermal system in the Waikato Region by Waikato Regional Council. This geothermal system has a c.10 × 15 metre wide geothermal spring and pool surrounded by sedges, reeds, and exotic terrestrial vegetation. Scattered pest plants such as Spanish heath (*Erica lusitanica*), blackberry, and buddleia (*Buddleja davidii*) occur around the pool and these should be removed. Additional springs near the Whangairorohea main spring, along the edge of the Waikato River were identified in 2023 (based on a location in Youngman 1996).

10. CHANGES IN EXTENT OF GEOTHERMAL SITES

A total of 750 hectares of geothermal vegetation was mapped in 2014, compared to 893 hectares in 2023. Since the last inventory study in 2014, an additional 142.8 hectares of geothermal vegetation has been mapped, however most of this area is the result of discovery of additional areas of existing habitat as the quality and resolution of aerial photography continues to improve. Real increase in vegetation extent was noted for two sites covering only relatively small areas. Waikato Regional

Council obtained very high resolution images (0.06 metres resolution) of some geothermal sites in the Region in 2021, and these have contributed to more accurate vegetation mapping, including the addition of more geothermal areas that have not previously been mapped, but which were always likely to have been present (e.g. in the Orākei Kōrako Geothermal System). Pine plantation harvest in some areas has resulted in additional areas being mapped, as areas previously obscured beneath a pine canopy in aerial photography are now visible. Indigenous forest also obscures geothermal habitat at some sites such as Maunga Kākaramaea (Rainbow Mountain), Te Kopia and Orākei Kōrako and Red Hills and additional geothermal features are likely to be present in these areas.

Overall, the extent of geothermal vegetation across the Waikato Region has been relatively stable in the last ten years. Minor real reductions have occurred at some sites due to increases in pest plant cover and, in some cases, from herbicide use on site margins. However, decreases in vegetation extents large enough to be seen against changes that are a result of more accurate mapping have not occurred. There have been changes in condition (both improved and declining) rather than extent.

Real increase in vegetation extent was noted for only two sites. At Waikite Valley this increase is a result of restoration effort in the wetland area. The increase at Te Maari Craters is a result of the 2012 eruptions which resulted in an expansion of geothermal habitat, which has now been colonised by some plant species. A very small real increase in vegetation has also occurred at Te Kiri o Hinekai as a result of expansion of the Wairākei Borefield.

Future changes to vegetation extent are likely to occur at some sites due to changes in the geothermal systems as a result of geothermal energy extraction (Wildland Consultants 2021c). Changes are already occurring at the Otumuheke site which have not been captured in this study, due to the timing of the aerial photography. At this site, the geothermal spring at the upper end of the Otumuheke Stream valley has reduced in flow over the last 10 years, resulting in a reduction in geothermal wetland extent and loss of steamy habitat for Threatened fern populations. A reduction in overall extent of geothermal vegetation at this site can be expected in future. Small losses at some sites were evident with conversion to farming or plantation forest, e.g. Tauhara South, East Taupō, Te Kopia, Waiotapu, Ohaaki Steamfield East.

The condition of many sites has changed positively as a result of ecological restoration effort. However, some sites are in poorer condition since the last survey, mainly as a result of pest plant expansion. It was noted in particular that many geothermal areas have been fenced sometime in the past 10+ years, but that in many cases, this has resulted in a significant increase in blackberry, pampas, and other pest plants where no other restoration effort such as planting has taken place. Further information on specific site changes is detailed in each site sheet in Sections 14-28.

Table 11: Changes in mapped area (ha) of geothermal vegetation between 2014 and 2023.

Geothermal Site	Area of Mapped Geothermal Vegetation		Extent of Change	Overall Real Change	Comments
	2014	2023			
Atiamuri Geothermal System					
Matapan Road	<0.1	<0.1	0	None	Minor change a result of mapping onto better quality aerial photographs.
Whangapoa Springs	0.1	0.2	0.07	No real change	
Total	0.1	0.2	0.07		
Horohoro Geothermal System					
Horohoro	<0.1	<0.1	0	None	
Total	<0.1	<0.1	0		
Mokai Geothermal System					
Paerata Road	1.7	1.3	-0.4	No real change	Minor change a result of mapping onto better quality aerial photographs.
Tirohanga Road	0.2	0.4	0.2	No real change	Minor change a result of mapping onto better quality aerial photographs.
Waipapa Stream	1.2	1.2	0.0	None	Minor change a result of mapping onto better quality aerial photographs.
Whakamaru	<0.1	<0.1	0	None	
Total	3.1	2.9	-0.2		
Ngatamariki Geothermal System					
Orakonui	0.9	1.1	0.2	No real change	Minor change a result of mapping onto better quality aerial photographs. A small geothermal stream was found at the south of this site in 2020, but this was probably always present.
Waikato River Springs/Mangamingi Stream	0.4	4.0	3.6	No real change	No real change evident. Increase in site size due to mapping of additional areas identified by site visits and aerial photographs.
Total	1.3	5.1	3.8		
Ohaaki Geothermal System					
Ohaaki Steamfield East	6.4	5.3	-1.1	May be a very small real decrease	Minor change a result of mapping onto better quality aerial photographs. Increase in blackberry in southern part of the site may be a real decrease in geothermal vegetation extent.
Ohaaki Steamfield West	11.6	13.1	1.5	No real change	No real change evident. Minor increase due to the addition of new areas identified during site visits.
Total	18.0	18.4	0.4		
Orākei Kōrako Geothermal System					
Akatārewa East	0.1	0.1	0.0	None	Minor change a result of mapping onto better quality aerial photographs.
Akatārewa Stream	1.4	1.8	0.4	No real change	
Orākei Kōrako and Red Hills	59.9	70.5	10.6	No real change	
Waihunuhunu	2.8	2.3	-0.5	No real change	Minor change a result of mapping onto better quality aerial photographs.
Total	64.2	74.7	10.5		
Reporoa Geothermal System					
Golden Springs	0.7	0.8	0.1	No real change	Minor change a result of mapping onto better quality aerial photographs, although extent and abundance of pest plants has increased.
Longview Road	5.9	6.0	0.1	No real change	Minor change a result of mapping onto better quality aerial photographs.
Wharepapa Road	3.4	4.3	0.9	No real change	Minor change a result of mapping onto better quality aerial photographs.
Total	10.0	11.1	1.1		
Rotokawa Geothermal System					
Rotokawa	114.8	144.8	30.0	No real change	No real change evident. Large increase in site size due to the addition of additional areas identified by site visits and aerial photographs which does not represent a real increase in extent at this site.
Total	114.8	144.8	30.0		
Te Kopia Geothermal System					
Murphy's Springs	0.2	0.1	-0.1	No real change	A very small additional area was found during field survey but this has not resulted in a real change to the extent of geothermal vegetation.
Te Kopia	65.1	68.5	3.4	Small area of real loss	The small increase in site size is likely a result of mapping onto better quality aerial photographs, with additional areas identified, particularly in Te Kopia Scenic Reserve. A small area of geothermal kānuka was sprayed as part of plantation pine preparation, but this loss has been obscured by mapping changes.
Total	65.1	68.5	3.4		
Tokaanu-Waihi-Hipaua Geothermal System					
Hipaua	12.1	12.7	0.6	No real change	Minor change a result of mapping onto better quality aerial photographs.
Maunganamu	2.1	2.1	0.0	No real change	Minor change a result of mapping onto better quality aerial photographs.
Tokaanu	7.3	7.5	0.2	No real change	Minor change a result of mapping onto better quality aerial photographs.
Tokaanu Lake Shore Wetland	37.7	43.7	6.0	No real change	No real change evident. Increase in site size is a result of mapping onto better quality aerial photographs.
Total	59.2	65.9	6.7		
Tongariro Geothermal System					
Ketetahi	8.2	8.5	0.3	No real change	Minor change a result of mapping onto better quality aerial photographs.
Ngarotopounamu/Red Crater	12.0	11.1	-0.9	No real change	Minor change a result of mapping onto better quality aerial photographs.

Geothermal Site	Area of Mapped Geothermal Vegetation		Extent of Change	Overall Real Change	Comments
	2014	2023			
Rotopaunga	Not surveyed	3.2			
Te Maari Craters	8.4	27.1	18.7	Increase	Increase in site size following the 2012 eruptions (which were not captured in the 2014 extents due to timing of the aerial photography used) which has resulted in a real increase in geothermal habitat.
Total	28.6	49.8	21.2		
Waikite-Waiotapu-Waimangu Geothermal System					
Waikite Geothermal System					
Northern PAEROA Range	0.3	0.4	0.1	No real change	Minor change a result of mapping onto better quality aerial photographs.
Waikite Valley	19.9	22.4	2.5	Increase	Real expansion of the wetland area as a result of restoration effort. Additional areas were found on Waikite Scarp as a result of them being visible on aerial photographs, but this does not represent real change.
Total (field)	20.2	22.8	2.6		
Waiotapu Geothermal System					
Maunga Kākaramēa (Rainbow Mountain)	51.6	49.4	-2.2	No real change	There is no real change at this site. Although additional areas were found and mapped in 2023, the extent quoted in 2023 excludes all areas located in the Bay of Plenty Region. It is possible that some of these areas were included in the 2014 extent.
Maungaongaonga	8.7	9.1	0.4	No real change	Minor change a result of mapping onto better quality aerial photographs.
Waiotapu	160.8	206.6	45.8	Small areas of loss	The overall site size has increased since 2014. This is due to mapping onto better quality aerial photographs, addition of previously unmapped areas, and harvest of pines allowing more areas to be seen on aerial photographs. However, some small areas have been destroyed as a result of pine harvest and replanting.
Total (field)	221.1	265.0	43.9		
SYSTEM TOTAL	241.3	287.9	46.6		
Wairākei-Tauhara Geothermal System					
Tauhara Geothermal System					
East Taupō	51.4	56.8	5.4	No real change	No real change at this site. Some of the increase is due to removal of stock from an area and subsequent recovery of geothermal vegetation here that has allowed areas of geothermal activity to be more evident. The remaining increase is likely a result of mapping onto better quality aerial photographs. The extent of geothermal habitat at this site is expected to be in the process of decline.
Otumuheke Stream	3.8	8.5	4.7	No real change	Additional areas were found and mapped in 2023 as a result of mapping onto better quality aerial photographs and increased knowledge of the site. The ecological condition of the site has declined. Changes to this site are discussed further in the text.
Tauhara South	0.1	0.1	0.0	Slight decrease	One small part of the site has been destroyed and converted to farmland since 2014.
Taupō Shoreline		0.3		No real change	No real change likely, the site was mapped within Waipahihi Valley in 2014, and considerably more areas were found in the 2020 site survey.
Waipahihi Valley	0.3	0.4	0.1	No real change	Minor change a result of mapping onto better quality aerial photographs.
Total (field)	55.6	66.1	10.5		
Wairākei Geothermal System					
Craters of the Moon	38.1	36.4	-1.7	No real change	Minor change a result of mapping onto better quality aerial photographs.
Hall of Fame Stream	0.3	0.2	-0.1	No real change	Minor change a result of mapping onto better quality aerial photographs.
Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	0.1	2.6	2.5	No real change	No real change evident. Additional areas were found and mapped in 2023 as a result of mapping onto better quality aerial photographs and increased knowledge of the site.
Te Kiri o Hinekai	35.6	42.8	7.2	Very small increase	No real change evident. A very small increase as a result of the expansion of the Wairākei Borefield, but most of the increase is a result of additional areas being mapped and mapping onto better quality aerial photographs.
Te Rau-o-Te Huia-Wairākei	14.6	15.2	0.6	No real change	Minor change a result of mapping onto better quality aerial photographs.
Tukairangi/Karapiti Forest	0.5	0.6	0.1	No real change	No real change evident. Minor change a result of mapping onto better quality aerial photographs with new areas of geothermal activity found. Elsewhere the condition of geothermal habitat has declined.
Total (field)	89.2	97.9	8.7		
SYSTEM TOTAL	144.8	164.0	19.2		
Whangaioroheia					
Whangaioroheia	<0.1	0.05	0	No real change	Minor change a result of mapping geothermal springs identified on Waikato River. No real increase to site size.
Total	<0.1	0.05	0		
Grand Total	750.5	893.3	142.8		

11. HUMAN DISTURBANCE AND ASSOCIATED THREATS

There are a range of human activities that cause disturbance and associated threats to the geothermal vegetation and habitats in the Waikato Region, as set out below:

Use of Geothermal Systems for Energy Production

This is one of the greatest threats to the viability and sustainability of geothermal vegetation and associated flora. Extraction of geothermal energy can completely change the character and extent of geothermal sites, although the relationship between extraction and site changes can be complicated. Extraction can change a range of factors at a site, such as groundwater levels, subsidence, create hotter ground and can create cooler ground. These changes have the potential to change both the character of geothermal sites, and the distribution of species within them. Extraction can result in increases in temperature and subsequent extent of geothermal habitat, or decreases in temperature which result in the disappearance of geothermally tolerant species and increased risk of invasion by pest plant species. For example, extraction of the Wairākei-Tauhara Geothermal System for electricity generation has resulted in a lowering of the water table and consequent loss of hot springs and geysers. Past collections indicate that Geyser Valley at Wairākei supported colonies of nearly all the tropical ferns and fern allies associated with thermal areas in New Zealand (Given 1989b). Most of these species are now either completely absent or much reduced in abundance and distribution at this site. A heat pulse in the past has resulted in a large increase in the extent of geothermally heated ground; this ground is now cooling and the geothermal vegetation is starting to both decline in geothermal character and retreat.

Knowledge of and management of geothermal systems has improved markedly since the first geothermal power station became operational in Aotearoa New Zealand (Wairākei in 1958; the second geothermal power station in the world). Present day energy extraction seeks to balance the effects of subsidence through re-injection of geothermal water, while still maintaining surface geothermal expressions, thus ensuring that geothermal habitats and vegetation remain.

Tourism and Recreation

Considerable damage to geothermal vegetation and habitats can result from the construction of recreational facilities such as tracks, roads, and buildings, and from the combined effects of large numbers of visitors. This is a particular threat at popular tourist sites such as parts of Waioatapu, Orākei Kōrako-Red Hills, Upper Wairākei Stream (part of Te Rau-o-Te Huia-Wairākei), Maunga Kākaramēa (Rainbow Mountain), Craters of the Moon, Waikite Valley, Tokaanu, and Ngarotopounamu/Red Crater.

An example of clearance of geothermal vegetation and features for construction of recreational infrastructure facilities occurred at the Crown Road part of the East Taupō site. Here areas of geothermal kānuka scrub and shrubland were destroyed for the construction of a motocross track, with further loss occurring during expansion of the track between 2007 and 2014. The managers of the motocross track have been more pro-active in avoiding damage to vegetation in recent years, and no further clearance has been recorded since 2014.

Geothermal sites are particularly vulnerable to damage from trampling by people walking through the natural areas, particularly where there are areas of bare ground, geothermal kānuka dominant vegetation, or populations of threatened ferns (Burns *et al.* 2013). Trampling can break vegetation and cause compaction of the ground which can make it difficult for indigenous plants to re-establish. Some sites, such as Craters of the Moon, have prepared a management plan to reduce the impacts of tourists, by using a variety of techniques to encourage visitors to refrain from walking off the formed tracks. This plan is being implemented successfully, although it has taken some time for vegetation to recover due to soil compaction with evidence of informal tracking remaining in places years after being formally discouraged.

Similar trampling damage to geothermal vegetation and habitats could occur at several sites as a result from other recreational activities such as mountain biking, if not properly managed. At Craters of the Moon, other sites in Wairākei-Tauhara Geothermal System, and at Maunga Kākaramēa (Rainbow Mountain), mountain bikers are discouraged from creating unofficial tracks or riding through vegetation and features. This protection strategy should continue to be emphasised at these sites.

Attempts to ‘tidy’ or otherwise ‘enhance’ areas for tourism and recreation can also degrade the geothermal vegetation. Mowing or slashing geothermal vegetation, the indiscriminate use of herbicides for weed control, replacement of ‘scruffy’ geothermal vegetation with grass or other introduced plants, and the application of fertiliser to promote growth of non-thermal vegetation all threaten the viability of geothermal vegetation. This practice is still continuing at some sites, such as Golden Springs, the thermal baths area at Waikite Valley, and at the golf course at East Taupō. Better communication with land managers/owners will be required to change these practices.

Dumping of Rubbish

Dumping of garden refuse into natural areas leads to the establishment of garden escapees and other pest plants. Some of the introduced species that are planted in gardens are particularly problematic and can spread rapidly from cut stems or vegetative material that is dumped. Examples of such species that are present in geothermal sites in the Waikato Region include montbretia (*Crocasmia* × *crocasmiiiflora*), aloe (*Aloe* sp.), hydrangea (*Hydrangea macrophylla*), and agapanthus (*Agapanthus praecox*). In addition, the introduced fern, Cretan brake (*Pteris cretica*) was recorded at several sites near Taupō during the current survey, some of which may have established as a result of garden dumping.

Dumping of other types of general rubbish, including litter, white-ware, and fencing materials, is also a problem at some sites, including Wharepapa Road, parts of East Taupō, Otumuheke, parts of Waiotapu, and Waihunuhunu. Dumped rubbish threatens the quality and viability of geothermal vegetation and habitats, as well as being unsightly.

Pest Plants

Invasive exotic plants, particularly wilding pines and blackberry, are the most obvious threat to most geothermal sites. The scale of the problem is large: in 2023 we calculated

that of the c.379 hectares of vegetation which is dominated by geothermal kānuka, approximately 70 hectares (nearly 20%) has a high cover of woody weeds (i.e. high enough cover of weeds for key pest plant species to be included in the vegetation type). More than 268 exotic plant species have been recorded from geothermal habitats in the Waikato Region, of which at least 42 are considered to be serious pest plants. While weeds will generally not survive on the hottest areas of ground, species such as wilding pines, blackberry, silver birch (*Betula pendula*), Montpellier broom, tree lucerne (*Chamaecytisus palmensis*), Himalayan honeysuckle (*Leycesteria formosa*), broom (*Cytisus scoparius*), Spanish heath, cotoneaster (*Cotoneaster glaucophyllus*), bamboo species (e.g. arrow bamboo, *Pseudosasa japonica*), montbretia, and pampas (mainly *Cortaderia selloana*) readily invade cooler ground around the margins of geothermal sites. Examples of larger sites where pest plants are common on the margins and are a high priority for control include Maunga Kākaramea (Rainbow Mountain), Te Kopia, Orakonui, Rotokawa, and Waiotapu. Pampas has increased to such an extent in some sites, that pampas tussockland is now recognised as a vegetation type in the current assessment.

Wilding pines - particularly maritime pine (*Pinus pinaster*) and radiata pine (*Pinus radiata*) - are the most common pest plants in geothermal areas. For example, seven species of wilding pines have been recorded at Maunga Kākaramea (Rainbow Mountain), and earlier reports (prior to pine control work which began in the 1980s) noted pines covering 6-20% of the geothermal vegetation at the site. However, considerable pine control work has been undertaken at this site by the Department of Conservation, with a dramatic improvement in vegetation condition. Pine control has also been undertaken at Waipapa Stream, Ohaaki, Waiotapu, Te Kopia, Orākei Kōrako-Red Hills, Orakonui, Rotokawa, and several sites near Wairākei and Taupō.

Other pest plant tree and shrub species recorded from geothermal habitats include flowering cherry (*Prunus* sp.), Chinese privet, *Cotoneaster franchetii*, false acacia (*Robinia pseudoacacia*), eucalyptus (*Eucalyptus* sp.), Tasmanian blackwood (*Acacia melanoxylon*), crack willow (*Salix fragilis*), and grey willow (*Salix cinerea*).

Blackberry, broom, buddleia, Himalayan honeysuckle, gorse (*Ulex europaeus*), Spanish heath, and exotic grasses are common on cooler geothermal soils and on the margins of sites, but are difficult to manage in most situations. Where they are present in low abundance, they should be controlled to prevent them from spreading.

Some pest plants are site specific and require urgent management, for example *Cyperus alternifolius* subsp. *flabelliformis*, Mexican daisy (*Erigeron karvinskianus*), and ivy (*Hedera helix*) are a significant threat to populations of *Nephrolepis flexuosa* and *Christella* aff. *dentata* ('thermal') at Waikite Valley. Willows are a particular threat to the condition of geothermal wetlands. Considerable improvements can be made by undertaking willow control, as has been undertaken in the northern part of Waikite Valley since 2012.

Nephrolepis flexuosa is an indigenous species of ladder fern that is present at several geothermal sites in the Waikato Region and is ranked as 'At Risk-Naturally Uncommon'. A threat to the maintenance of populations of this species is the potential for mixing with a naturalised and invasive species, tuber ladder fern (*N. cordifolia*). At one geothermal site in the Bay of Plenty, colonies of *Nephrolepis* probably comprise

both the indigenous ladder fern and introduced tuber ladder fern. The presence of both species growing together means that it would be difficult to control the invasive species without damaging any of the indigenous plants. Therefore, it is important that any planting or dumping of *N. cordifolia* at or near geothermal sites is discouraged.

Weed control methods need to avoid or minimise risk to geothermal vegetation. For example, removal of pest plants may make geothermal ferns more susceptible to damage during frosts if the canopy providing shelter is removed. Pest plant control can also pose a risk to species of Threatened and At Risk ferns that occur alongside stream margins by making stream banks more vulnerable to erosion. Where pest plant management could damage habitat of Threatened and At Risk plant species, implementation of a pest plant management plan written by an appropriately qualified person should be undertaken (particularly for sites larger than 10 hectares).

Notable changes in the presence of pest plants that were observed at geothermal sites during the current survey include:

- Royal fern (*Osmunda regalis*) was recorded in the wetland at Waikite Valley for the first time. This small population was subsequently controlled by the Department of Conservation.
- Scattered plants of Japanese hill cherry (*Prunus serrulata*) were recorded in the wetland at Waikite Valley for the first time.
- A small population of Asiatic knotweed (*Reynoutria japonica*) was recorded at Lower sections: Te Kiri o Hinekai Stream and Wairākei Stream. This site was not included in the survey previously so the infestation may have been present for some time. This infestation should be prioritised for control as Asiatic knotweed is listed in the Eradication programme of the Waikato Regional Pest Management Plan.
- The cover of pampas has increased at some sites since the previous survey. In some cases this increase in cover has been sufficient that areas of pampas have now been mapped as a separate Vegetation and Habitat Type, e.g. Orakonui, and Waipahihi Valley.
- The introduced ferns, male fern (*Dryopteris affinis*) and golden shield fern (*D. filix-mas*) are becoming widespread and were recorded at several sites during the current survey, e.g. East Taupō, Waiotapu, and Waikato River Springs/Mangamingi Stream. *Pteris cretica* is also becoming abundant at a number of geothermal sites, particularly those near Taupō township.
- The infestation of African feather grass (*Cenchrus macrourus*) that was identified at Waiotapu in Wildland Consultants (2014a) has since been controlled by Timberlands and work is continuing in an attempt to eradicate it.

Herbicide Drift

Drift of herbicide or fertiliser that is used during management of adjoining land is also a threat to geothermal vegetation. For example, spraying to control pest plants alongside road margins, or within farmland, or plantation forest could lead to damage of geothermal vegetation. Drift of fertiliser could increase the growth and competition

from pest plants. Damage from herbicide has previously been recorded at several sites including Craters of the Moon, Te Kopia, and at Orakonui. In 2014 at Orakonui, spray drift from aerial herbicide application on adjoining land, led to some decline of geothermal kānuka, and likely led to the loss of the population of arrow grass that was present; this arrow grass population was one of the larger populations of this species at a geothermal site on sinter in the Waikato Region, although it is widespread in coastal areas in general.

Damage from Domestic Livestock

Where livestock have access to geothermal vegetation e.g. in the Crown Road part of East Taupō, they are a major threat to its viability, and stock-proof fencing is a high priority. Livestock cause damage to vegetation by grazing, trampling and pugging of the ground surface and opening up sites for weed invasion. Stock can also cause considerable damage to sites by congregating in the warm areas during cold weather.

Considerable areas of geothermal vegetation have been fenced by farmers in the last 20 years. Deer (*Cervus* sp.) were noted to have caused considerable damage by trampling in some areas of geothermal kānuka shrubland at Te Rau-o-Te Huia-Wairākei in 2006. This part of the site is no longer farmed, and is now threatened by the spread of dense blackberry. An area within the Golden Springs site has been fenced since surveyed in 2007, and the fencing was well maintained in 2023. At some sites the existing fencing is in a poor condition and maintenance is recommended, e.g. the eastern edge of the Orākei Kōrako-Red Hills site. Since 2014, some small areas at East Taupō have also been lost to farmland development.

Following the establishment of fences around geothermal areas that have previously been accessed by stock, pest plants such as blackberry and pampas will often establish rapidly on the disturbed margins. It is therefore important that a plan for managing pest plants on the margins of geothermal sites is prepared and implemented following fencing.

Plantation Forestry and Shelterbelts

A number of geothermal sites in the Waikato Region are located adjacent to plantation forest and wilding pines are invading the geothermal vegetation, particularly around the margins. Where geothermal areas adjoin plantation forests, management and harvesting operations need to be undertaken with care to avoid damaging the geothermal vegetation or associated buffer vegetation. Any damage during harvest can create canopy gaps that increase the chances of weed invasion or further damage by wind, and thereby threaten the viability of geothermal vegetation. The adverse effects of plantation forestry on geothermal sites can also be addressed, as recommended by Given (1995), by establishing or maintaining zones of indigenous vegetation around the margins of geothermal sites. There are currently few buffer zones. For example, a protection buffer was not established around geothermal habitats at the southern part of the Te Kopia site and at Akatarewa East when plantation pines were recently planted. There is an example of a buffer at Waipapa Stream between plantation forest and the geothermal stream. This improves the viability of this site for threatened fern species.

Some sites (e.g. Northern Paeroa Range and parts of Te Kopia in farmland) are surrounded by shelter belts. Adjacent shelterbelts should be managed to ensure that trees are not felled into geothermal sites. Windfall can also be an issue with shelterbelts.

Introduced Pest Animals

Pest animals can threaten the health and viability of indigenous vegetation and habitats associated with geothermal sites. For example, possums, lagomorphs (European rabbit, *Oryctolagus cuniculus*; brown hare, *Lepus europaeus*), feral deer, and pigs can damage vegetation through browsing, disturbing plant roots, or trampling on foliage. In addition, rats (*Rattus* spp.), mice (*Mus musculus*), and mustelids (ferrets (*Mustela furo*); stoats (*Mustela erminea*); weasels (*Mustela nivalis vulgaris*)) are significant predators and threaten populations of indigenous fauna. Control of pest animals should be undertaken where they are causing notable problems. The managers/landowners of several sites have established pest animal control including at Alum Lake (part of Te Kiri o Hinekai), Upper Wairākei Stream (Geyser Valley, part of Te Rau-o-Te Huia-Wairākei), and Rotokawa.

Of particular note, significant damage to understorey vegetation by pigs was recorded at Waiotapu in Orotu Wetland in 2011 and 2023. This is the best quality geothermal wetland in New Zealand, and control of pigs should be undertaken to reduce their impacts on this site. Pig damage was also evident at Orākei Kōrako-Red Hills in November 2022.

The impacts of dama wallabies (*Macropus eugenii*) on fragile geothermal vegetation are likely to be high if the populations are allowed to increase and expand in the Waikato Region.

Plague or rainbow skinks (*Lampropholis delicata*) were recorded in the current survey at Te Kopia. This species is able to reach high densities and can potentially compete with other lizard species for food. Argentine ants (*Linepithema humile*) are also a threat to indigenous ecosystems and can live in geothermal areas.

Fire

Geothermal vegetation is frequently dominated by flammable species such as geothermal kānuka and monoao, and great care needs to be taken with fire in the vicinity of geothermal sites. Fires have occurred at several sites in the Waikato Region, including East Taupō, Otumuheke, Waiotapu, and Te Rau-o-Te Huia-Wairākei. A fire in late 2012 at Upper Wairākei Stream (Geyser Valley) (part of Te Rau-o-Te Huia-Wairākei) started as a result of a discarded cigarette butt and resulted in degradation of the site through weed invasion of the burnt area. A fire in 2015 in the Broadlands Road part of East Taupō burnt through a large area of geothermal kānuka vegetation and habitat. Although geothermal kānuka is now recovering well, the fire has returned this area to a younger, less developed stage of geothermal habitat. Smoking should be discouraged at all geothermal sites.

Genetic Pollution

The planting of indigenous species around geothermal areas using plants sourced from other parts of New Zealand can result in genetic mixing of different ecotypes (e.g. see Timmins and Wassilief 1984, Simpson 1992). When restoration or amenity plantings are undertaken within or adjacent to geothermal areas, only locally-sourced plants from within the same ecological region or district should be used and, where possible (particularly for sites of Regional/National/International significance), plant stock should be sourced from the site (or from within the same geothermal system).

Wetland Infilling and Drainage

Some geothermal activity is associated with wetlands, and these sites are vulnerable to infilling and drainage. Wetlands have been much reduced in extent in the Waikato Region and remaining wetlands deserve a high level of protection. Geothermal wetlands also provide habitat for Threatened and At Risk fern species such as *Thelypteris confluens* at Waikite Valley and *Cyclosorus interruptus* at Waioatapu, Orākei Kōrako, and Orakonui.

There has been considerable effort to restore the geothermal wetlands at Waikite Valley (Reeves *et al.* 2018). Since the early 2000s, several of the drains have been removed, water tables have been raised, and the stream has been rediverted to reflect its original location. Indigenous sedgeland has now recovered to much of the restored area of wetland, although regular control of pest plants, particularly willows, will be important.

Industrial/Residential/Roading Development

In a few cases, geothermal vegetation and habitats near urban areas have been destroyed during the development of industrial, residential, and roading infrastructure. This is particularly prominent at sites near Taupō. For example, at the East Taupō site between 2007 and 2014, the State Highway 1 bypass was constructed through part of the site, and areas of geothermal kānuka scrub and shrubland were cleared for the construction of an industrial subdivision (Crown Road part) and a building associated with a BMX track (Crown Road part).

12. FUTURE MANAGEMENT RECOMMENDATIONS

12.1 Assessment of threats and priorities for ecological management

An updated assessment of the threats and ecological management priorities for each geothermal site in the Waikato Region is presented in Wildland Consultants (2023a).

12.2 Buffers and connections

Protective buffers enhance the viability of natural areas by buffering sensitive ecosystems from external modifying influences such as plantation forest harvesting, wind, and weed invasion. Geothermal habitats were previously surrounded by non-geothermal indigenous vegetation, which also provided connective links or corridors to other geothermal sites. Buffers around geothermal sites are also important due to natural

fluctuations in surface geothermal activity at a particular location and across the landscape. Creating and maintaining good buffers around geothermal sites would allow greater protection of sites in response to this variability.

Many geothermal sites are relatively small and currently have inadequate buffers. Buffers of non-geothermal indigenous vegetation should be made around geothermal areas wherever possible. Connections between areas should also be made wherever possible. Buffers and connections should be subject to regular weed control that achieves effective suppression.

12.3 Ecological restoration

Many sites would benefit from ecological restoration in the Waikato Region and the priority for this have been ranked in Table 11. Restoration works should include:

- Fencing
- Weed control (particularly of wilding trees)
- Pest animal control (particularly of, for example, pigs which extensively damage geothermal vegetation)
- Planting of appropriate indigenous vegetation in non-geothermal habitat to prevent further weed invasion.

The number of geothermal sites that have been fenced since previous surveys is encouraging. A number of sites have also had significant restoration effort undertaken in the last 10 years, and in some sites, this has resulted in real increases in extent of geothermal vegetation as a result.

Ecological restoration and pest plant control works are a high priority at 15 sites, and a very high priority at seven sites, as summarised in Table 12 below:

Table 12: Priority of restoration effort required at geothermal sites within the Waikato Region.

Site Name	Priority for Restoration	Restoration Effort Required
Atiamuri Geothermal System		
Matapan Road	Low	Fencing and subsequent pest plant control.
Whangapoa Springs	Medium	Pest plant management. Pest animal control.
Horohoro Geothermal System		
Horohoro	Medium	Pest plant management.
Mokai Geothermal System		
Paerata Road	Medium	Fencing and planting of appropriate indigenous species to reduce weed issues.
Tirohanga Road	Low	Maintain indigenous plantings.
Waipapa Stream	High	Pest plant management.
Whakamaru	Not required	
Ngatamariki Geothermal System		
Orakonui	High	Pest plant management.
Waikato River Springs/Mangamingi Stream	Medium	Pest plant management, particularly willows.
Ohaaki Geothermal System		
Ohaaki Steamfield East	High	Pest plant management.
Ohaaki Steamfield West	High	Pest plant management.

Site Name	Priority for Restoration	Restoration Effort Required
Orākei Kōrako Geothermal System		
Akatarewa East	Medium	Buffer required between plantation forestry and site, pest plant control.
Akatarewa Stream	High	Protection of <i>Christella</i> aff. <i>dentata</i> ("thermal") population and pest plant management. Management of surrounding plantation when harvesting. Establish indigenous buffer.
Orākei Kōrako and Red Hills	Very high	Pest plant management and pest animal control (pig damage). Fence maintenance on eastern boundary.
Waihunuhunu	High	Pest plant management. Removal and management of rubbish.
Reporoa Geothermal System		
Golden Springs	High	Pest plant management (bamboo, willows in particular), planting of appropriate indigenous species in recently fenced areas.
Longview Road	High	Pest plant and pest animal management, fencing and blocking of drains where possible.
Wharepapa Road	Medium	Pest plant management, fencing and blocking of drains where possible.
Rotokawa Geothermal System		
Rotokawa	Very high	Wilding pine control, pest plant and pest animal management.
Te Kopia Geothermal System		
Murphy's Springs	Medium	Pest plant management. Management of surrounding plantation e.g. buffers.
Te Kopia	Very high	Pest plant management. Planting of buffers and connections between geothermal areas. Pest animal control.
Tokaanu-Waihi-Hipaua Geothermal System		
Hipaua	Medium	Pest plant and pest animal management. Threats poorly known.
Maunganamu	Medium	Pest plant management, particularly willows in wetland areas.
Tokaanu	High	Pest plant and pest animal management.
Tokaanu Lakeshore Wetland	Very high	Willow control. Potential predator control for threatened birds. Threats poorly known.
Tongariro Geothermal System		
Ketetahi	Low	None known, but threats poorly known.
Ngarotopounamu/Red Crater	Very high	Ongoing control of bulbous rush.
Rotopaunga	Not required	
Te Maari Craters	Not required	
Waikite-Waiotapu Geothermal System		
Waikite Geothermal System		
Northern Paeroa Range	Medium	Pest plant management, plantation forestry and shelter belt management.
Waikite Valley	High	Pest plant management to continue. New infestations of willows and royal fern to be controlled. A management plan for stream margins below Corbett Road Bridge is recommended. The plantings around the Waikite Thermal Pools should be reviewed and a plan and guidelines prepared so that the values of surrounding geothermal habitats will not be invaded by the species that are present.

Site Name	Priority for Restoration	Restoration Effort Required
Waiotapu Geothermal System		
Maunga Kākaramea (Rainbow Mountain)	Very high	Pest plant management particularly wilding conifers, pampas and willows.
Maungaongaonga	High	Pest plant management.
Waiotapu	Very high	Ongoing wilding conifer control, pest animal management particularly of pigs in wetland areas, appropriate management of plantation forestry. Fencing of geothermal features in farmland.
Wairākei-Tauhara Geothermal System		
Tauhara Geothermal System		
East Taupō	High	Pest plant management, removal of rubbish, fencing, protection of existing features from further development.
Otumuheke	Very high	Pest plant management and implementation of restoration plan that includes management of threatened species populations and planting requirements.
Tauhara South	Low	Fencing.
Taupō Shoreline	Low	Pest plant management.
Waipahihi Valley	Medium	Pest plant management.
Wairākei Geothermal System		
Craters of the Moon	Medium	Pest plant management.
Hall of Fame Stream	Medium	Pest plant management (while retaining the <i>Christella</i> aff. <i>dentata</i> ("thermal") population).
Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	High	Pest plant management.
Te Kiri o Hinekai	High	Ongoing control of wilding pines and other pest plants.
Te Rau-o-Te Huia-Wairākei	High	Pest plant management, fencing where stock have access.
Tukairangi/Karapiti Forest	Medium	Wilding pine control.
Whangaioroheha Geothermal System		
Whangaioroheha	Low	Pest plant management.

12.4 Priorities for field survey

The assessments of some sites in this report were made from aerial photographs with no field inspections since the first version of this report in 2000 (Hipaua and Ketetahi) as landowner permission to access the site has been withheld. These areas are likely to contain areas of geothermal habitat that are not yet mapped. While changes to mapped areas are likely to be relatively small, field survey should be a high priority if and when access can be arranged. Other sites have not been visited in the field for more than ten years. These areas should also be a high priority for future survey, particularly those in the Mokai and Tokaanu-Waihi-Hipaua Geothermal Systems.

12.5 Future surveys

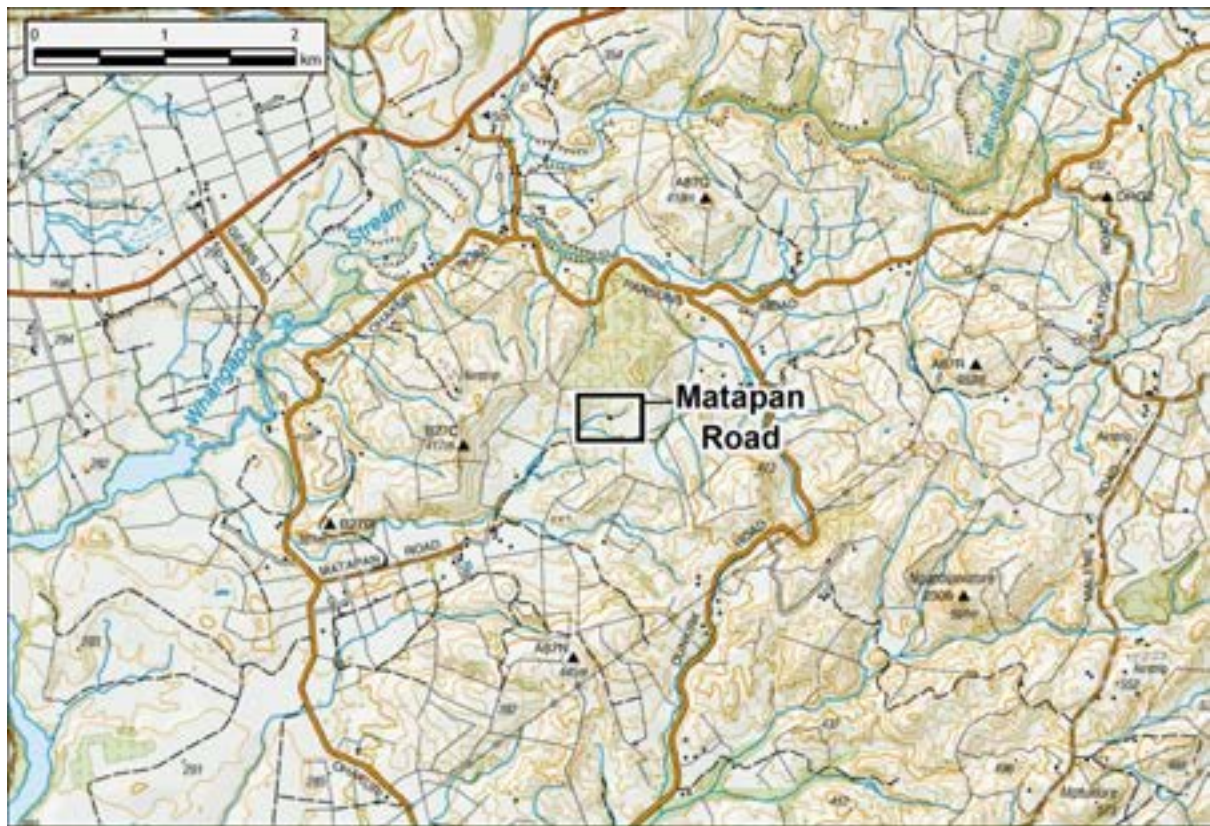
The assessments of sites and mapping of vegetation extent should be undertaken in five years time (2032/33), or sooner, for most of the sites. Sites noted in Section 12.4 should be assessed as soon as land access permission is able to be arranged.

13. REPORTING FRAMEWORK

Geothermal Systems and Fields are used as the framework for presenting site information because sites within the same Geothermal System are known, or inferred, to be sourced from the same geothermal reservoir. This is more relevant to the character of geothermal ecosystems than ecological district boundaries, and avoids splitting sites within fields that span two ecological districts, for example the Tokaanu-Waihi-Hipaua Geothermal System, that spans Tongariro and Taupō Ecological Districts, and the Wairākei-Tauhara Geothermal System that spans Atiamuri and Taupō Ecological Districts. Maunga Kākaramea (Rainbow Mountain) lies within both the Atiamuri Ecological District and Rotorua Lakes Ecological District. This split across ecological districts also roughly matches the administrative boundary between the Waikato and Bay of Plenty Regions. For vegetation area (hectares) in this report, only the parts of Maunga Kākaramea /Rainbow Mountain within the Waikato Region are considered, although the entire area was considered with regards to the assessment of this site.

In this report geothermal sites are arranged within the framework established by the overarching structure provided by Geothermal Systems, and geothermal systems within each System. Sites are arranged alphabetically by Geothermal System.

14. ATIAMURI GEOTHERMAL SYSTEM



Data Acknowledgment Map information data sourced from LRI Crown Copyright Reserved © National Aerial Photography Service (NAPS) 2021 Report: 21034 Client: WRC Ref: 21 2103 Path: E:\gtd\Geothermal Sites 2003-2022\road\figures File: Matapan.mxd	Matapan Road 0 50 100 m	Wildlands www.wildlands.co.nz 0800 910242 Scale: 1:2,500 Date: 21/03/2023 Cartographer: FM Format: A4

MATAPAN ROAD

Ecological District:	Atiamuri	GPS Reference:	NZTM E1869082 N5750467
Geothermal System:	Atiamuri	Altitude:	340 m
Bioclimatic Zone:	Submontane	Local Authority:	Rotorua
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	2 February 2011		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Indigenous fernland (07.01) <i>Deparia petersenii</i> fernland (07.01.12) <i>Deparia petersenii</i> occurs around a geothermal spring and on stream margins. Green, orange, and red algae are present on the substrate behind the waterfall. <i>Paesia scaberula</i> , whekī, <i>Asplenium oblongifolium</i> , and <i>Epilobium ciliatum</i> also occur on the cooler margins of this area.	Hillslope	<0.1 ha
2.	Exotic grassland (08.01) Yorkshire fog grassland (08.01.01) Pasture along the margins of the warm water stream includes Yorkshire fog, tall fescue, and creeping bent.	Hillslope	<0.1 ha

Indigenous Flora: No 'Threatened' or 'At Risk' plant species have been recorded from this site.

Fauna: Yellowhammer was heard during the 2011 survey and other common pasture bird species are likely to be present.

Geothermal Ecosystems: Geothermal streamsides, geothermal wetlands.

Current Condition: At least two small (c.10 m × 3 m) geothermal springs are present on a hillslope. The site was unfenced and the margins were grazed in 2011. The water temperature of the spring at the time of survey (2011) was 69.1 C. The geothermal stream flows into a small (cold) stream c.20 metres below the spring.

Threats/Modification/ Vulnerability:

Invasive pest plants: None evident in 2011, surrounded by pasture grasses.

Human impacts: The site and its surrounds were in a farm paddock in 2011, and stock had access to stream margins. This appears to still be the case based on an assessment of 2021 aerial photographs.

Grazing: In 2011, this spring was unfenced and within grazed pasture.

Adjoining land use: Grazed pasture (farmed).

Site Change:

Recent change: Site has not been assessed recently, although there is no evidence that there has been a change of management based on an assessment of aerial photographs.

*Historical:*¹ No historical photos found; site not assessed.

Management Requirements: This site should be fenced to exclude stock, and ecological restoration planting on the margins should be considered.

Significance Level: Local (Criterion 5).

Significance Justification: Locally significant because it comprises a very small example of a nationally uncommon habitat type (geothermal).

Notes: A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.

References: Wildland Consultants 2012, 2014a.



Spring at Matapan Road, surrounded by *Deparia petersenii* and rank exotic grassland. 2 February 2011.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



WHANGAPOA SPRINGS¹

Ecological District: Atiamuri **GPS Reference (NZTM):** E1866465 N5749485 (Whangapoa Springs); E1866297 N5749798 (Quenched fumarole); E1866338 N5749636 (Geothermal pit)

Geothermal System: Atiamuri **Altitude:** c.275 m

Bioclimatic Zone: Lowland **Local Authority:** Rotorua

Extent of Geothermal Habitat: c.0.2 ha

Extent of Geothermal Vegetation: c.0.2 ha

Date of Most Recent Field Survey: 2 December 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Mixed indigenous species scrub (04.08) Kānuka-mānuka-rautāwhiri-tarata scrub (04.08.04) An area of planted indigenous vegetation ranging in height from 4 to 6 metres surrounding the two main hot springs in the eastern part of this site. The most abundant species are kānuka, mānuka, rautāwhiri, and tarata, with lesser amounts of toetoe², and koromiko. Local bracken and blackberry occur on margins. There are local areas of geothermally influenced bare ground.	Flat	c.0.1 ha
2.	Exotic species-dominant scrub (04.10) Blackberry scrub (04.10.01) This area comprises a tomo with a geothermal spring at the base (2 metres wide and 2.5 metres deep). Dense blackberry in association with broom, bracken and exotic grasses surround the tomo with a canopy height of 1-2 metres. A sinter deposit which extends c.1 m into the tomo is also present.	Geothermal gully	<0.1 ha
3.	Indigenous shrubland Mixed indigenous fernland (07.01.07) (Mānuka)/bracken-Nephrolepis flexuosa-mingimingi fernland A few emergent mānuka to 3 metres occur over a fernland with abundant bracken and local patches of <i>Nephrolepis flexuosa</i>. Scattered mingimingi and occasional blackberry, broom, Spanish heath, <i>Paesia scaberula</i>, and toetoe are present.	Hillslope terrace	<0.1 ha
4.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Silica deposits are present downstream of southeastern pool with occasional toetoe, tūrutu, and several geothermal kānuka plants present on the margins. Patches of exotic grasses occur on the terraces. A small sinter terrace is present downslope of this pool. The terraces have abundant brown algae and local arrow grass. A second smaller sinter terrace was mapped in 2022 and is located downslope of the northern pool.	Hillslope terrace	<0.1 ha

¹ Previously mapped as two separate sites: Upper Atiamuri West and Whangapoa Springs in Wildland Consultants (2014), these sites have been merged in the current assessment.

² The name toetoe is generally used for all the species in the genus *Austroderia*. In this report it refers to *A. fulvida*, the most common species at geothermal sites in the Waikato, unless specified.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
5.	Water (22.01) Geothermal water (22.01.01) a) Two geothermal springs in the eastern part of the site. b) Small area of geothermal water in farm paddock. Dominated by <i>Persicaria maculosa</i> and Yorkshire fog.	Hot spring, quenched fumarole; Geothermal pit	<0.1 ha

Indigenous Flora:

Geothermal kānuka (Threatened-Nationally Endangered) occurs around the margins of these two hot springs. *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) is present on the northern steep sides of the two larger pools. This small population of *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) appears has been present at the site since the late 1970s (see Ecroyd 1979a). The *Nephrolepis flexuosa* population at this site is quite some distance from other populations of this species, with the nearest populations being at Waihunuhunu and Waikite Valley.

Lycopodiella cernua, another species characteristic of geothermal areas, was present in 2011, however it was not observed during the survey. In 2022 it was observed that a population of arrow grass had established on the sinter below the pools.

Fauna:

Common indigenous and introduced bird species typical of the habitat are present. Indigenous species recorded include: kāhu/swamp harrier, pūkeko, pīpīwharau/shining cuckoo riroriro/grey warbler, pīwakawaka/North Island fantail, and kōtare/sacred kingfisher. Introduced species recorded include: common pheasant, Australian magpie, Eurasian skylark, song thrush, Eurasian blackbird, yellowhammer, European goldfinch, European greenfinch, chaffinch, house sparrow, common starling and common myna.

Geothermal Ecosystems:

Geothermal streamsides, fumaroles.

Current Condition:

The condition of the vegetation surrounding the two larger eastern pools has greatly improved since a survey in 2003. Blackberry and broom infestations have been controlled, and indigenous tree and shrub species have been planted and this area has been fenced to exclude stock. The small population of a fern species, *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) around one of the pools has remained since the 1970s. One small feature in the western part of the site has a wooden fence surrounded by grazed paddocks, but when the water table is high, the pool extends beyond the fence into the farm paddock, subjecting it to stock impacts. The other small part is in a fenced gully dominated by blackberry and other exotic species.

Threats/Modification/Vulnerability:

Invasive pest plants:

Scattered blackberry (<5% cover) is present around the northern pool at Whangapoa Springs. Blackberry and broom surround the small geothermal quenched fumarole in the northwest of site, together comprising over 90% of the vegetation cover around this small feature.

Human impacts:

A two metre tall fence surrounds northern of the two larger eastern pools. The natural outlet of this pool has been lowered and reformed as a drain, and there was a small concrete trough present at the outlet.

	In the past there was a small wooden platform in southeastern pool that was used for cooking food, however this has been removed.
<i>Grazing:</i>	All areas are fenced to exclude grazing by stock.
<i>Adjoining land use:</i>	Reserve (planted indigenous shrubs), farmland.
Site Change:	
<i>Recent change:</i>	The two eastern large pools themselves are unchanged since 2003. However, the site is now securely fenced, and has been planted with indigenous tree species. Changes to the two small isolated areas to the west in farmland and a gully are mostly related to changes in water tables after a wet season.
<i>Historical:</i> ¹	Site not assessed, no historical photos found.
Management Requirements:	The small area of blackberry shrubland in the gully has potential for ecological restoration (e.g. control and planting of indigenous species).
Significance Level:	N: National (Criteria 1, 3, 5, 9). L: Local (Criteria 5).
Significance Justification:	N: This part of the site has been ranked as being of national significance because it is a scientific reserve. L: This part of the site is ranked of local significance because it contains geothermal habitat, a nationally uncommon habitat type.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and in this study, this site was classed as Category C - the third highest category. A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007. The classification as a scientific reserve under the Reserves Act is because of the high value of the “hot flowing neutral springs” that are present. The springs were ranked C2 in Cody (1995) using the NZ Geopreservation Inventory Ranking System where C stands for “Regional - site of regional scientific, education or aesthetic importance” and 2 stands for “moderately vulnerable to modification by humans” (defined in Kenny and Hayward 1993).
References:	Ecroyd 1979a; Given 1996; Hochstein 2007a; Spring-Rice 1996; Wildland Consultants 2004c, 2007a, 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



The largest (southeastern) pool at Whangapoa Springs. NZTM E1866488 N5749515. 2 December 2022.



Patches of arrow grass below southeastern pool. NZTM E1866450 N5749482. 2 December 2022.



The second largest pool in the eastern part of the Whangapoa Spring site. There is local *Nephrolepis flexuosa* on the pool margins. NZTM E1866469 N5749560. 2 December 2022.

VASCULAR PLANT SPECIES RECORDED AT SURFACE
GEOTHERMAL SITES IN THE ATIAMURI GEOTHERMAL SYSTEM

Scientific Name	Common Name	Whangapoa Springs	Matapan Road
INDIGENOUS SPECIES			
Dicot. trees and shrubs			
<i>Kunzea serotina</i>		✓	
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	
<i>Leptospermum scoparium</i>	Mānuka	✓	
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	
<i>Pittosporum colensoi</i>	Rautāwhiri, rautāhiri	✓	
<i>Pittosporum eugenoides</i>	Tarata; lemonwood	✓	
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓	
Dicot. lianes			
<i>Muehlenbeckia australis</i>	Puka	✓	
Ferns			
<i>Asplenium oblongifolium</i>	Huruhuru whenua, shining spleenwort		✓ (Recorded in February 2011)
<i>Deparia petersenii</i> subsp. <i>congrua</i>			✓ (February 2011)
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	
<i>Hiya distans</i>		✓ (Recorded 2011)	
<i>Hypolepis ambigua</i>		✓	
<i>Paesia scaberula</i>	Mātātā, hard fern	✓	✓ (Recorded 2011)
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	
Sedges			
<i>Carex virgata</i>	Pūrei	✓	
Monocot. herbs (other than orchids, grasses, sedges, and rushes)			
<i>Dianella nigra</i>	Tūrutu	✓	
<i>Triglochin striata</i>	Arrow grass	✓	
NATURALISED AND EXOTIC SPECIES			
Dicot. trees and shrubs			
<i>Cytisus scoparius</i>	Broom	✓ (Recorded in 2011)	
<i>Erica lusitanica</i>	Spanish heath	✓	
<i>Leycesteria formosa</i>	Himalayan honeysuckle	✓	
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	
Grasses			
<i>Agrostis stolonifera</i>	Creeping bent	✓	✓ (Recorded in 2011)
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓	
<i>Holcus lanatus</i>	Yorkshire fog	✓	✓ (Recorded in 2011)
<i>Lolium arundinaceum</i> subsp. <i>arundinaceum</i>	Tall fescue		✓ (Recorded in 2011)
Composite herbs			
<i>Hypochaeris radicata</i>	Catsear	✓	
<i>Sonchus oleraceus</i>	Puha, sow thistle	✓	
Dicot. herbs (other than composites)			
<i>Digitalis purpurea</i>	Foxglove	✓	
<i>Epilobium ciliatum</i>	Tall willow herb		✓ (Recorded in 2011)
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	Scarlet pimpernel	✓	
<i>Persicaria maculosa</i>	Willow weed	✓	

15. HOROHORO GEOTHERMAL SYSTEM



HOROHORO

Ecological District: Atiamuri **GPS Reference:** NZTM E1878248 N5761370
Geothermal System: Horohoro **Altitude:** 340 m
Bioclimatic Zone: Submontane **Local Authority:** Rotorua
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Most Recent Field Survey: 25 January 2023

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic scrub dominant species (04.10) Blackberry scrub (04.10.01) (Radiata pine)/blackberry-Spanish heath scrub Occasional radiata pine to five metres tall are emergent over mostly dense scrub (1-2 metres high) dominated by blackberry and to a lesser extent Spanish heath and occasional broom. Patches of grasses and herbs are present, mostly at the eastern end of the pool alongside the bathing facilities. Species include sweet vernal, Yorkshire fog, lotus, narrow-leaved carpet grass, paspalum, catsear, hawksbeard, narrow-leaved plantain, and broad-leaved plantain. A clump of montbretia occurs on the southwestern edge of the pool.	Gently to moderately sloping	<0.1 ha
2.	Indigenous fernland (07.01) Gleichenia microphylla fernland (07.01.22) There are two small patches of <i>Gleichenia microphylla</i> fernland (c.1 metre tall) on the pool margins. There are a few Spanish heath, blackberry, <i>Machaerina rubiginosa</i> and swamp kiokio present.	Hillslope	<0.1 ha
3.	Indigenous sedgeland (09.01) Harakeke/Machaerina rubiginosa sedgeland (09.01.13) There is a small wetland at the western end of the geothermal pool. <i>Machaerina rubiginosa</i> is dominant close to the pool, with harakeke more abundant further away from the pool. <i>Lepidosperma australe</i> is locally dominant, and <i>Eleocharis acuta</i> occurs locally on the pool margin. There is scattered blackberry, swamp kiokio, <i>Histiopteris incisa</i> , soft rush and Spanish heath.	Wetland	<0.1 ha
4.	Geothermally influenced bare-ground (20.01) Geothermally-influenced bare ground (20.01.01) There is a small area of sinter at the western end of the larger northeastern pool, with a few patches of narrow-leaved carpet grass on the sinter. Sinter is also present in the pool.	Flat	<0.1 ha
5.	Water (22.01) Geothermal water (22.01.01) Northeastern pool: A temperature of 52 °C was recorded in January 2023 (compared with 48 °C in February 2014). The pool is about 10 metres wide and is approximately circular. Abundant green and orange algae is present. In 2023 the southwestern pool was viewed from a distance for safety as the pool is completely surrounded by dense blackberry. The pool was steaming on a warm day in January 2023. The pool temperature was 55 °C in 2014. The pool is located under a	Open water	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	canopy of grey willow and whekī ponga over blackberry. <i>Carex virgata</i> , kiokio and <i>Histiopteris incisa</i> are present on pool margins. By 2023 the exotic grassland that was surrounding the pool area in 2014 had been replaced by dense blackberry scrub. Around the pool area is a canopy of maritime pine (c.30 metres tall).		

Indigenous Flora: Two species that were present between 2003 and 2014 were not seen during the 2023 survey: *Lycopodiella cernua* and *Leucopogon fraseri*. *Machaerina rubiginosa* and *Lepidosperma australe* have established near the larger northeastern pool since 2014¹. *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) was recorded by Given in 1995 but was not found in 2003, 2014 and 2023 and is presumed to be extinct at this site.

Fauna: Common bird species typical of the habitat are present, including: pūkeko, kōtare/kingfisher, riroriro/grey warbler, tauhou/silvereye, tūi, spur-winged plover. Introduced species include common pheasant, Australian magpie, Eurasian blackbird, European goldfinch, yellowhammer. In 2014 eastern rosella were also recorded at the site.

There were abundant dragonflies (*Hemicordula* sp.) present at the larger spring in January 2023.

Geothermal Ecosystems: Geothermal wetlands, geothermal streamsides.

Current Condition: Both areas are now fenced and stock have been excluded (c.f. in 2014 cattle sign was present near both pools).

At the larger northeastern pool, the vegetation cover has changed since the exclusion of stock. A small wetland at the eastern end of the pool has established with a cover of harekeke flaxland and *Machaerina rubiginosa* sedgeland. Exotic shrubs, mostly blackberry and Spanish heath, now dominate much of the area that was previously in exotic grassland species.

The small southwestern pool is mainly surrounded by blackberry scrub, with a few small areas of indigenous vegetation.

It would be beneficial for a restoration plan to be prepared for both features to guide restoration activities such as weed control and re-establishment of indigenous species around the pool margins.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Vegetation surrounding larger northeastern pool: blackberry 50%, Spanish heath 20%, radiata pine 1%, montbretia (1%), grey willow (1%).

Vegetation surrounding the southwestern pool: blackberry (80%). Maritime pine and poplar are abundant in the wider area. Grey willow is present to the south of this pool.

¹ The area of geothermal wetland has expanded at the western end of the pool since 2014 and is dominated by *Machaerina rubiginosa*.

<i>Human impacts:</i>	Fencing and removal of stock have benefited the features present in both areas. However, pest plants have increased in density and extent, including the following species: montbretia, blackberry and Spanish heath, and is of concern. The larger northeastern pool has bathing facilities at its eastern end. Users do not appear to impact the geothermal features.
<i>Grazing:</i>	No sign of stock was seen at either site. Although the fencing around southwestern smaller pool is in poor condition, the dense blackberry restricts stock access.
<i>Adjoining land use:</i>	Riparian fenced vegetation and farmland.
Site Change:	
<i>Recent change:</i>	There was little change evident at the site between the 2003 and 2014 field surveys. However, since 2014 there has been a marked increase in pest plant abundance at the site. The quality of the small wetland at the western end of northeastern pool has improved and is now dominated by indigenous wetland species.
<i>Historical:</i> ¹	The two areas are too small to identify any evidence of change since 1948 ² .
Management Requirements:	A brief restoration plan should be prepared to guide the management of weeds and enhancement of indigenous vegetation around the two Horohoro geothermal pools. Fences should be checked regularly to ensure that stock do not have access to the site.
Significance Level:	Local (Criteria 4, 5, 6)
Significance Justification:	The site is of local significance because it comprises a small example of nationally uncommon habitat type (geothermal) and a nationally under-represented habitat type (wetland).
Notes:	Given (1995 & 1996) assessed the botanical value of many of the geothermal sites in the Waikato Region. In these studies, this site was ranked as 'D' in 1995 and 'C' in 1996 (was the highest ranking). The large pool is referred to as Waipupumahana Pool in the Waikato Regional Plan Geothermal Module (Waikato Regional Council 2007).
References:	Given 1995 & 1996; Spring-Rice 1996; Waikato Regional Council 2007; Wildland Consultants 2004c, 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photo SN 255 Run 715 Photo 69, 1948.



A few areas of sinter occur at the bathing end of the larger northeastern pool. The remainder is dry habitat dominated by blackberry and Spanish heath, with local patches of *Gleichenia microphylla* fernland. NZTM E1878240 N5761611. 25 January 2023.

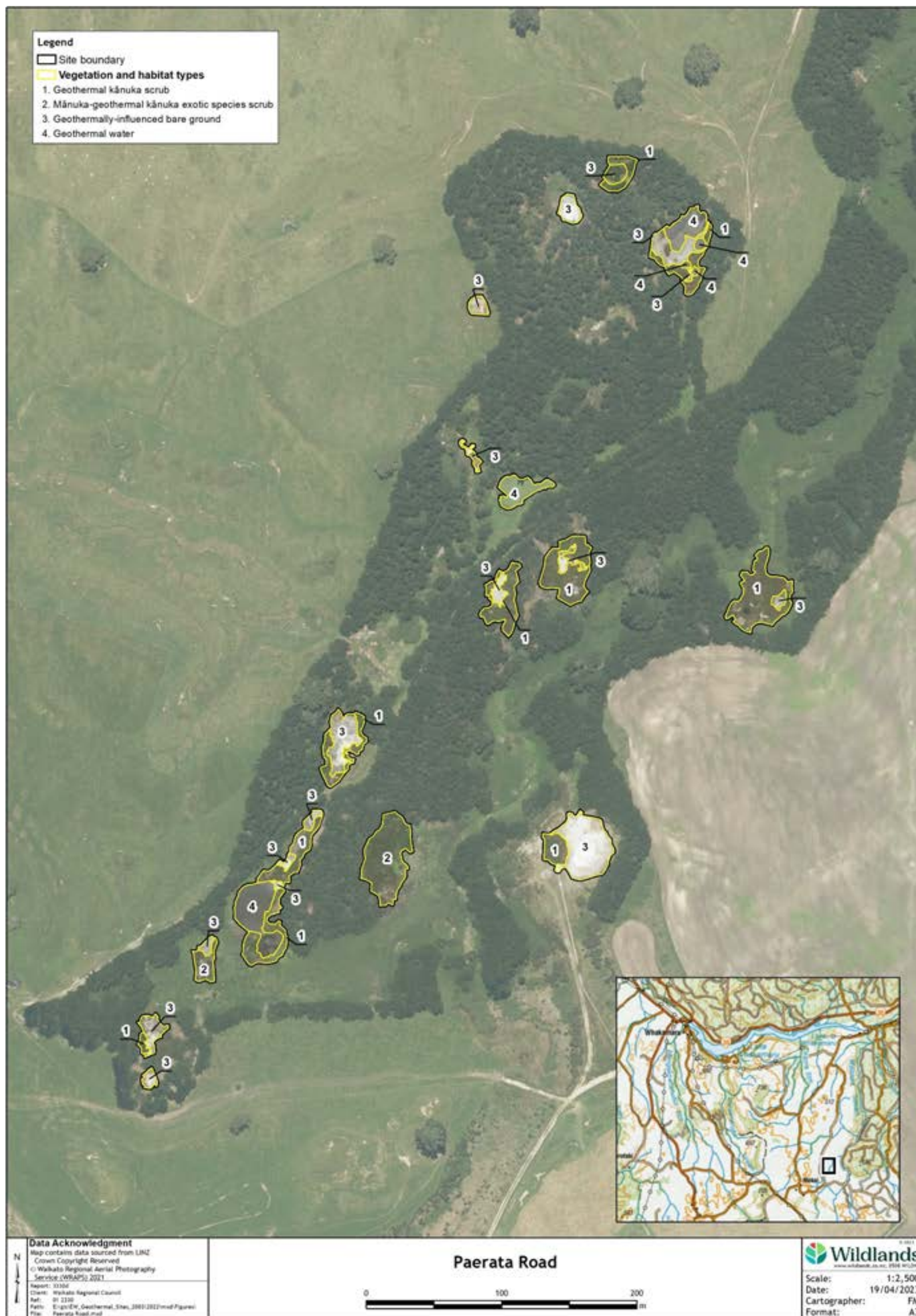


The smaller southwestern pool is located in the centre of the photograph. NZTM E1877948 N5761370. 25 January 2023.

VASCULAR PLANT SPECIES RECORDED FROM SURFACE GEOTHERMAL HABITAT IN THE HOROHORO GEOTHERMAL SYSTEM

Scientific Name	Common Name	Horohoro
INDIGENOUS SPECIES		
Ferns		
<i>Blechnum minus</i>	Swamp kiokio	✓
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio	✓
<i>Dicksonia fibrosa</i>	Wheki-ponga, kuripaka	✓
<i>Gleichenia microphylla</i>	Waewaekaka, carrier tangle fern	✓
<i>Histiopteris incisa</i>	Mataata, water fern	✓
<i>Hypolepis ambigua</i>		✓
<i>Paesia scaberula</i>	Mataata, hard fern	✓
Orchids		
<i>Microtis unifolia</i> agg.		✓
<i>Thelymitra</i> spp.		✓
Sedges		
<i>Eleocharis acuta</i>	Spike sedge	✓
<i>Lepidosperma australe</i>		✓
<i>Machaerina rubiginosa</i>		✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)		
<i>Phormium tenax</i>	Harakeke, flax	✓
NATURALISED AND EXOTIC SPECIES		
Gymnosperms		
<i>Pinus pinaster</i>	Maritime pine	✓
<i>Pinus radiata</i>	Radiata pine	✓
Dicot. trees and shrubs		
<i>Cytisus scoparius</i>	Broom	✓
<i>Erica lusitanica</i>	Spanish heath	✓
<i>Eucalyptus</i> sp.	Eucalyptus	✓
<i>Ulex europaeus</i>	Gorse	✓
Grasses		
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass	✓
<i>Holcus lanatus</i>	Yorkshire fog	✓
<i>Paspalum dilatatum</i>	Paspalum	✓
Sedges		
<i>Juncus effusus</i> var. <i>effusus</i>	Soft rush, leafless rush	✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)		
<i>Crocsmia ×crocsmiiflora</i>	Montbretia	✓
Composite herbs		
<i>Crepis capillaris</i>	Hawksbeard	✓
<i>Hypochaeris radicata</i>	Catsear	✓
<i>Jacobaea vulgaris</i>	Ragwort	✓
Dicot. herbs (other than composites)		
<i>Lotus pedunculatus</i>	Lotus	✓
<i>Plantago lanceolata</i>	Narrow-leaved plantain	✓
<i>Plantago major</i>	Broad-leaved plantain	✓

16. MOKAI GEOTHERMAL SYSTEM



PAERATA ROAD

Ecological District: Atiamuri
Geothermal System: Mokai
Bioclimatic Zone: Submontane
Extent of Geothermal Habitat: c.1.5 ha
Extent of Geothermal Vegetation: c.1.3 ha
Date of Most Recent Field Survey: 2 March 2011

GPS Reference: NZTM E1855210 N5732941
Altitude: 465 m
Local Authority: Taupō

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka dominates the depression faces around small geothermal mud pools (too small to map separately) and geothermally influenced bare ground. Scattered blackberry, broom, mingimingi, mānuka, bracken, and <i>Histiopteris incisa</i> are present.	Flat, craters, hillslope	c.0.6 ha
2.	Mānuka-dominant scrub (04.04) Mānuka-geothermal kānuka exotic species scrub (04.04.04) A discontinuous canopy of mānuka of varying height (c.0.5-1.5 m), with mingimingi, blackberry, and broom scattered throughout, and occasional grey willow. The understorey contains <i>Histiopteris incisa</i> , bracken, and blackberry with local tūrutu and kiokio, and small patches of sedges, rushes, ferns, and geothermal kānuka.	Flat to undulating farmland; small gullies	c.0.2 ha
3.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) These areas comprise mainly bare ground and hot water pools. Introduced grasses (mainly Yorkshire fog, browntop, and Indian doab), <i>Gonocarpus micranthus</i> subsp. <i>micranthus</i> , and the moss <i>Campylopus clavatus</i> occur around the margins of these areas with scattered mānuka, koromiko, mingimingi, geothermal kānuka, broom, bracken, <i>Histiopteris incisa</i> , <i>Paesia scaberula</i> , and blackberry on cooler areas.	Flat to undulating farmland	c.0.5 ha
4.	Water (22.01) Geothermal water (22.01.01) Geothermal water with local areas of bare soil when water tables are lower. Patches of geothermal kānuka, mingimingi, and exotic grasses (including Yorkshire fog, browntop and narrow-leaved carpet grass) are present on the margins.	Flat to undulating farmland	c.0.2 ha

Indigenous Flora:

A small population of geothermal kānuka (Threatened-Naturally Endangered) is present. Other species typical of geothermal habitats present include *Lycopodiella cernua*, mānuka, bracken, tūrutu and kiokio. *Psilotum nudum*, another species characteristic of geothermal areas, has been previously recorded at the site but has not been seen since 1986 (see Beadel and Clarkson 1986).

Fauna:	Common indigenous and introduced birds typical of the habitat are present, including pūtangitangi/paradise shelduck, kāhu/Australasian harrier, spur-winged plover, and pīwakawaka/North Island fantail. Delich (2022) note that elegant gecko, forest gecko, Raukawa gecko and crenulate skink (all At Risk-Declining) are likely to be present within the Mōkai geothermal areas.
Geothermal Ecosystems:	Heated ground (dry), hydrothermally altered ground (now cool), geothermal streamsides.
Current Condition:	Delich (2022) suggests that the geothermal vegetation extent at this site has increased since initial measurements in 1986. The site has been retired from grazing, allowing the vegetation to expand.
Threats/Modification/Vulnerability:	
<i>Invasive pest plants:</i>	Blackberry control has occurred over a large part of this area, however blackberry still comprises 1-5% cover of the site. Several large wilding pines have been killed. Planted radiata pine seedlings may shade geothermal vegetation in the future and geothermal kānuka is not tolerant of complete canopy closure.
<i>Human impacts:</i>	Radiata pine were planted within 5 metres of some geothermal features in 2010/2011. In preparation for planting, large areas of blackberry were sprayed and, in some cases, adjacent mānuka (and possibly other indigenous plant species) have died as a result of herbicide application. These have now recovered (Delich 2022). Parts of this site had been used as a rubbish dump, with rubbish present adjacent to, and encroaching into, geothermal areas. Rubbish is not present in any photographs in Delich (2022).
<i>Grazing:</i>	The site is now entirely within plantation forestry.
<i>Adjoining land use:</i>	This site occurs within plantation pines.
Site Change:	
<i>Recent Change:</i>	Geothermal vegetation has expanded since the removal of grazing and recovery from any herbicide spraying during establishment of forestry. The major change on observation of aerial photographs is the growth of plantation pines around many features.
<i>Historical:</i> ¹	Site not assessed, no historical photos found. As most features are small, changes are unlikely to be evident on historical photographs.
Management Requirements:	The planted radiata pine should be set back at least 10 m from the outside margin of all geothermal areas. All pine trees in geothermal areas should be controlled. Pest plant control at these sites would be beneficial.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

Significance Level:	Local (Criteria 3, 5)
Significance Justification:	Paerata Road is of local significance because it contains a nationally uncommon habitat type (geothermal).
Notes:	This site was identified as a recommended area for protection (RAP) under the Protected Natural Areas Programme (Spring-Rice 1996). Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and in this study, this site was classed as Category C - the third category. This site contains the largest area of geothermal kānuka shrubland in the Mokai Geothermal System.
References:	Beadel and Clarkson 1986; Delich 2022; Given 1989a & 1996; Merrett 2001b; Merrett and Fitzgerald 2004; Spring-Rice 1996; Wildland Consultants 2000, 2004c & 2012, 2014a.



Two geothermal features at the north of Paerata Road site, 2 March 2011. These features are now surrounded by a pine plantation.



A geothermal feature that included mud pools surrounded by geothermal kānuka, Paerata Road, 2 March 2011.



TIROHANGA ROAD

Ecological District:	Atiamuri	GPS Reference:	NZTM E1853319 N5734204
Geothermal System:	Mokai	Altitude:	495 m
Bioclimatic Zone:	Submontane	Local Authority:	Taupō
Extent of Geothermal Habitat:	c.0.6 ha		
Extent of Geothermal Vegetation:	c.0.4 ha		
Date of Most Recent Field Survey:	2 March 2011		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-mingimīngi scrub (04.02) Geothermal kānuka-mingimīngi scrub (04.02.01) Occasional mānuka, mingimīngi, and kāmahī (less than 5 m tall) are emergent over geothermal kānuka scrub (to c.1 m tall) surrounded by rank exotic grasses (Yorkshire fog, browntop, and Indian doab with occasional patches of <i>Paesia scaberula</i>). Patches of blackberry (both alive, and dead following herbicide spray) are present on the margins. Small areas of geothermally-influenced bare ground are present within this vegetation type.	Crater rim and flat	c.0.3 ha
2.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Heated soil, vents, and mud pools occur throughout the site. Indian doab, paspalum, browntop, Yorkshire fog, sheep's sorrel, broad-leaved fleabane, and bracken occur on the margins of these areas.	Crater; gently sloping; geothermal hole	<0.1 ha
3.	Water (22.01) Geothermal water (22.01.01) A series of geothermal pools, oriented in a north-south series, surrounded by browntop grassland with patches of blackberry (alive, sprayed, and dead), bracken, and Californian thistle. Occasional patches of <i>Histiopteris incisa</i> and Yorkshire fog, and some small isolated patches of geothermally influenced bare ground are also present.	Base of craters	c.0.1 ha

Indigenous Flora: Geothermal kānuka (Threatened-Nationally Endangered) is present on the crater rims. Other species typical of geothermal sites include mānuka and mingimīngi.

Fauna: Common indigenous and introduced bird species are present, including Australian magpie, yellowhammer, and European goldfinch.

Delich (2022) note that elegant gecko, forest gecko, Raukawa gecko and crenulate skink (all At Risk-Declining) are likely to be present within the Mokai geothermal areas.

Geothermal Ecosystems: Geothermal streamsides, heated ground (dry), hydrothermally altered ground (now cool), fumaroles.

Current Condition: In 2011, the geothermal habitat was surrounded by rank exotic grasses and blackberry, some of which has been sprayed. The entire geothermal area has been fenced to exclude stock, and there is potential for restoration plantings.

Photographs in Delich (2022) show considerable improvement in the vegetation of the geothermal areas since 2012, with establishment of geothermal kānuka. However wilding pines have also increased in extent.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: There appears to be few invasive pest plants at this site (Delich 2022), although wilding pines are present in low numbers and should be controlled.

Human impacts: A cooking pit (umu) is present in the north of the site. It appears on 2021 aerials, and from Delich (2022) that most of the vegetation surrounding the pools has been planted and the vegetation now comprises planted mānuka, geothermal kānuka, and/or other kānuka species.

Grazing: Domestic stock did not have access to this site in 2011, however, stock have gained access to the site in the past (see Wildland Consultants 2007a).

Adjoining land use: This site is surrounded by pastoral land, and planted scrub habitats.

Site Change:

Recent change: The fence excluding stock appears to have been relocated further away from the geothermal expressions (parts of the old fence remain). Indigenous plantings have been undertaken around features since 2011 (based on observations of 2021 aerial photographs and Delich (2022)). In 2011, large areas of blackberry as well as geothermal kānuka scrub and mānuka (and possibly *Histiopteris incisa*) had been killed by herbicide spraying. The geothermal vegetation in this area has now recovered, and geothermal vegetation has increased in extent and quality at this site.

*Historical:*¹ Site not assessed, no historical photos found. As most features are small, changes are unlikely to be evident on historical photographs.

**Management
Requirements:**

Changes to geothermal vegetation that appear to be associated with draw-off associated with the extraction of geothermal energy in the Mokai Geothermal System should be monitored. Major fluctuations have been evident in geothermal features over the last twenty years including a series of hydrothermal eruptions at this site between 2007 and 2009, which caused a loss of geothermal vegetation (Delich 2022). The geothermal vegetation condition has been improving at this site (Delich 2022).

Significance Level: Local (Criteria 3, 5).

**Significance
Justification:** Tirohanga Road is of local significance because it is a nationally uncommon habitat type (geothermal).

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and in the 1996 study, this site was classed as Category C - the third highest category.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.

References:

Beadel and Clarkson 1986; Department of Conservation 1998; Delich 2022; Given 1996; Hochstein 2006 & 2007a; Merrett and Fitzgerald 2004; Wildland Consultants 2000, 2004c, 2007a, 2012, 2014a.



Overview of part of the Tirohanga Road site. The pasture visible in this photograph around the site is now indigenous scrub based on assessment of recent aerial photographs. Photograph 2 March 2011.



Bare ground habitats and holes at Tirohanga Road. Most of the rank grassland visible is now indigenous scrub based on an assessment of recent aerial photographs. Photograph 2 March 2011.



WAIPAPA STREAM

Ecological District: Atiamuri **GPS Reference:** NZTM E1857719 N5739348
Geothermal System: Mokai **Altitude:** 285 m
Bioclimatic Zone: Lowland **Local Authority:** Taupō
Extent of Geothermal Habitat: c.1.2 ha
Extent of Geothermal Vegetation: c.1.2 ha
Date of Most Recent Field Survey: 8 October 2020

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Mixed indigenous and exotic species shrubland (05.08) Mixed indigenous and exotic shrub shrubland (05.08.08) (Whēkī)-grey willow/karamū-kōhūhū-blackberry/<i>Cyperus ustulatus</i>-<i>Gleichenia microphylla</i> shrubland with local scrub and sedgeland. In the northern part of this site, a series of geothermal springs and pools are present on both sides of the Waipapa Stream. The most active geothermal area with wetlands, springs and geothermal ferns extends over 100 metres and is up to 30 metres wide. Hot springs are likely to be present over a larger area of the Waipapa Stream and are likely to extend further downstream than the area that is currently mapped. On the western side of the stream, the springs are generally close to the stream margin and occur under a canopy of mixed indigenous and exotic shrub species, predominantly karamū, whēkī, māhoe and kōhūhū. Some parts of the stream margin are currently dominated by blackberry. Scattered emergent wilding radiata pines are also present, up to 15 metres tall. The eastern side of the stream has a series of springs and associated geothermal streams. An area of <i>Cyperus ustulatus</i> dominated wetland is present, which contains scattered <i>Carex virgata</i> and kiokio, and a few <i>Lycopodiella cernua</i> and <i>Christella</i> aff. <i>dentata</i> ("thermal"). There are approximately 20 clumps of <i>Christella</i> aff. <i>dentata</i> ("thermal") and at least three clumps of <i>Lycopodiella cernua</i>. Approximately ten pampas tussocks and four grey willow plants are present within and on the edge of the wetland. The wetland is surrounded by local patches of <i>Gleichenia microphylla</i> fernland and narrow-leaved carpet grass grassland. Surrounding these geothermal habitats, the predominant vegetation in the surrounding gully system is mixed exotic and indigenous scrub (ranging from 3-7 metres tall). A few scattered mānuka (to four metres tall) and geothermal kānuka are present on pool margins along with karamū, kōhūhū, whēkī, blackberry, and bracken. There is one emergent tōtara and several wilding radiata pines.	Alluvial terrace, riparian margins, geothermal spring, geothermal stream, wetland	c.0.1 ha
2.	Indigenous sedgeland (09.01) Mixed indigenous sedgeland (09.01.14) <i>Carex virgata</i>-watercress sedgeland In the southern part of this site, a series of geothermal springs occur within Waipapa Stream and on the eastern stream margins. This area was viewed from the eastern bank in 2020. Some of the	Stream gully, geothermal spring, wetland	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	species recorded in 2011, including <i>Christella</i> aff. <i>dentata</i> (“thermal”) and <i>Lycopodiella cernua</i>, were not seen in 2020. <i>Carex virgata</i> sedgeland, watercress herbfield and geothermal water form a mosaic. A few patches of Yorkshire fog and lotus, and several <i>Deparia petersenii</i> subsp. <i>congura</i> and kiokio are present. The geothermal areas are surrounded by scrub dominated by are karamū, kōhūhū, whēkī, blackberry, and bracken, with a few scattered emergent wilding radiata pines. This area previously contained plantation pine forest which was harvested shortly before the 2011 site survey. A buffer has since been established between the geothermal area and replanted forest.		

Indigenous Flora:

A large population (c.400 plants) of *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) was recorded in 2004 (Merrett and Fitzgerald 2004). In 2011, the population appeared to be stable although the number of plants was not counted. Since this time, the population has declined; 20 plants were recorded in 2020. However, the actual size of the population is likely to be 50-100 plants as not all parts of the site could be accessed during the 2020 survey. Delich (2022) estimate there are approximately 160 clumps at this site.

Lycopodiella cernua and *Psilotum nudum*, both characteristic species of geothermal areas, occur at this site (Beadel and Clarkson 1986). Although *Psilotum nudum* has not been seen at the site since 2011, it is often very inconspicuous and so may still be present.

Other species typical of geothermal habitats that are present include: mānuka (At Risk-Declining), geothermal kānuka (Threatened-Nationally Endangered), *Cyperus ustulatus*, *Carex virgata*, *Gleichenia microphylla*, kiokio, mingimingi, and bracken.

Fauna:

In October 2020 the following species were recorded at this site: Indigenous species: toutouwai/North Island robin (At Risk-Declining), pōpokatea/whitehead, pīwakawaka/North Island fantail, and riroriro/grey warbler. Introduced species recorded were: common pheasant, California quail, dunnoek, European greenfinch, chaffinch, and Australian magpie.

Delich (2022) note that elegant gecko, forest gecko, Raukawa gecko and crenulate skink (all At Risk-Declining) are likely to be present with the Mokai geothermal areas.

Geothermal Ecosystems:

Geothermal streamsides, geothermal wetlands.

Current Condition:

Several areas of geothermal vegetation occur in association with hot springs and seepages, both within and near to the stream. Shortly prior to a 2011 survey, pine forest harvesting disturbed the indigenous vegetation that buffered threatened fern populations on the stream margins. However, since then a larger buffer has been established between the geothermal area and the replanted forest. Scattered wilding pines and abundant blackberry are present

around geothermal features in both parts of the site. The southern part has a few grey willow trees (up to four metres tall), as well as scattered weeds such as pampas and Spanish heath around the geothermal springs.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Blackberry is abundant on the edge of geothermal habitats, and has become more extensive since the pine plantation harvest that was undertaken between 2005 and 2011. The southern part of the site has patches of blackberry (over 50% cover).

The northern part of the site has a few grey willow shrubs and small trees that require control. Ten pampas tussocks occur on the edge of pools and pampas is establishing within the secondary vegetation alongside geothermal areas. A small patch of narrow-leaved carpet grass (5 × 2 metres wide) is also present near a pool in the northern part of the site.

Overall, the cover of radiata pine has decreased since surveys in the early 2000s, but remains at c. 1-5% cover. Several radiata pine trees may damage geothermal features if they are allowed to fall into the site. Spanish heath, buddleia, and Himalayan honeysuckle all have a cover of less than 1%. Waikato Regional Council undertook control of wilding pines, broom, and buddleia at this site in 2010/2011.

Wilding pines in the northern part of the site have been controlled, but further work is required along riparian margins. Grey willow and pampas have established in the southern part of the site and require control. The site should be inspected regularly to identify threats and management requirements, and further control of pest plant species should be undertaken in the future, if required.

Human impacts: Following harvest of surrounding pine plantation in the 1970s, the populations of *Christella* aff. *dentata* (“thermal”) took several years to recover (Beadel and Clarkson 1986). Harvesting to the west of the stream between 2005 and 2011 may have impacted populations of this fern species, as only one plant was located in the southern part of the site during the 2011 survey. The population may be slowly declining at this site over time.

It is unclear if extraction from the Mokai Geothermal System continues to have any effect on the seepages and springs at this site, as reported by Merrett and Smale (1999). However, all features were active during the 2020 survey.

Grazing: Domestic livestock are not a threat to this site, but feral goats have been recorded in the past (Wildland Consultants 2000).

Adjoining land use: Plantation forest surrounds this site, although there is now a larger buffer between the geothermal vegetation and the plantation forest.

Site Change:

Recent change: Since 2011, a buffer between the geothermal site and the replanted plantation forest has been established. At the southern site, forestry crews found an additional geothermal area and reported it to land managers. The southern site was not surveyed or known in the literature prior to 2011. At the northern

site, populations of *Christella* aff. *dentata* (“thermal”) may have also been negatively affected by the damage to the vegetation on the stream banks. The buffer that has since been established will allow habitat for this species to remain, and recovery of the population is likely. There are however ongoing impacts from competition of pest plants, particularly blackberry and wilding pines.

Management of wilding pines at the site has been undertaken by the landowner since 2004, although more work is required. The cover of other pest plants (particularly grey willow, pampas, and blackberry) at the site has increased since 2014. Geothermal pools on the eastern side of the stream in the northern part of the site have been partly damaged by floods and sediment deposition.

The condition of the southern part of the site prior to the 2011 survey is unknown, as this part of the site had not been assessed previously. No change was evident at the southern site between 2014 and 2020.

*Historical:*¹

Site not assessed, as no historical photographs were found. It is unlikely that any changes would be evident on historic photographs as the geothermal features at this site are located in a steep sided gully.

Management Requirements:

Greater care needs to be taken during harvesting operations and subsequent management of the surrounding plantation forest to ensure that the geothermal features and vegetation of this site do not continue to be disturbed. Monitoring of impacts relating to power draw-off from the Mokai Geothermal System should continue. Protection of *Christella* aff. *dentata* (“thermal”) populations from the potential impacts of wilding and planted radiata pine trees (outlined in Wildland Consultants 2004a) will assist in maintaining the ongoing survival and good health of this species at the site. The management requirements of *Christella* aff. *dentata* (“thermal”) should be reassessed and updated within the next few years. Control of pest plants is recommended at this site, particularly for pampas, buddleia, grey willow, and wilding pines. Spanish heath and blackberry should also be controlled within the most geothermally active areas.

Significance Level:

National (Criteria 3, 4, 5, 6, 9)

Significance Justification:

The site is of national significance as it contains a relatively large population of *Christella* aff. *dentata* (“thermal”) (a nationally threatened taxon). This is an important population by its relative size and also its geographically isolation.

References:

Beadel and Clarkson 1986; Delich 2022; Given 1989a, 1996; Merrett 2001a, 2001b; Merrett and Fitzgerald 2004; Merrett and Smale 1999; Merrett *et al.* 1999; Spring-Rice 1996; Wildland Consultants 2000, 2004a, 2004b, 2012, 2014a, 2020c; 2021.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



Geothermal pool in the northern part of the Waipapa Stream site surrounded by *Cyperus ustulatus*-*Gleichenia microphylla*-*Lycopodiella cernua* sedgeland. Note a few pampas and blackberry are present on the margin (left side of photograph). NZTM E1857755 N5739385. 8 October 2020.



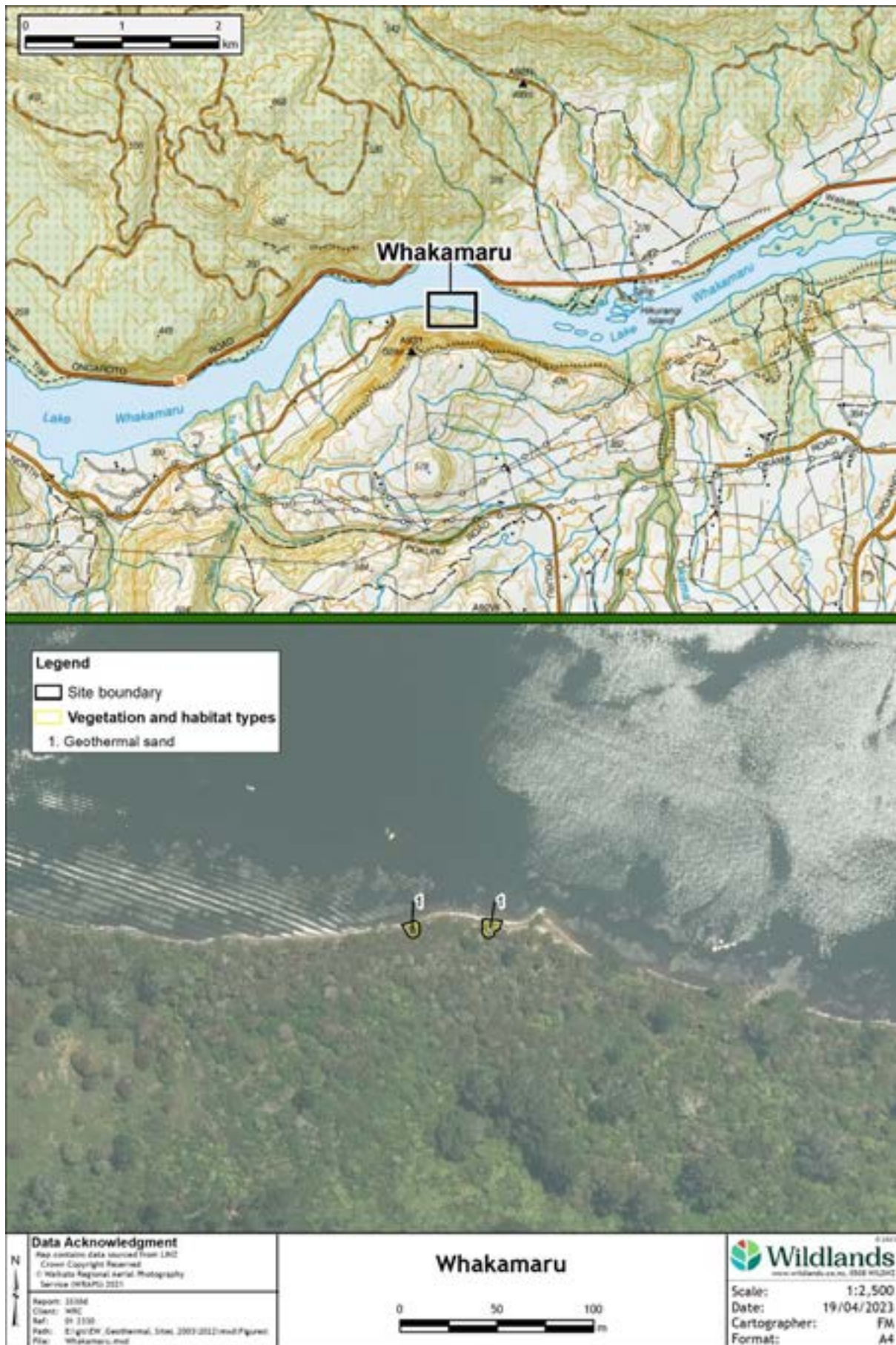
Christella aff. *dentata* ("thermal") on the margin of a geothermal spring at the Waipapa Stream site. NZTM E1857746 N5739380. 8 October 2020.



Geothermal stream in the northern part of the Waipapa Stream site. NZTM E1857723 N5739353. 8 October 2020.



Southern part of the Waipapa Stream site, with hot springs and abundant *Carex virgata*, watercress, kiokio, and Yorkshire fog. NZTM E1857641 N5739052. 8 October 2020.



WHAKAMARU

Ecological District:	Atiamuri	GPS Reference:	NZTM E1851114 N5742958
Geothermal System:	Mokai	Altitude:	230 m
Bioclimatic Zone:	Lowland	Local Authority:	Taupō
Extent of Geothermal Habitat:	<0.1 ha		
Extent of Geothermal Vegetation:	<0.1 ha		
Date of Most Recent Field Survey:	17 February 2008		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Sandfield (19.01) Geothermal sand (19.01.01) Two hot pools in lakeshore sands on the margins of Lake Whakamaru. Temperatures of 45.7 °C and 46.2 °C were recorded in 2008. More geothermal pools are likely to be present. The pools are surrounded by occasional mānuka seedlings and <i>Morelotia affinis</i> . Kānuka scrub is present a few meters from the pool edge.	Beach	<0.1 ha

Indigenous Flora: Species typical of geothermal habitats are present near the geothermal springs including kānuka, mānuka, *Morelotia affinis*, and *Cyperus ustulatus*.

Fauna: No fauna was noted.

Geothermal Ecosystems: Geothermal streamsides.

Current Condition: The site is small and is used recreationally by boat users. The vegetation will be regularly disturbed by recreational activities.

Threats/Modification/ Vulnerability:

Invasive pest plants: No serious pest plant issues noted in 2008.

Human impacts: Holes are often dug in the sand to create small hot water pools for bathing by people who access the site by boat.

Grazing: This site was not grazed by stock in 2008.

Adjoining land use: Lake Whakamaru, indigenous forest and scrub.

Site Change:

Recent change: Unknown; this site was surveyed for the first time in 2008.

*Historical:*¹ The site may have been larger prior to when the Whakamaru Dam became operational in 1956 (<http://www.mightyriverpower.co.nz/>)

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

[Generation/AboutUs/HydroStations/Whakamaru/Technical.aspx](#); Accessed 27 June 2010).

This site is too small to see any evidence of change since 1949¹.

*Management
Requirements:*

None noted.

Significance Level:

Local (Criterion 5)

*Significance
Justification:*

Whakamaru is a locally significant site because it comprises a small example of a nationally uncommon habitat type (geothermal).

Notes:

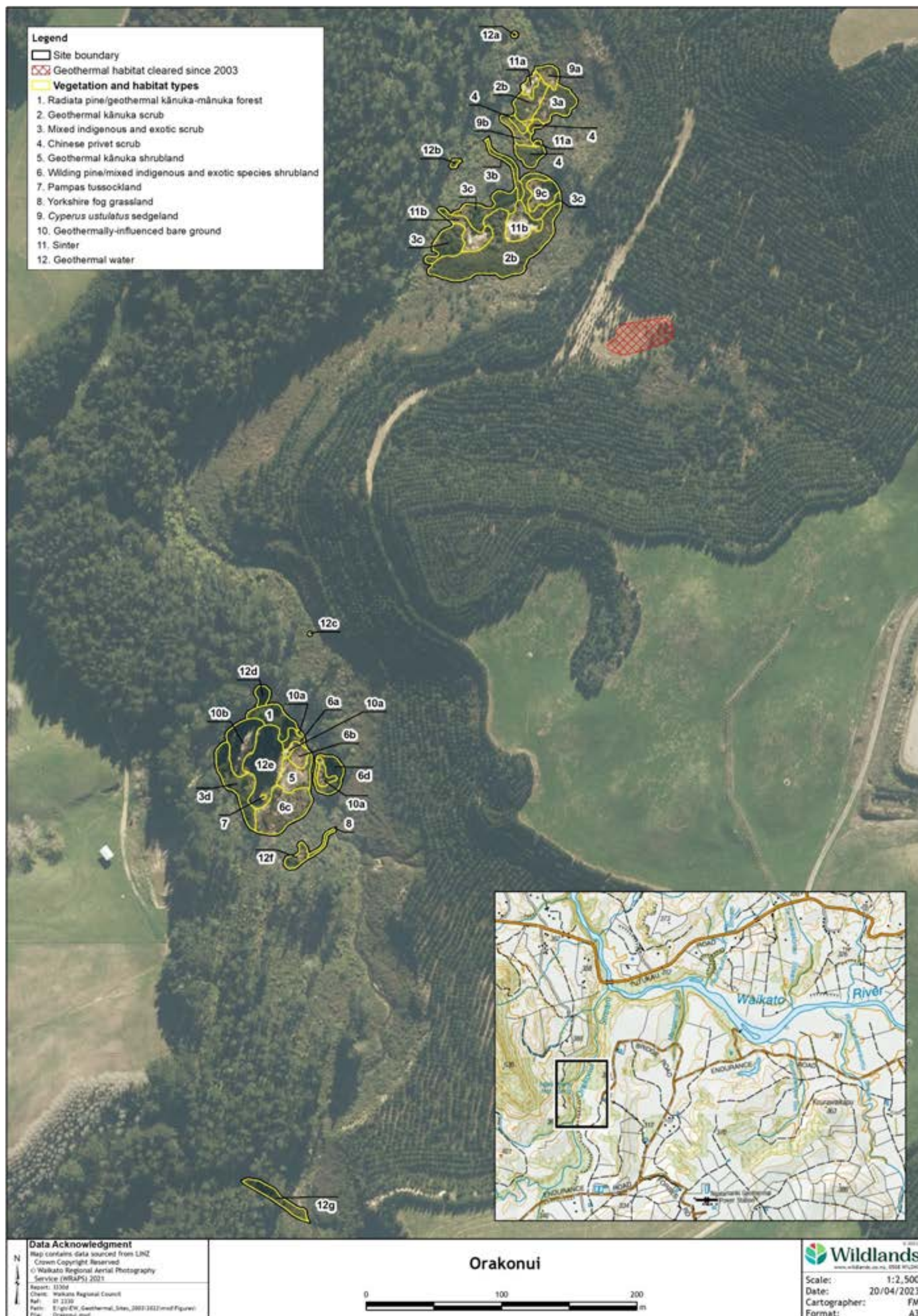
The above information is based on a site visit with the Rotorua Botanical Society on 17 February 2008.

References:

Wildland Consultants 2012.

¹ Historical photos: SN 258 Run 1071 Photos 72-73, 1949.

17. NGĀ TAMARIKI GEOTHERMAL SYSTEM



ORAKONU^{1,2}

Ecological District: Atiamuri **GPS Reference:** NZTM E1876675 N5730627
Geothermal System: Ngā Tamariki **Altitude:** 310 m
Bioclimatic Zone: Lowland -Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.1.3 ha
Extent of Geothermal Vegetation: c.1.1 ha
Date of Most Recent Field Survey: 23 September and 6 October 2020

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic forest (01.02) Radiata pine/geothermal kānuka-mānuka forest (01.02.07) Radiata pine forest (20-30 metres tall) with a subcanopy (4-6 metres tall) dominated by mānuka, geothermal kānuka, and mingimingi. Radiata pine comprises approximately 75% of the canopy vegetation. Tāwiniwini and prickly mingimingi are common in the understorey over a ground cover that is dominated by mosses and liverworts (most notably <i>Chiloscyphus semiteres</i> , <i>Neolepidozia praenitens</i> , and <i>Campylopus</i> spp.). Scattered plants of sundew (<i>Drosera auriculata</i>) plants have often been recorded in this vegetation type during field surveys.	Narrow ridge	<0.1 ha
2.	Geothermal kānuka scrub (04.01) Geothermal kānuka scrub (04.01.01) 2a. Geothermal kānuka, up to five metres tall, occurs in the northern part of the site with occasional whekī, whekī-ponga, and harakeke in the canopy. There has been some recovery of <i>Cyperus ustulatus</i> following the accidental aerial application of herbicide in 2014. The ground cover comprises mosses and liverworts (most notably <i>Campylopus</i> sp. and <i>Chiloscyphus semiteres</i>), bare ground, and abundant decaying radiata pine and lodgepole pine debris. A few wilding radiata pine, Chinese privet, and Spanish heath are present. The ground is mainly bare substrate or covered with woody debris. By 2020 there was little evidence of the effects of the herbicide dieback that were evident in 2015. 2b. Geothermal kānuka forms a canopy c.1-5 metres tall, with occasional mānuka, mingimingi, bracken, and Spanish heath. The ground has a patchy cover of tūrutu, mosses, bare ground, and litter. The vegetation in most of this area was damaged by herbicide overspray in 2014, but is recovering well. Occasional karamū, foxglove, Chinese privet, Montpellier broom, blackberry, Himalayan honeysuckle, radiata pine, buddleia, Spanish heath, <i>Hiya distans</i> , and toetoe are also present. Debris from the radiata pine control operations conducted in 2012 is becoming less obvious over time. In the understorey, a few <i>Schizaea</i> sp. (most likely <i>S. fistulosa</i>) plants were present in 2020, a species that had not previously been recorded at Orakonui.	Flat, gully, hillslope	c.0.3 ha

¹ Mercury allowed the use of data collected in recent work undertaken to assess the condition of geothermal vegetation as part of monitoring the effects of energy extraction in Ngā Tamariki Geothermal System to be used in updating these site sheets.

² Previously called Ngatamariki in earlier reports (Wildlands Consultants 2004b and 2012).

CODE	VEGETATION TYPE	LANDFORM	EXTENT
3.	Mixed indigenous and exotic scrub (04.09) 3a. Mixed indigenous and exotic scrub (04.09.02) The vegetation in this area changed quite markedly between 2014 and 2020. In 2014, this type comprised scattered woody shrubs (mostly geothermal kānuka, Spanish heath, and Chinese privet) surrounded by tūrutu, scattered ferns (<i>Hiya distans</i> and <i>Gleichenia microphylla</i>), and <i>Cyperus ustulatus</i>. Many woody species, and virtually all ferns and tūrutu were killed by the overspraying of herbicide in 2014. However, the vegetation had substantially recovered from this herbicide damage by 2020. In 2016, the ground cover was mostly woody debris (from decomposing pines that were felled prior to the 2012 survey) and bare ground (c.60%), with some recovery of geothermal kānuka, Spanish heath, <i>Cyperus ustulatus</i> and tūrutu evident. In 2020, the cover of Chinese privet, Montpellier broom, and blackberry had increased and the cover of bare ground had reduced to <10%. Local patches of the mosses <i>Campylopus</i> sp. and <i>Chiloscyphus semiteres</i> are present. 3b. Mixed indigenous exotic scrub on geothermal stream margins In the northern part of the site, a geothermal stream drains a spring from one of the southern areas of sinter and passes along a shallow gully system into Orakonui Stream. In 2012, the slopes above the stream comprised scattered areas of whekī and Montpellier broom, with local geothermal kānuka, Himalayan honeysuckle, Chinese privet, and occasional karamū over blackberry, tūrutu, and <i>Paesia scaberula</i>. Occasional radiata pine seedlings and saplings were present. Short lived plant species such as <i>Senecio minimus</i> (not recorded in 2020) and broad-leaved fleabane occurred occasionally in open areas. Now, the upper section of the stream is mostly surrounded by geothermal kānuka (c.2-3 metres tall) with occasional mānuka, karamū, mingimingi, <i>Pomaderris amoena</i>, Spanish heath, and blackberry. Emergent dead whekī trunks are abundant throughout this type, along with scattered emergent radiata pine and Chinese privet. <i>Histiopteris incisa</i> and <i>Chiloscyphus semiteres</i> also occur near the stream margins. A small population of <i>Lycopodiella cernua</i> occurs next to a small waterfall. <i>Dicranopteris linearis</i> was recorded next to the stream between 2012 and 2015, but has not been found in subsequent surveys. Downstream, the canopy of tree ferns and woody species increases to c.5 metres tall with abundant Chinese privet, tree ferns, and karamū. 3c. Vegetation includes scrub (canopy varies between c.1-6 metres tall) with local areas of <i>Cyperus ustulatus</i> sedgeland in wetter areas, that are too small to map separately. Mānuka (up to c.3 metres tall) is locally dominant with geothermal kānuka, whekī, Montpellier broom, <i>Pomaderris amoena</i>, toetoe, Spanish heath and blackberry. Scattered karamū, whekī-ponga, Himalayan honeysuckle and Spanish heath, Chinese privet, and buddleia (c.1%) are present. Three radiata pine (c.3 metres tall) have emerged through the canopy since 2016. Radiata pine debris from trees felled prior to 2012 remain present throughout.	Gully, crater walls, flat	c.0.3 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	3d. Emergent (overhanging) radiata pine (to c.10 metres tall) occur over geothermal kānuka (up to c.0.5 metres tall), and mānuka scrub (to c.2 metres tall) with pampas, blackberry and ferns common on the scarp faces above the geothermal pool (described as Vegetation Type 12e). Occasional buddleia are present. There is local bracken, mingimingi, whekī, <i>Hiya distans</i>, <i>Hypolepis ambigua</i>, and <i>Histiopteris incisa</i>. A small patch of <i>Lycopodiella cernua</i> occurs on pool margins. There has likely been a small decline in pampas since 2020 as the cover of pines has increased from 5% in 2012 to 50% in 2020, thus shading the pampas. Two small Tasmanian blackwood trees (and possibly more) occur in this type on the southwestern end of the geothermal pool (labelled as 12e on map).		
4.	Exotic species scrub (04.10) Chinese privet scrub (04.10.03) Two small areas are dominated by Chinese privet (to c.5 metres tall). This type has expanded in area since 2014. Occasional blackberry and mingimingi are present in the understorey. Scattered plants of <i>Psilotum nudum</i> are present in the ground cover in the northern geothermal site.	Flat, terrace, gully	<0.1 ha
5.	Geothermal kānuka shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Between 2012 and 2016 the extent of wilding pines and pampas increased, but following control of these species the area now comprises a mosaic of geothermal kānuka (20% cover, up to c.0.5 metres tall), scattered soft rush, local areas of <i>Campylopus</i> sp. and <i>Racomitrium lanuginosum</i> mossfield (c.25% cover), and bare ground (20% cover). There is abundant woody debris and dead pampas tussocks are present. A geothermal stream flows along the northeastern edge of this vegetation type, with temperatures recorded in excess of 50 °C. Pampas, kāpūngāwhā, <i>Cyperus ustulatus</i>, <i>Isolepis prolifera</i>, watercress, water figwort, <i>Nertera depressa</i>, lotus, soft rush, monkey musk, and exotic grasses, particularly creeping bent and Yorkshire fog, are common on the edge of the stream.	Gently sloping ridge and riparian margins	<0.1 ha
6.	Mixed indigenous and exotic shrubland (05.08) Wilding pine/mixed indigenous and exotic species mosaic shrubland (05.08.09) 6a. A small area of geothermal kānuka - mānuka shrubland (up to c.2-3 metres tall) with a discontinuous canopy cover (approximately 35% is bare ground), with scattered soft rush is located near the confluence of the Orakonui Stream and the hot stream outflow that drains the geothermal pool labelled as 12e on site map. Local mingimingi and bracken, and emergent radiata pines (to c.5 metres tall) are present. Other species that occur within the type include pampas, prickly mingimingi, jointed rush, and <i>Campylopus</i> sp. There has been an increase in the cover of exotic grasses present since 2016. The cover of both radiata pines and pampas in this type have increased since 2016 and is currently c.5% for each species. 6b. Geothermal kānuka forms a canopy between 0.25 and 1.5 metres tall with occasional mingimingi, bracken, mānuka, and Spanish heath. Scattered emergent radiata pines are present to	Crater, crater margins, gully, flat, gently sloping ridge.	c.0.2 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	20 metres tall. The ground cover comprises patchy tūrutu, soft rush, mosses (e.g. <i>Campylopus</i> spp.), leaf litter and woody debris. 6c. A mosaic of geothermal kānuka, mingimingi, bracken, <i>Histiopteris incisa</i>, blackberry, soft rush, <i>Cyperus ustulatus</i> and bare ground. There is abundant woody debris from recently felled pines. The cover of patches of <i>Campylopus</i> mossfield increases at the northern end of this type. In 2016, this area comprised a mosaic of wilding pines, pampas tussockland, bracken fernland and bare ground, however the cover of wilding pines and pampas has decreased following control. In 2020, the cover of pampas had decreased by 50% to 10% since 2016, and the cover of radiata pines had decreased by 25% to 10%. The cover of soft rush was similar between 2020 and 2016, at c.15%. Much of the bare ground and shorter-stature vegetation is a result of the gradual regeneration of vegetation on the debris from the April 2005 hydrothermal eruption, which is abundant around the geothermal pool labelled 12b on the site map. Occasional geothermal kānuka, mānuka and mingimingi plants have colonised and established, with scattered buddleia present on steep banks in the southeastern corner. On the geothermal pool margin, occasional <i>Carex virgata</i>, <i>Cyperus ustulatus</i>, <i>Isolepis prolifera</i>, <i>Leersia oryzoides</i> (an exotic grass species), creeping bent, and jointed rush are present. 6d. Bracken and blackberry are establishing on what was previously bare ground. Scattered radiata pine seedlings and saplings (up to 9 metres tall) and plants of Yorkshire fog are also present. Since 2018, there has been some control of the radiata pines and pampas undertaken at the site. Montpellier broom, blackberry, bracken and karamū dominate the shrubland on the steep sides of the gully where the pine plantation was recently felled. Radiata pines have increased in cover from c.1% in 2012, to 25% in 2020. The stream margins support abundant monkey musk, <i>Cyperus ustulatus</i>, Yorkshire fog, creeping buttercup and water figwort.		
7.	Exotic tussockland (06.01) Pampas tussockland (06.01.03) Dense pampas tussockland (to 1.5 metres tall) currently occurs on a small island in a geothermal pool. In 2012, one small pampas tussock and scattered soft rush, Yorkshire fog and ferns (bracken and <i>Histiopteris incisa</i>) occurred on the island. However, the island is now completely dominated by pampas.	Small island	<0.1 ha
8.	Exotic grassland (08.01) Yorkshire fog grassland (08.01.01) Grassland, dominated by Yorkshire fog, currently occurs in the southern part of the site. The vegetation in this area previously comprised riparian vegetation surrounding a small, warm stream, which appears to be an overflow from the spring labelled 12f on the site map. The riparian margins were dominated by harakeke in 2016, however it appears that flooding since 2018 has removed the harakeke and it has been replaced with Yorkshire fog. Occasional <i>Carex geminata</i>, blackberry, and creeping bent are present, and patches of <i>Carex secta</i> and <i>Cyperus ustulatus</i> are scattered through the type. Whekī, mingimingi, karamū, blackberry, and <i>Gleichenia microphylla</i> are locally present on banks that overhang the waterway.	Flat, gully	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
9.	Indigenous sedgeland (09.01) <i>Cyperus ustulatus</i> sedgeland (09.01.15) 9a. <i>Cyperus ustulatus</i> (averaging c.1.5 metres tall) dominates an area of sinter at the northern end of the site. Several dead whekī are present, probably as a result of over-spraying of herbicide in 2014. Scattered radiata pines occur throughout the type. Lodgepole pine has previously been recorded at the site, however it was not observed in 2020. Occasional <i>Cyclosorus interruptus</i>, bracken, kiokio, <i>Leersia oryzoides</i>, <i>Histiopteris incisa</i>, geothermal kānuka, blackberry and patches of <i>Chiloscyphus semiteres</i> are also present. Occasional emergent Chinese privet, karamū, and mingimingi occur on the northern and eastern margins. There is one geothermal kānuka (up to 1.3 metres tall) present. 9b. This type comprises <i>Cyperus ustulatus</i> (to c.1.2 metres tall) with scattered tūrutu. Most of the <i>Cyperus ustulatus</i> died back in 2015, but most of it had recovered by 2020. Local patches of <i>Gleichenia microphylla</i>, <i>Hypolepis ambigua</i> and <i>Cyclosorus interruptus</i>, and occasional Chinese privet and Himalayan honeysuckle are present. Abundant felled pines occur in this vegetation type, along with some dead emergent whekī and radiata pine saplings. Occasional harakeke, toetoe, foxglove, <i>Hiya distans</i>, <i>Paesia scaberula</i>, and <i>Histiopteris incisa</i> are present, along with scattered patches of geothermal kānuka. 9c. <i>Cyperus ustulatus</i> sedgeland with scattered geothermal kānuka, Spanish heath, mingimingi, <i>Leersia oryzoides</i>, Chinese privet (up to c.3 metres tall), karamū (up to c.3 metres tall), koromiko, lotus, Yorkshire fog, blackberry, a few radiata pines (up to c.5 metres tall), and tūrutu. Bare ground covers c.30% of this type.	Terrace, gully	<0.1 ha
10.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) 10a. Three small areas of this habitat type are present at the southern area of geothermal habitat. There is a small area of geothermal clay forming a tongue that extends into the Orakonui Stream where it meets the hot stream that discharges from the geothermal pool (labelled as 12e on site map). Most of the clay is bare, but kāpūngāwhā and soft rush are present on the margin of the clay where it grades into geothermal kānuka-mānuka shrubland. Several plants of geothermal kānuka, mānuka and kāpūngāwhā are present along the stream edge. A small area of this type is present on the eastern side of Orakonui Stream that is surrounded by radiata pine treeland. This area of bare ground is slowly being colonised by bracken, blackberry and radiata pines. 10b. A new area of bare ground is now present along the north-western margins of the geothermal pool that is labelled as 12e on site map; likely created by increased sedimentation since 2018. A few geothermal kānuka and mingimingi are present on the margins, with a local patch of <i>Lycopodiella cernua</i>. Local patches of exotic grasses (for example, Yorkshire fog) and herbs (for example, foxglove and catsear) are present. A few small pampas are also establishing.	Crater, gently sloping ridge, hillslope, gully	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
11.	Sinter (20.01.04) Sinter deposits are more widespread than the area mapped in the northern part of Orakonui. There are some areas of sinter that are covered with vegetation (including geothermal kānuka scrub and shrubland, and <i>Cyperus ustulatus</i> sedgeland), vegetative litter, and soil, and are therefore mapped as other habitat types. Two subtypes of sinter are identified. 11a. Two separate areas of sinter fans and terraces occur in the northern part of Orakonui. The sinter fans and terraces range from bare sinter to isolated patches of geothermal kānuka shrubland and <i>Cyperus ustulatus</i> sedgeland. Occasional whekī, mingimingi, and harakeke are also present. The sinter terraces support occasional tūrutu, Yorkshire fog, creeping bent, <i>Leersia oryzoides</i>, and <i>Histiopteris incisa</i>. Prior to 2012, several pine trees were felled onto sinter fan surfaces and down sinter terrace faces. These are continuing to decompose in 2020. Several radiata pine saplings are present near the margin of the sinter. 11b. Two areas of geothermal sinter are present in the southern half of the northern geothermal site at Orakonui. Patches of herbs, grasses, and sedges are present on the sinter, including <i>Lachnagrostis filiformis</i>, <i>Leersia oryzoides</i>, creeping bent and <i>Isolepis cernua</i> (abundant on the sinter margins). Mānuka, mingimingi, and geothermal kānuka overhang the sinter margins in places. Clumps of <i>Cyperus ustulatus</i> are common on the edge of the sinter. A small area of kāpūngāwhā sedgeland is present on the margins of the easternmost sinter terrace, with dieback evident in 2020. Pines have been felled onto sinter terraces in the eastern parts of this vegetation type, and the decomposing pine debris often supports abundant growths of the lichen <i>Usnea inermis</i>. Arrow grass was abundant on the margins of the geothermal sinter prior to 2015, but it was not recorded in 2020. This species was probably killed following spray drift from aerial herbicide application on nearby land, and is probably no longer present at the site.	Terrace, gully	c.0.1 ha
12.	Water (22.01) Geothermal water (22.01) 12a. The northernmost spring is a small geothermal seepage beneath a canopy of whekī. Temperatures of up to 31 °C were recorded in the seepage in 2012. A small population of <i>Psilotum nudum</i> was found in the ground cover tier, growing amongst <i>Nertera depressa</i>. The seepage flows through a small area of kiokio fernland and <i>Juncus edgariae</i> rushland before draining into Orakonui Stream. This part of the site has not been inspected since the 2012 field survey, because a safe access route has not been found during subsequent field surveys. 12b. The middle springs in the northern part of Orakonui is a series of springs and mudpools, located on the margin of Orakonui Stream. There were multiple springs present with the sound of bubbling mud in one of the deeper springs. One spring had a significant flow. Pine debris overhung part of the springs, along with <i>Histiopteris incisa</i> and bracken.	Crater, springs, stream	c.0.2 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	12c. Northeastern spring in the southern part of the site. No evidence of geothermal flowing water was found in 2015, but sinter was present. Milicich and Reeves (2009) note that when the spring was originally discovered in 1993 it was depositing calcite and silica sinter over an area of 12×6 metres. It stopped expelling silica around 2003 and currently has a weak overflow that has become overgrown with vegetation. Temperatures in the pool have declined from 86°C to 37°C between 1993 and 2009. Vegetation surrounding the spring comprises kiokio, <i>Paesia scaberula</i>, tūrutu, blackberry, bracken, <i>Carex secta</i>, Yorkshire fog, and karamū. Small geothermal seepages are present in the stream bed immediately adjacent to the old spring and these were active in 2015. This spring was viewed from the true right side of the river in 2016, but was not surveyed in 2020. 12d. While it does not appear to be currently active, Milicich and Reeves (2009) describe this pool as being warm and it was historically the main and most active spring at the site. Water temperatures have declined in the pool since 1983, along with a continuing lowering of the water level. The pool is located at the bottom of a steep-sided crater that supports bracken fernland with common whekī, kiokio, mingimingi, and blackberry, and scattered plants of grey willow and <i>Cyperus ustulatus</i>. Grey willows surrounding the pool have steadily increased in cover and height since 2012, although some dieback occurred between 2014 and 2015. Several pine trees surrounding the pool have fallen and this has opened up the canopy (mostly between 2014 and 2015). Other species present include <i>Hypolepis ambigua</i>, <i>Histiopteris incisa</i>, mānuka, and Himalayan honeysuckle. Vegetation on the pool margins does not appear to be geothermal in character. 12e. This pool is the largest body of geothermal water at the Orakonui site. Milicich and Reeves (2009) describe the pool as being a 50×40 metre crater formed during a 1948 hydrothermal eruption and modified during the 19 April 2005 hydrothermal eruption. The pool has at least five springs feeding it and several mud pools. Since 2018, sedimentation has occurred along the northeastern margins of the pool, reducing its overall size. Occasional <i>Carex virgata</i>, <i>Juncus edgariae</i>, <i>Hiya distans</i>, <i>Histiopteris incisa</i>, jointed rush, soft rush, <i>Cyperus ustulatus</i>, pampas, and Yorkshire fog are present on the pool margins. Two populations of <i>Lycopodiella cernua</i> are also present. The cover of pampas, soft rush and radiata pine has increased markedly since 2012 on the western banks. 12f. This spring has a previously recorded pool temperature of up to 78°C (Milicich and Reeves 2009). A warm ($c.30^{\circ}\text{C}$) stream from this pool flows into the Orakonui Stream. In previous surveys, the pool contained green and orange algae, but in 2020 there were no algae present. In 2020, the northern end of the pool had dried up, and soft rush, <i>Carex virgata</i>, creeping bent, Yorkshire fog and water forget-me-not were present. Radiata pine debris, including several logs, were present in the pool. Scattered plants of <i>Carex virgata</i> and patches of raupō reedland occur on pool margins, as well as occasional <i>Histiopteris incisa</i>, kiokio, and whekī-ponga. Vegetation on the pool margins is relatively diverse and mostly comprises whekī/mingimingi-Spanish heath scrub (increased in height since 2016 to 2.1 metres tall) with bracken,		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	blackberry, Himalayan honeysuckle, Spanish heath, karamū, and <i>Hiya distans</i> common throughout. Small patches of <i>Hiya distans</i> fernland and whekī (with a few whekī-ponga) treeferns are present on the eastern margins of the pool. <i>Cyperus ustulatus</i> and <i>Carex secta</i> are common at the pool outlet with occasional emergent whekī and harakeke. Several radiata pine seedlings were noted on the pool margins in 2016 and have since increased in height. Along the stream outlet of the original pool, two smaller pools have formed since 2018 and are likely being fed by the upper pool. These are surrounded by Yorkshire fog, harakeke, mingimingi, and <i>Carex geminata</i>. 12g. Southern geothermal stream springs. A new area of geothermal activity was found adjacent to a small side-stream on the true left of Orakonui Stream in 2020. There is no terrestrial vegetation associated with this type, but there are a series of springs and seepages within the stream. Seepages are also present on steep faces above the stream, with abundant green algae present.		

Indigenous Flora:

The population of *Cyclosorus interruptus* (At Risk-Declining) at Orakonui has fluctuated between 2 and 50 clumps between 1979 and 2020. The decline between 2014 and 2015 was probably a result of herbicide overspray. The following numbers of *Cyclosorus interruptus* have been recorded at various intervals, as follows:

- 1979: 30 plants (Ecroyd 1979)
- 1999: 18 clumps (Merrett and Burns 1999)
- 2007: 16 clumps (Bycroft and Beadel 2007)
- 2012: 48 clumps (Bycroft in Wildland Consultants 2013a)
- 2013: 41 clumps (Bycroft in Wildland Consultants 2013b)
- 2014: 50 clumps (Bycroft in Wildland Consultants 2014b)
- 2015: 4 clumps (Bycroft in Wildland Consultants 2015)
- 2016: 18 clumps (Bycroft in Wildland Consultants 2016b)
- 2020: 17 clumps (Bycroft in Wildland Consultants 2020b)

Dicranopteris linearis (Threatened-Nationally Endangered) was previously recorded alongside a geothermal stream in the northern part of the site. Another population of *D. linearis* found under radiata pine trees in the northern part of the site in 2007 was not relocated in 2012 or 2013 and may have been affected by the harvesting of pine trees.

Geothermal kānuka (Threatened-Nationally Endangered) and the moss *Campylopus capillaceous*, which are both endemic species restricted to geothermal areas, occur in both the northern and southern parts of the site. The population of geothermal kānuka declined following herbicide drift in 2014, but has since recovered. A small population of *Lycopodiella cernua*, which is characteristic of geothermal areas, is also present in both the northern and southern parts of the site.

Psilotum nudum, a plant usually restricted to geothermal and northern coastal and lowland areas, is also present. At least one population was recorded at the site in 2020, while five populations have been recorded between 2012 and

2020. All populations are small and vulnerable to both natural and human-induced disturbances. A population recorded below a waterfall in 1979 (Ecroyd 1979) has not been recorded in recent surveys; this may reflect the inaccessibility of the site rather than a population decline.

One new species of botanical interest was recorded in 2020. This was a species of *Schizaea* (most likely *Schizaea fistulosa*). Identification to species level was not possible due to the small population size, which prevented the collection of specimens. This species is very inconspicuous, so may have been missed in earlier surveys.

Another species of botanical interest at the site was arrow grass. Two populations were present at the northern Orakonui site and covered approximately *c.* 50 metres², and *c.* 100 metres² each in 2012. No arrow grass has been seen since a site survey in 2014 and it appears that these plants may have been killed by herbicide spray drift from the adjacent land. Based on current observations, it appears that this species may have been lost from the site.

Fauna:

Fifteen indigenous and fourteen introduced bird species were recorded at Orakonui in 2020. The kārearea/New Zealand (not threatened) bush falcon (Threatened-Nationally Increasing) and pōpokotea/whitehead were seen or heard in 2020. Both of these species have been recorded intermittently at the site during previous surveys. Three species of conservation concern that have been recorded previously were not recorded during the 2020 surveys: māātātā/North Island fernbird (At Risk-Declining), koekoeā/long-tailed cuckoo (Threatened-Nationally Vulnerable), and toutouwai/North Island robin (At Risk-Declining). Māātātā/North Island fernbird were recorded at the site in 2009 (Mitchell Partnerships 2009), but has not been recorded during the 2012-2020 surveys. Koekoeā/long-tailed cuckoo were recorded at the site in 2013 and 2014, but have not been recorded since (Wildland Consultants 2014b). Toutouwai/North Island robin (At Risk-Declining) were recorded at Orakonui in 2013, 2014 and 2015, although none have been recorded in more recent surveys. The amount of suitable habitat for koekoeā and toutouwai may have declined following the felling of extensive areas of pine plantation and its conversion to pasture since 2012.

The remaining indigenous bird species that were recorded in 2020 are all common species that have been observed during most of the previous surveys. Common indigenous bird species that were recorded at the site between 2012 and 2020 include pūtangitangi/paradise shelduck, kāhu/swamp harrier, spur-winged plover, pīpīwharau/shining cuckoo, korimako/bellbird, warou/ welcome swallow, riroriro/grey warbler, pīwakawaka/North Island fantail, and tauhou/silvereye.

Common introduced bird species that were recorded at the site between 2012 and 2020 include mallard, California quail, Eastern rosella, common pheasant, dunnoek, Eurasian blackbird, song thrush, European goldfinch, European greenfinch, yellowhammer, chaffinch, house sparrow, common starling, and Australian magpie.

Possums and ungulate sign (including deer and pigs) have been noted during previous surveys. In 2020, there was little pest animal sign at Orakonui apart from pig rooting on mud associated with sinter terraces.

Longfin eel (*Anguilla dieffenbachii*; At Risk-Declining in Dunn *et al.* 2017) have been recorded in Orakonui Stream (James and Bowman 2009). An eel was also seen by one of the authors (CMB) in 2015 (Wildland Consultants 2015a).

**Geothermal
Ecosystems:**

Geothermal streamsides, hydrothermally altered ground (now cool), geothermal wetlands, heated ground (dry).

Current Condition:

The site comprises two areas of geothermal features and vegetation that contain several plant species of note. Natural changes in geothermal activity have been an ongoing feature at Orakonui (Milicich and Reeves 2009), and are likely to continue to exert a strong influence on any patterns observed. The southern end of the site has changed significantly as a result of a hydrothermal eruption, which resulted in the creation of a geothermal pond and a large area of debris. This area has also been subject to ongoing weed invasion, particularly of pampas and wilding pines, although some control work has been undertaken between 2018 and 2020. Indigenous vegetation condition in the northern part of the site has improved significantly following radiata pine control, with a noticeable expansion of geothermal kānuka. This was set back by spray drift from herbicide application in 2014. Geothermal kānuka has recovered from the damage caused by the spray drift, but arrow grass appears to have died out.

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Thirty-seven exotic plant species were recorded at the site between 2012 and 2020. A number of these species are having a significant impact on the ecological character of the site, and have the potential to alter habitats and suppress the growth of geothermal vegetation.

Radiata pine plantation is planted in close proximity to parts of the site, and some trees have fallen into geothermal vegetation and features. Although extensive control of radiata pines has been undertaken within the northern part of the site, pines have been felled into significant geothermal features, particularly sinter fans and terraces. Live pines, comprising local saplings and scattered seedlings, now have a cover of <5% within the geothermal vegetation in the northern part of the site. In the southern part, plantation and wilding radiata pines surround most geothermal features. Some pine control has been undertaken over time, but more control work is needed.

A small population of grey willow is present near a geothermal pool at the southern site, and should be controlled. A few scattered plants of Tasmanian blackwood should also be controlled.

Pampas has increased in cover markedly in the southern part of the site, and is adversely affecting the cover of indigenous vegetation. Debris from the 2005 eruption is becoming dominated by pampas and wilding pines, despite some control undertaken between 2018 and 2020.

Chinese privet has expanded significantly within the site to become the dominant species in some small parts of the site within the northern area of geothermal vegetation at Orakonui, although the entire site the cover of Chinese privet is still relatively low (c.5% cover).

Other adventive plant species present include buddleia (1% cover), pampas (2% cover), blackberry (10% cover), Himalayan honeysuckle (1% cover), Montpellier broom (5% cover), and Spanish heath (1% cover).

Human impacts: Informal access tracks are present within the site and pose a threat to the ecological values of geothermal vegetation. Although current visitor numbers to Orakonui are low, access is more common now than historically due to monitoring associated with consents for the extraction associated with the energy production from the Ngā Tamariki Geothermal System. The Ngā Tamariki Power Station was commissioned in September 2013. No changes associated with this draw-off have been observed to date.

Grazing: Livestock are not a threat to the site.

Pest animals: Ungulates can cause significant trampling impacts in geothermal areas, and pigs can also cause further damage through “rooting” of the substrate, including on sinter terraces. The geothermal habitats, particularly the sinter terraces should be monitored on a regular basis to ensure that these areas are not impacted by pigs. The current monitoring programme is adequate for this purpose. If any significant degradation of geothermal vegetation by pest animals is evident, then pest animal control should be undertaken.

Adjoining land use: Pine plantation, farmland.

Site Change:

Recent change: Geothermal activity has changed the landforms and species composition of the southern end of this site. A hydrothermal eruption in 2005 has formed a new geothermal lake and mud pools, and deposited hydrothermal eruption debris. Changes in the mapped extent of vegetation and habitat up to 2014 was likely the result of higher resolution aerial photographs taken in 2014. Since 2014, there has been little change in the overall extent of geothermal vegetation and habitats, but changes have occurred in vegetation composition and quality. These changes are mostly the result of expansion of invasive pest plant species, and the benefits of local pest control. Herbicide drift in 2014 set succession back, and has appeared to have resulted in the local extinction of arrow grass from the site.

Historical : Comparisons of 1941 aerial photographs¹ and 2007 aerial photographs were made in 2011. There was a larger buffer between geothermal features and forestry operations in 1941 compared with 2007, particularly around the southern part of the site. Bare ground was more extensive in 1941 than in 2007. The location/extent of the northern area of geothermal vegetation could not be identified on the 1941 aerial photographs. The extent of geothermal vegetation and habitats is likely to have declined by 10-25%, but this decline may be mainly related to weed invasion, and changes of the surrounding land use to plantation forest.

Management Requirements: The remaining radiata pines, other pest trees (including Chinese privet and Tasmanian blackwood), and pampas within geothermal areas and on the margins of the site should be removed, and trees felled away from geothermal features/vegetation. Damage during plantation forest harvesting operations

¹ Historical photo: SN 172 Run 1168 Photo 14, 1941.

is a potential threat. Ongoing monitoring of geothermal vegetation and threatened species should continue at this site to assess the impacts of energy extraction in the Ngā Tamariki Geothermal System, and natural variation of features and vegetation within the site.

Significance Level: Regional (Criteria 1, 3, 5, 6, 9)

Significance Justification: Orakonui is of regional significance because most of the site is protected as a Scenic Reserve. It also provides important habitat for one Threatened (geothermal kānuka) and one At Risk plant species (*Cyclosorus interruptus*).

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category B – the second highest category.

References: Bycroft and Beadel 2007; Chambefort *et al.* 2016; Department of Conservation 1997; Ecroyd 1979; Given 1989a, 1995, & 1996; James and Bowman 2009; Merrett and Burns 1999; Milicich and Reeves 2009; Simpson *et al.* 2014; Spring-Rice 1996; Wildland Consultants 2000, 2004b, 2007a, 2012, 2013a, 2013b, 2014a, 2014b, 2015a, 2016b, 2020b, 2021b.



The largest geothermal pool at Orakonui. Debris from recent wilding pine control are evident on the right side of the photograph.
NZTM E1876503 N5730176. 6 October 2020.



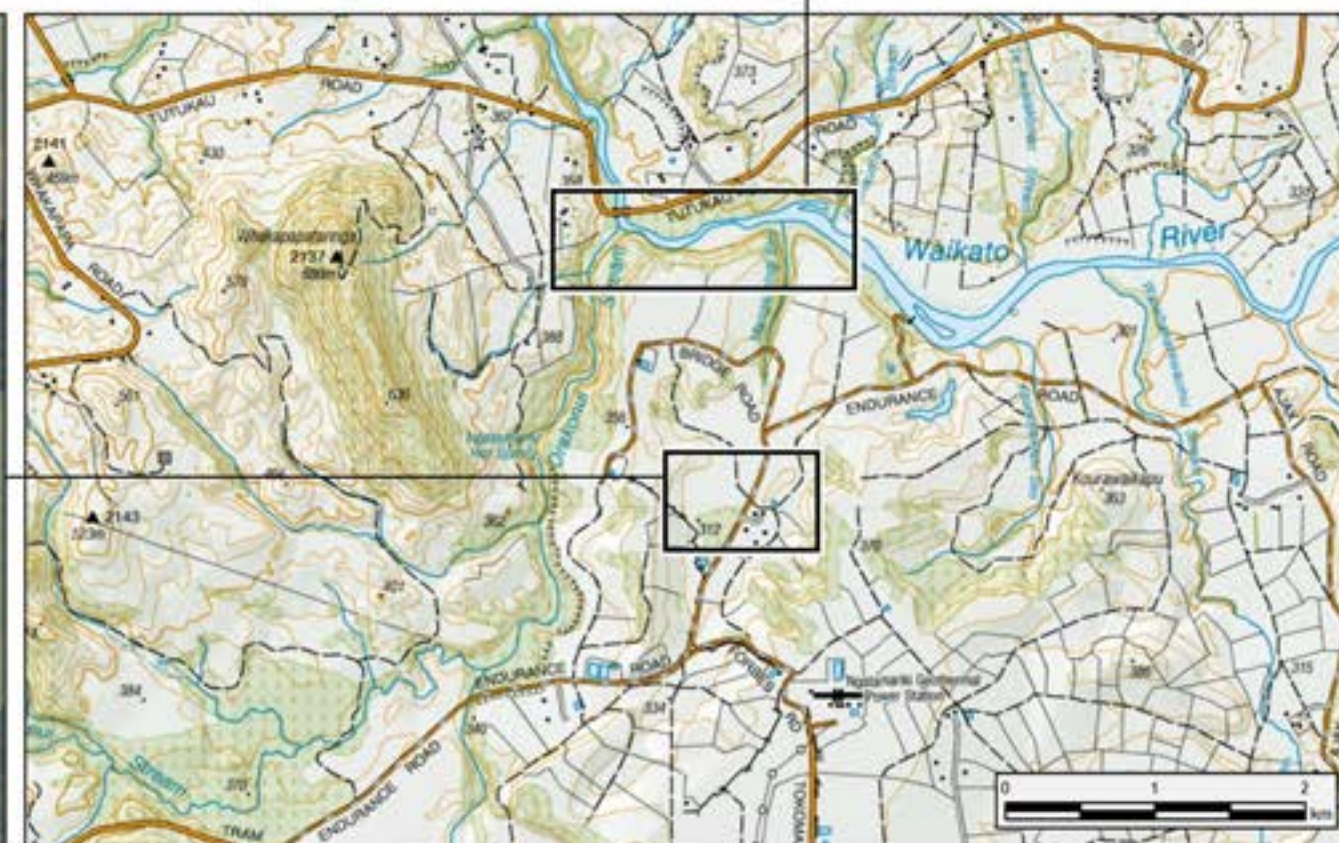
Geothermal sinter and geothermal scrub in the northern part of the Orakonui site.
NZTM E1876697 N5730719. 23 September 2020.



Northern part of the Orakonui site. NZTM E1876734 N5730630. 1 October 2020.

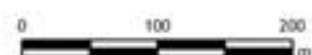


Arrow grass in the northern part of the Orakonui site was killed by herbicide spray drift in 2014. NZTM E1876686 N5730614. 1 October 2020.



Data Acknowledgment
 Map contains data sourced from LINZ
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 Service (WRAPS) 2021
 Report: 3330d
 Client: Waikato Regional Council
 Ref: 31336
 Path: R:\GIS\Geothermal Sites\2019\2022\mod\Figures
 File: Waikato River Springs, Mangamingi Stream.mxd

Waikato River Springs/Mangamingi Stream



Wildlands
 Scale: 1:5,000
 Date: 4/05/2023
 Cartographer: FM
 Format: A3R

WAIKATO RIVER SPRINGS/MANGAMINGI STREAM

Ecological District:	Atiamuri	GPS Reference:	NZTM E1877904 N5731853
Geothermal System:	Ngā Tamariki	Altitude:	310 m
Bioclimatic Zone:	Lowland	Local Authority:	Rotorua
Extent of Geothermal Habitat:	c.4.6 ha		
Extent of Geothermal Vegetation:	c.4.0 ha		
Date of Most Recent Field Survey:	14 October and 15 November 2022		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic forest (01.02) Grey willow forest (01.02.03) NZTM E1877426 N5731837 and NZTM E1877438 N5731857 Grey willow-kōhūhū forest, with local areas of open water alongside the Waikato River. The forest understorey has abundant blackberry, kiokio, whekī and karamū. The water temperature in the part visited ranged from 11.5 °C to 16.7 °C. Extensive areas of reed sweetgrass were evident in aerial photographs beyond the areas that were safe to access, by either foot or boat. <i>Christella</i> aff. <i>dentata</i> (“thermal”) was observed alongside geothermal springs on the north side of the Waikato River in 2006 (Wildland Consultants 2014). <i>Christella</i> aff. <i>dentata</i> (“thermal”) was not found in the 2022 survey. It may still be present in some locations here.	Wetland, river margin	c.0.5 ha
2.	Exotic conifers/geothermal kānuka-mingimingi forest (01.02.07) Radiata pine to 20 metres tall with abundant geothermal kānuka, Chinese privet and mingimingi in the understorey. The ground cover includes dense mosses and leaf litter. The soil temperatures indicate a weak geothermal influence.	River margin, riparian island	c.0.3 ha
3.	Exotic grassland (08.01) Reed sweet grass-raupō-kāpūngāwhā-grassland (08.01.10) Reed sweet grass, raupō, and lake clubrush dominate the margins of a geothermally influenced pool (temperatures up to 45 °C in the northern pools in 2011), with emergent grey willow, blackberry, harakeke, Chinese privet, bracken, and radiata pine on the drier margins. Swamp millet is locally common. Other species present include <i>Cyperus ustulatus</i>, and mercer grass. Mexican lily is common in open water areas. The Waikato River Springs part of the site was inspected at four locations on the south side of the river, and two locations on the north side of the river. One of the authors (CMB) had visited these springs previously in 2011. High water levels in the Waikato River during the October and November 2022 inspections hampered access to parts of the site. <u>South Side Location 1: NZTM E1877979 N5731850</u> Scattered grey willow present over raupō and reed sweetgrass. Dry hummocks comprise blackberry and Chinese privet. Water temperatures ranged from 17.2 °C to 18.3 °C, but are almost	River margin, wetland	c.3.2 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	certainly higher in areas that were not able to be accessed. In open water beside the river, Mexican water lily is abundant. <u>South Side Location 2: NZTM E1877901 N5731842</u> Mosaic of reed sweetgrass and raupō emergent above the river, with local Mexican water lily in open water. Occasional harekeke (<i>Phormium tenax</i>) present. The water temperature was 17-18 °C. The temperature of the river bed at 30 cm depth was 23.8 °C. <u>South Side Location 3: NZTM E1877612 N5731767</u> Similar vegetation to Location 2, with abundant reed sweetgrass and raupō, with Mexican water lily in open water. The temperature in substrate at 10 cm deep under shallow water was 36.7 °C. A few local crack willow are present. <u>South Side Location 4: NZTM E1877528 N5731740</u> The survey has extended the boundary of the site a further 150 metres to the west, with springs found that had not been recorded previously. A spring with temperatures of at least 46.7 °C with sinter forming deposits was found at the northern end of the site. Temperatures are likely to be hotter in some parts, but were unsafe to measure. Another spring located c.5 metres to the northwest had a temperature of 32 °C. Both springs contain green algae. The wetland vegetation is a mosaic of reed sweetgrass, raupō and open water areas. The island between the wetland areas has characteristics of geothermal vegetation and includes radiata pine/Chinese privet-geothermal kānuka-mingimingi forest and scrub with a moss ground cover with abundant <i>Leucobryum javense</i>, <i>Ptychomnion aciculare</i>, and <i>Chiloscyphus</i> sp. The open water of the Mangamingi Stream at its confluence with the Waikato River is dominated by a dense reed sweetgrass grassland. Local <i>Carex virgata</i> are also present. The surrounding vegetation is scattered emergent radiata pine trees over a dense cover of blackberry, Spanish heath, and scattered indigenous woody species such as kōhūhū and karamū. The water temperature was 14-15 °C in 2022. The temperature of the stream bank was 20 °C at 35 cm depth, indicating that weak geothermal influence is present. This geothermal anomaly was recognised by Bromley <i>et al.</i> 2022. The lower section of Orakonui Stream was inspected in two places. Towards the outlet (NZTM E1877019 N5731895) of Orakonui into the Waikato River, local patches of reed sweetgrass, raupō and scattered <i>Carex virgata</i> are present. There is overhanging crack willow, radiata pine, kōhūhū, and karamū. The stream temperature in this area was 10-11 °C. Upstream, where an old road bridge crosses the Orakonui Stream (NZTM E1876872 N5731690), the vegetation was viewed from both the bridge and stream edge. The water temperature was 9-10 °C, with soils on the stream edge 12.5 °C. A slightly elevated temperature was present in streamside mud at 14.3 °C at 40 cm. This is not warm enough to confirm geothermal influence. The vegetation alongside the stream had abundant kōhūhū, grey willow, makomako, Chinese privet, Tasmanian blackwood, blackberry, and kiokio.		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
4.	Indigenous sedgeland (09.01) Mixed <i>Carex</i> species-Yorkshire fog sedgeland (09.01.04) The stream at this location has weak evidence of geothermal influence, based on sub-surface soil temperatures increasing with depth. The temperature range of the stream water was between 14.4 and 15.5 °C, and the stream bed was slightly warmer, at 16.5 °C. The main stream has abundant emergent <i>Carex virgata</i> and watercress with Yorkshire fog and blackberry on margins. On the banks above the stream, a few seepages are present with <i>Carex geminata</i> and <i>Carex virgata</i>. These seepages are apparently weakly geothermal with temperatures increasing slightly at depth (10 cm: 14.8 °C, 35 cm: 15.5 °C), contrasting with the cooler ground temperature next to the seep (13.0 °C at 10 cm depth). The upper stream gully system has been fenced to exclude stock. Radiata pine have been planted along the stream corridor; vegetation is dense blackberry scrub with scattered bracken, Himalayan honeysuckle, Spanish heath and buddleia. One small clump of male fern (<i>Dryopteris</i> species, probably <i>D. affinis</i>) is present on the banks above the culvert. It is likely that weak geothermal influence (mostly seepages, and perhaps some geothermal springs) with slightly elevated temperatures are scattered along the length of Mangamingi Stream. The stream margin was viewed from the top of the gully system at several locations. Riparian vegetation is dominated by dense blackberry with scattered Chinese privet, Himalayan honeysuckle, Spanish heath, and bracken, and local emergent whekī-ponga, tī kōuka and kōhūhū, and radiata pine. Grey willow are present along the stream margin. We were not able to access the stream to check temperatures safely during the survey.	Gully	<0.1 ha
5.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Geothermally-heated soil.	River terraces, river margins	<0.1 ha
6.	Water (22.01) Geothermal water (22.01.01) Warm springs, hot stream, and pools. In cooler water, Mexican water lily is locally common.	Stream, pools	c.0.7 ha

Indigenous Flora:

Christella aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) has previously been recorded at this site (Wildland Consultants 2006). No specimens were located during the 2011 or 2022 surveys but the entire site could not be inspected due to high river levels so the population is likely to still be present.

Fauna:

Birds typical of riparian, farmland, and shrubland habitats are likely to be present. Mātātā/North Island fernbird (At Risk-Declining) were present in 2006 (Wildland Consultants 2006), although none were recorded in 2011 and 2022. The wetlands are also likely to provide habitat for pūweto/spotless crane (At Risk-Declining). Species recorded during site visits in 2006, 2011 and 2022 include kāhu/swamp harrier, pūkuko, kōtare/sacred kingfisher, pīpīwharau/shining cuckoo, tūi, korimako/bellbird, warou/welcome swallow, and pīwakawaka/North Island fantail, riroriro/grey warbler, and tauhou/silvereye. Introduced bird species include mallard, common pheasant,

California quail, skylark, Eurasian blackbird, European greenfinch, yellowhammer, and goldfinch.

Additional indigenous bird species recorded in riverine habitats near the site between 2012 and 2019 (Wildland Consultants 2020d) include māpunga/black shag (At Risk-Relict), kawaupaka/little shag (At Risk-Relict), pāpango/New Zealand scaup, pārerā/grey duck (Threatened-Nationally Vulnerable¹), spur-winged plover, karoro/southern black-backed gull, and tarāpunga/red-billed gull (At Risk-Declining).

Geothermal Ecosystems:

Geothermal streamsides, geothermal wetlands, heated ground (dry).

Current Condition:

Exotic species such as reed sweetgrass, Mexican water lily and grey willow dominate large parts of the wetland areas of this site.

Threats/Modification/Vulnerability:

Invasive pest plants:

Reed sweetgrass is often the dominant vegetation wetlands on river margin habitats within this site (c.50% cover). Mexican water lily (15%), grey willow (5% cover), Chinese privet (1-5% cover, mostly on margins), radiata pine <1% cover), broom (5%), blackberry (5%), buddleia (1-5% cover), pampas (1% cover), Tasmanian blackwood (1% cover), are also present.

Human impacts:

In areas recently harvested for plantation pines, the margins have not been replanted with plantation species. A mixture of indigenous and exotic shrub species, mainly woody species, are re-establishing on the southern side of the river. The margins of Mangamingi Stream have been fenced, and the gullies are dominated by exotic pest plants.

Grazing:

Sites with farmland nearby have been fenced. Site is not accessible to stock.

Adjoining land use:

Waikato River, mixed indigenous and exotic scrub, plantation forest, farmland.

Site Change:

Recent change:

The water levels of the river were high during the 2011 and 2022 field survey, so overall change is difficult to assess. However, the site appeared similar to earlier surveys. New areas mapped in 2022 are based on improved knowledge of the site.

*Historical:*²

This site is too small to see any evidence of change since 1941³, however the site is subject to water level fluctuations in the Waikato River, and it is likely that the vegetation cover has changed since 1941.

Management Requirements:

Chinese privet (on the southern side of the river), grey willow, and radiata pine should be removed from this site before weed management becomes an

¹ Most of the New Zealand grey duck population is believed to be extensively hybridised with the introduced mallards to such an extent that few pure grey ducks may now exist (Williams, M.J. 2013 [updated 2022]. Grey duck | pārerā. In Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz: accessed: 29 March 2023.

² This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

³ Historical photos: SN 172 Run 1168 Photos 15-16, 1941.

issue. Reed sweetgrass and Mexican water lily dominate this site but control may be impracticable as infestations of these species are extensive along this section of the Waikato River.

Significance Level: Regional (Criteria 3, 5, 6)

Significance Justification: This site is regionally significant because it comprises a nationally uncommon vegetation type (geothermal) and a nationally under-represented type (wetland). This site contains one of the largest areas of riparian geothermal habitat in the Waikato Region.

Notes: Bromley *et al.* (2022) notes several examples of geothermal anomalies alongside the lower Orakonui Stream, Waikato River margins between Orakonui Stream and Mangamingi Stream and in the Mangamingi Stream catchment. These areas were visited in October and November 2022, and while only weak additional geothermal influence were found, these are described in this site sheet. It should be recognised that there is likely many more geothermal anomalies both beneath and along the margins of the Waikato River, Orakonui Stream, and Mangamingi Stream beyond what has been identified to date.

A site of potential geothermal springs was visited by boat on 15 November 2022 approximately 200 metres north (downstream) of the Tutukau Road bridge on the western side of the river NZTM E576959 N57321491. It was not safe to get out of the boat at the site due to the nature of the currents and the substrate (where there was a high risk of sinking in). The substrate temperatures were measured at several locations from the boat and were all in the range of 17-19 °C, so we were unable to confirm the presence of geothermal activity. Wetlands can often contain warmer water than the nearby river. The main species present are raupō and reed sweetgrass. There appeared to be geothermal influence at one site, but we were unable to get the boat close enough to measure any temperatures at this location.

Part of this site was recorded as Lake Ōhakuri/Tainui Road in Wildland Consultants 2000 and 2004c.

The water temperature in one spring was 65 °C with a flow rate of 1 m/second. The spring was depositing small amounts of sinter. The water temperature in one stream was 54°C, with a water flow of c.2 m/second (Wildland Consultants 2006).

References: Bignall 2009; Brotheridge *et al.* 1995; Bromley *et al.* 2022; Wallin 2010; Wildland Consultants 2000, 2004c, 2006, 2012, 2014a, 2020d.



A spring located in the western end of the Waikato River Springs site. Local sinter deposition evident. NZTM E1877528 N5731740. 15 November 2022.



The small island to the western end of the Waikato River Springs site has radiata pine to 20 metres tall, with an understorey of geothermal kākūka, Chinese privet, and mingimingi. The soil temperatures indicated a weak geothermal influence. NZTM E1877524 N5731758. 15 November 2022.



Potential sites of springs located c.200 metres downstream of the Tutukau Road bridge. No confirmation of geothermal influence was found, although only a relatively small area could be safely inspected. NZTM E576959 N5732149. 15 November 2022.



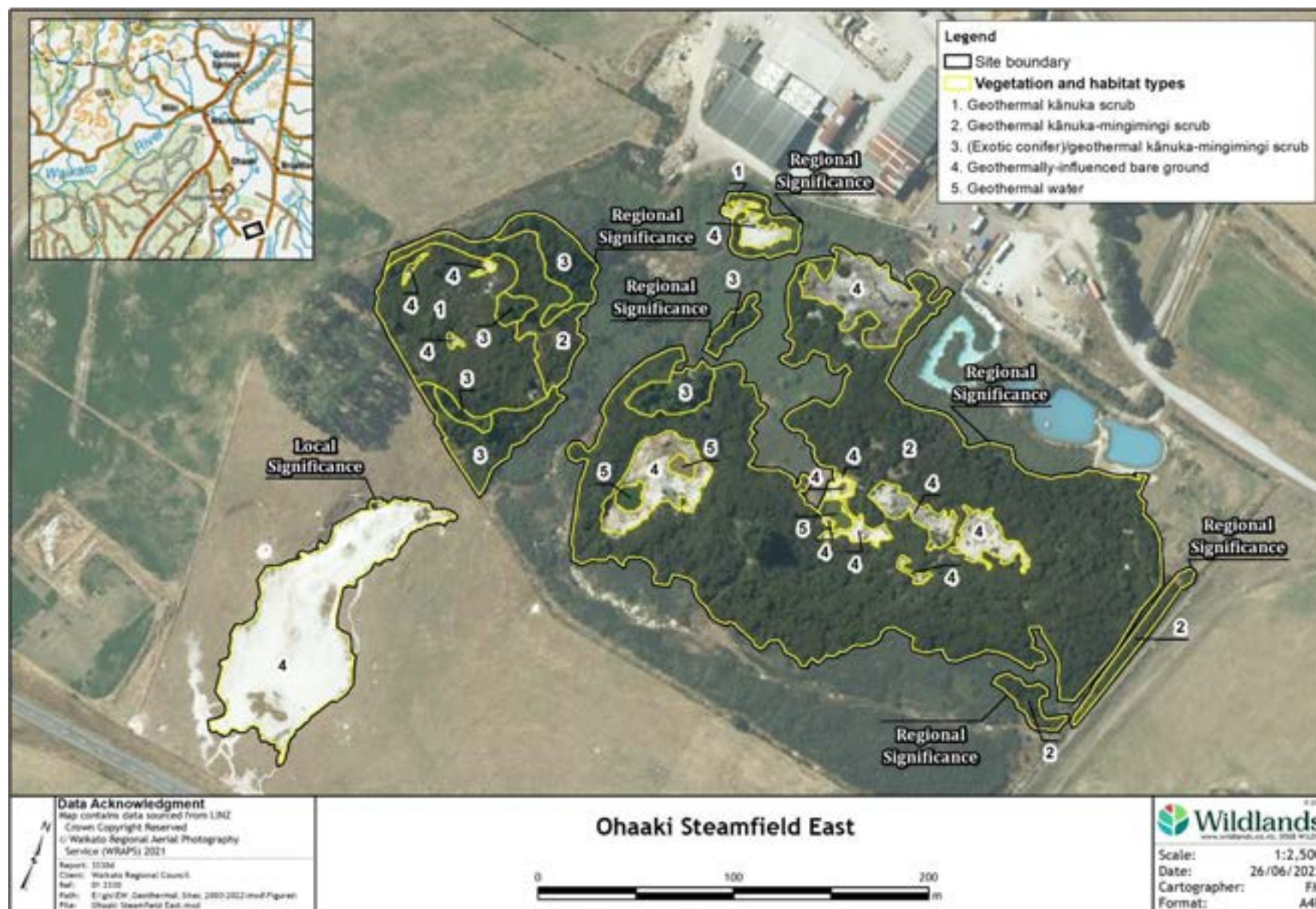
Steam upstream of base of culvert with abundant water cress and *Carex virgata* showed weak geothermal influence. NZTM E1877860N 5730063. 14 October 2022

VASCULAR PLANT SPECIES RECORDED AT SURFACE
GEOTHERMAL SITES IN THE NGĀ TAMARIKI GEOTHERMAL SYSTEM

Scientific Name	Common Name	Waikato River Springs	Orakonui
INDIGENOUS SPECIES			
Monocot. Trees and shrubs			
<i>Cordyline australis</i>	Ti kōuka, cabbage tree	✓	
Dicot. Trees and shrubs			
<i>Coprosma ×cunninghamii</i>			✓
<i>Coprosma lucida</i>	Karamū, kāramuramu, glossy karamū		✓
<i>Coprosma robusta</i>	Karamū, kāramuramu		✓
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taupuku	✓	✓
<i>Geniostoma ligustrifolium</i> var. <i>ligustrifolium</i>	Hangehange	✓	
<i>Kunzea robusta</i>	Kānuka	✓	✓
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	✓
<i>Leptecophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi		✓
<i>Leptospermum scoparium</i>	Mānuka	✓	✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	✓
<i>Melicytus lanceolatus</i>	Māhoe wao		✓
<i>Melicytus ramiflorus</i> subsp. <i>ramiflorus</i>	Māhoe	✓	
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓	✓
<i>Pomaderris amoena</i>	Tauhinu		✓
<i>Pterophylla racemosa</i>	Kāmahi		✓
<i>Veronica stricta</i> var. <i>stricta</i>	Koromiko, kōkōmuka		✓
Lycopods and psilopsids			
<i>Lycopodiella cernua</i>	Mātukutuku		✓
<i>Psilotum nudum</i>	Fork fern		✓
Ferns			
<i>Asplenium flaccidum</i> subsp. <i>flaccidum</i>	Makawe, ngā makawe o raukatauri, drooping splenwort		✓
<i>Blechnum minus</i>	Swamp kiokio		✓
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio		✓
<i>Cyathea dealbata</i>	Ponga, silver fern	✓	
<i>Cyclosorus interruptus</i>			✓
<i>Dicksonia fibrosa</i>	Whekī-ponga, kuripākā		✓
<i>Dicksonia squarrosa</i>	Whekī	✓	✓
<i>Dicranopteris linearis</i>			✓
<i>Gleichenia microphylla</i>	Waewaekākā, carrier tangle fern		✓
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	✓
<i>Hiya distans</i>			✓
<i>Hypolepis ambigua</i>			✓
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pāraharaha, hound's tongue fern		✓
<i>Paesia scaberula</i>	Mātātā, hard fern		✓
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken		✓
<i>Pteris macilenta</i>	Titipo, sweet fern		✓
<i>Pteris tremula</i>	Turawera, shaking brake		✓
<i>Pyrosia elaeagnifolia</i>	Leather-leaf fern		✓
<i>Schizaea</i> sp.			✓
Grasses			
<i>Austroderia fulvida</i>	Toetoe		✓
<i>Lachnagrostis filiformis</i>			✓
<i>Microlaena stipoides</i>	Pātītī, meadow rice grass	✓	
Sedges			
<i>Carex geminata</i> agg.	Rautahi		✓
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio	✓	✓
<i>Carex virgata</i>	Pūrei		✓
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata	✓	✓
<i>Isolepis cernua</i>			✓
<i>Isolepis prolifera</i>			✓
<i>Machaerina tenax</i>			✓
<i>Morelotia affinis</i>			✓
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā		✓

Scientific Name	Common Name	Waikato River Springs	Orakonui
Rushes			
<i>Juncus edgariae</i>	Wi, wīwī		✓
Monocot. Herbs (other than orchids, grasses, sedges, and rushes)			
<i>Astelia fragrans</i>	Kakaha		✓
<i>Dianella nigra</i>	Tūrutu		✓
<i>Phormium tenax</i>	Harakeke, flax	✓	✓
<i>Triglochin striata</i>	Arrow grass		✓
<i>Typha orientalis</i>	Raupō		✓
Dicot. Herbs (other than composites)			
<i>Drosera auriculata</i>	Sundew, wahu		✓
<i>Gonocarpus micranthus</i>	Piripiri		✓
<i>Hydrocotyle heteromeria</i>			✓
<i>Lobelia anceps</i>	Punakura		✓
<i>Nertera depressa</i>			✓
NATURALISED AND EXOTIC SPECIES			
Gymnosperms			
<i>Pinus contorta</i>	Lodgepole pine		✓
<i>Pinus radiata</i>	Radiata pine	✓	✓
Dicot. Trees and shrubs			
<i>Acacia melanoxylon</i>	Tasmanian blackwood		✓
<i>Buddleja davidii</i>	Buddleia		✓
<i>Erica lusitanica</i>	Spanish heath	✓	✓
<i>Leycesteria formosa</i>	Himalayan honeysuckle	✓	✓
<i>Ligustrum sinense</i>	Chinese privet	✓	✓
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓
<i>Salix cinerea</i>	Grey willow	✓	✓
<i>Salix ×fragilis</i>	Crack willow	✓	✓
<i>Teline monspessulana</i>	Montpellier broom		✓
Grasses			
<i>Agrostis stolonifera</i>	Creeping bent	✓	✓
<i>Anthoxanthum odoratum</i>	Sweet vernal		✓
<i>Cortaderia selloana</i>	Pampas		✓
<i>Glyceria declinata</i>	Blue sweetgrass		✓
<i>Glyceria maxima</i>	Reed sweetgrass	✓	✓
<i>Holcus lanatus</i>	Yorkshire fog		✓
<i>Leersia oryzoides</i>			✓
Sedges			
Rushes			
<i>Juncus articulatus</i>	Jointed rush		✓
<i>Juncus bufonius</i> var. <i>bufonius</i>	Toad rush	✓	
<i>Juncus effusus</i> var. <i>effusus</i>	Soft rush, leafless rush	✓	✓
<i>Juncus tenuis</i> var. <i>tenuis</i>	Track rush	✓	
Composite herbs			
<i>Cirsium vulgare</i>	Scotch thistle		✓
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane		✓
<i>Gamochaeta calviceps</i>	Silky cudweed		✓
<i>Gamochaeta coarctata</i>	Purple cudweed		✓
<i>Hypochaeris radicata</i>	Catsear		✓
<i>Mycelis muralis</i>	Wall lettuce		✓
<i>Sonchus oleraceus</i>	Puha, sow thistle		✓
Dicot. Herbs (other than composites)			
<i>Cerastium fontanum</i> subsp. <i>Vulgare</i>	Mouse-ear chickweed		✓
<i>Digitalis purpurea</i>	Foxglove		✓
<i>Galium aparine</i>	Cleavers		✓
<i>Mimulus guttatus</i>	Monkey musk		✓
<i>Nasturtium officinale</i>	Watercress		✓
<i>Nymphaea mexicana</i>	Mexican water lily	✓	
<i>Parentucellia viscosa</i>	Tarweed		✓
<i>Ranunculus repens</i>	Creeping buttercup		✓
<i>Scrophularia auriculata</i>	Water figwort		✓
<i>Stellaria media</i>	Chickweed		✓

18. OHAAKI GEOTHERMAL SYSTEM



OHAAKI STEAMFIELD EAST

Ecological District:	Atiamuri	GPS Reference:	NZTM E1888672 N5731579
Geothermal System:	Ohaaki	Altitude:	310 m
Bioclimatic Zone:	Submontane	Local Authority:	Taupō
Extent of Geothermal Habitat:	c.5.3 ha		
Extent of Geothermal Vegetation:	c.5.3 ha		
Date of Most Recent Field Survey:	26 March and 16 June 2022		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka scrub with occasional patches of mānuka. Mingimingi, monoao, Spanish heath, broom, and bracken are present on the margins with scattered emergent radiata pine and maritime pine. Small areas of geothermally-influenced bare ground and moss patches are also present.	Flat, gentle hillslope, crater	c.0.6 ha
2.	Geothermal kānuka-mingimingi scrub (04.02) Geothermal kānuka-mingimingi scrub (04.02.01) Geothermal kānuka and mingimingi scrub with occasional patches of mingimingi, monoao, Spanish heath, broom, and bracken present on the margins with scattered emergent radiata pine and maritime pine. Local mānuka. Yorkshire fog, lotus, broad-leaved fleabane, and gorse are also present. Small areas of geothermally-influenced bare ground and moss patches are also present.	Flat, gentle hillslope	c.3.2 ha
3.	Geothermal kānuka-mingimingi scrub (04.02) (Exotic conifer)/geothermal kānuka-mingimingi scrub (04.02.03) Similar to vegetation type 2, but with more emergent wilding conifers (mostly maritime pine and radiata pine) present between 3 and 20 metres tall.	Flat, gentle hillslope	c.0.4 ha
4.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) In the south of this site, geothermal bare ground is surrounded by Indian doab. In the main geothermal area to the north, scattered plants of geothermal kānuka, mingimingi, broad-leaved fleabane, lotus, and Yorkshire fog are present.	Flat, gentle hillslope, crater	c.1.1 ha
5.	Open water (22.01) Geothermal water (22.01.01) Geothermal pools.	Open water	<0.1 ha

Indigenous Flora: Geothermal kānuka (Threatened-Nationally Endangered) is present at this site. Arrow grass, generally a coastal species which occasionally occurs inland, has been recorded at the site in the past (Beadel 1986 and Burns 1997a).

Fauna: Common indigenous and introduced bird species typical of the habitat are present, including kāhu/swamp harrier, spur-winged plover, karoro/southern black-backed gull, warou/welcome swallow, and pīwakawaka/North Island fantail. Introduced species include Californian quail, yellowhammer, chaffinch, house sparrow and Australian magpie.

Geothermal Ecosystems:	Heated ground (dry), hydrothermally altered ground (now cool), fumaroles, geothermal streamsides.
Management Requirements:	The site is currently in relatively poor condition, with abundant pest plants and recent human disturbance, however values are likely to improve if management of threats is undertaken. Beadel (1986), Given (1989), and Burns (1997a) noted that the quality of this site had deteriorated due to rubbish disposal, effluent from the lucerne drying plant polluting the ponds, and an increase in adventive weeds. Geothermal wastewater is no longer discharged into this site from the former lucerne-drying plant and the landowner is investigating options for reinjection. There is no longer open geothermal water here. In 2011, the landowner had plans to restore the area and had started to fell wilding pines. However, in 2022, there appeared to have been little further management at the site.
Threats/Modification/Vulnerability:	
<i>Invasive pest plants:</i>	Weeds are abundant, particularly blackberry, pines, Spanish heath, and broom, which together cover <i>c.</i> 50% of the site. A single mature lodgepole pine is present in this site. Hot spots appear to be resistant to weed invasion as long as the indigenous vegetation remains free from disturbance.
<i>Human impacts:</i>	Ohaaki Power Station draws water from the underlying geothermal resources and this may affect geothermal features dependent on geothermal heat. To date there is no evidence of cooling or heating of the site (Burns 1997a; Merrett and Burns 1998a; and general observations of site visits between 2000 and 2022). Geothermal wastewater dumping into this site has ceased in the last four or five years, but reinjection options are being considered. Waste water is collected into storage ponds from the kiln in the north.
<i>Grazing:</i>	Most of this site is fenced to exclude domestic livestock but one area of geothermally-influenced bare ground is located in a grazed paddock.
<i>Adjoining land use:</i>	This site is mainly surrounded by farmland with the Ohaaki Thermal Kiln operation on the northern margin.

Site Change:

Recent change:

Little change can be determined by assessing aerial photographs of the site. The changes to vegetation types boundaries are mostly related to better quality imagery. Geothermal kānuka has become established on part of what was previously bare ground.

Blackberry appears to have increased in dominance, particularly in the southern half of the site (the fenced portion), but mostly outside geothermal areas.

*Historical:*¹

In 1941² the site appeared to be in better ecological condition. The western part of the site was not farmed and appears to be in shrubland. Exotic trees were not a major component of the site in 1941, and there were no impacts from the industrial site to the north. The eastern part of the site appeared to be in pasture, whereas part of this area is now fenced to exclude stock. The scrub vegetation appears very similar in character to geothermal and non-geothermal habitat, so the exact reduction in extent of geothermal vegetation at the site is difficult to determine. The vegetation present was likely to be of significantly higher quality in 1941 due to the absence of pest plants and industrial waste. There was *c.*10-25% more geothermal vegetation and habitats at this site in 1941 than in 2007. The extent of geothermally-influenced bare ground was also greater.

Management Requirements:

Control of wilding pines and pampas within this site is a priority. Other species that need to be controlled at this site include blackberry, Spanish heath, broom, and gorse. The existing, recently-formed tracks could be used for access for weed control and planting, but they should be allowed to naturally revert if geothermal kānuka re-establishes. Ideally, the site requires a long term restoration plan to ensure that weed control and planting operations are appropriate, and that the ecological values of the site are protected and enhanced.

Significance Level:

R: Regional (Criteria 1, 3, 5).
L: Local (Criterion 5)

Significance Justification:

R: Most of the Ohaaki Steamfield East is of regional significance because it is partially protected by a QEII National Trust covenant.

L: The remainder of the site is locally significant because it is a nationally uncommon habitat type: geothermal.

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study, this site was classed as Category B - the second highest category.

References:

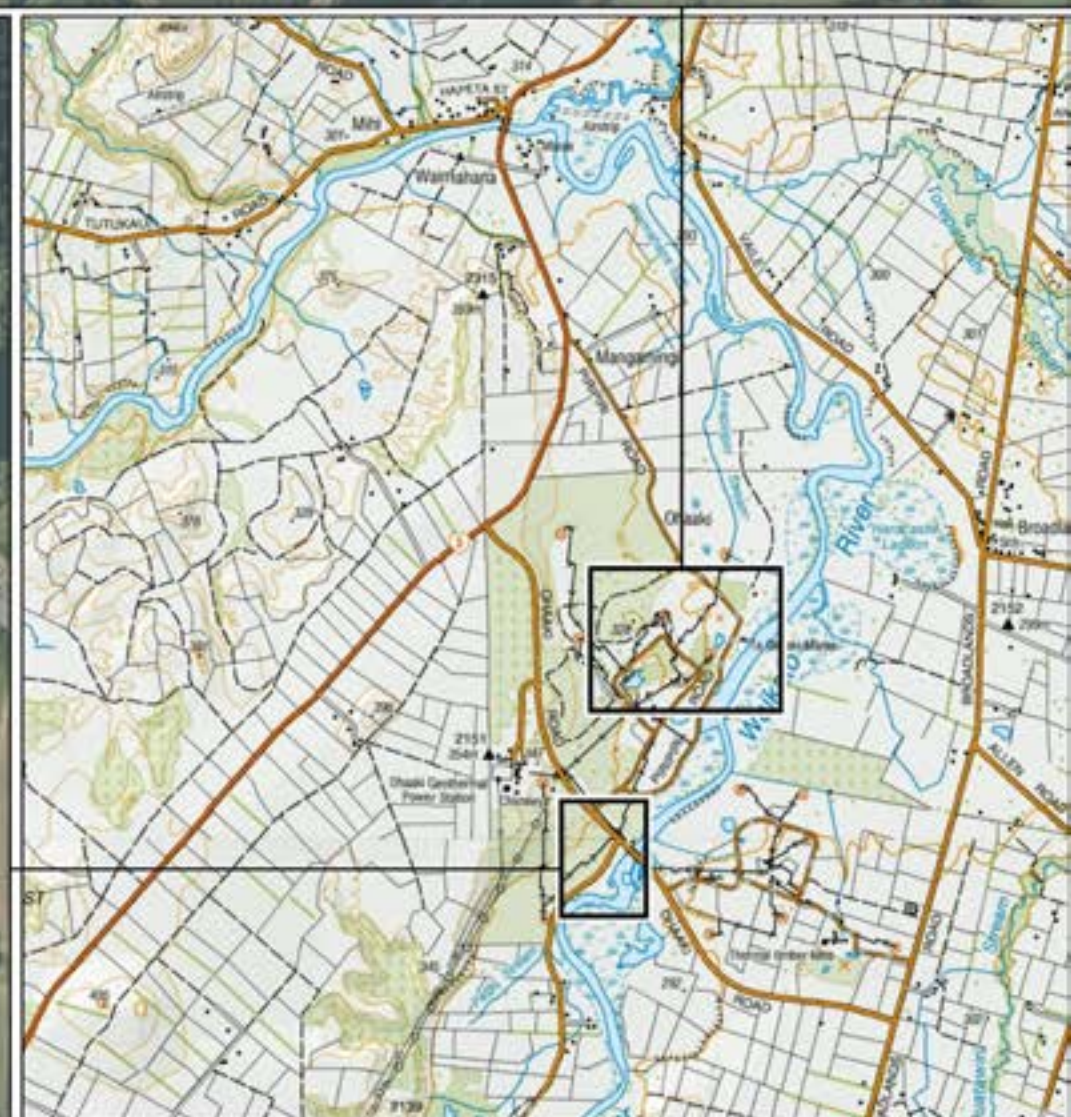
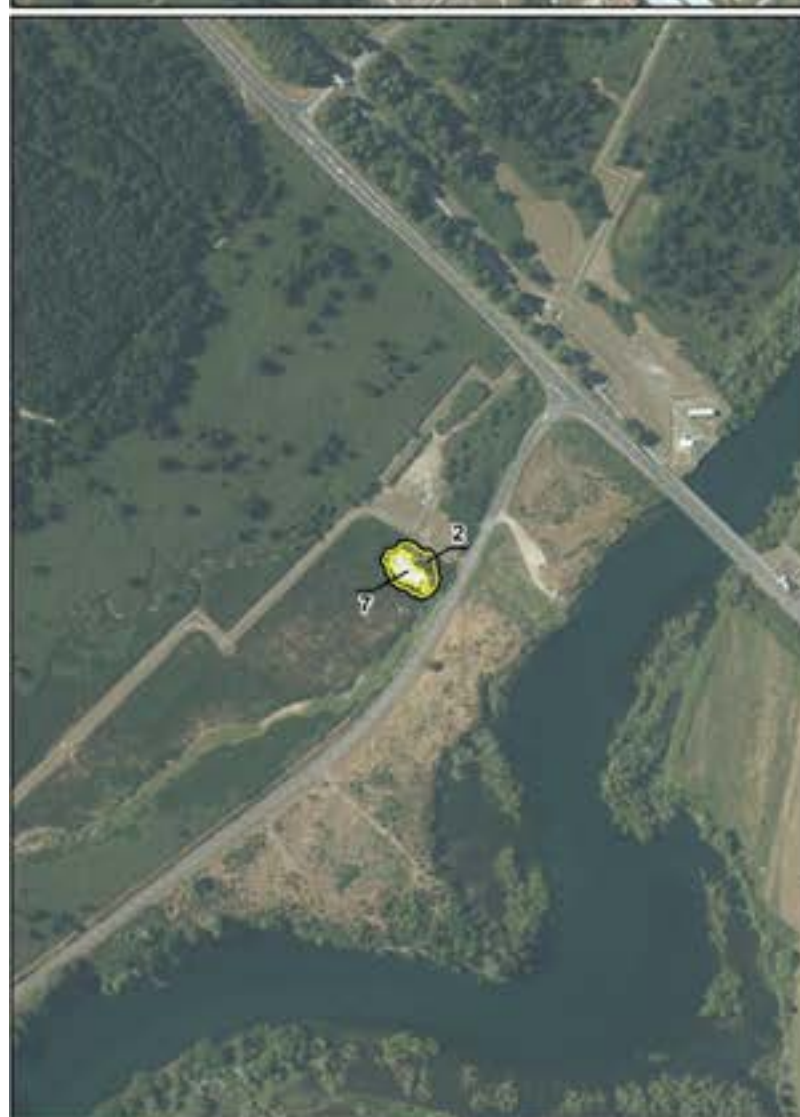
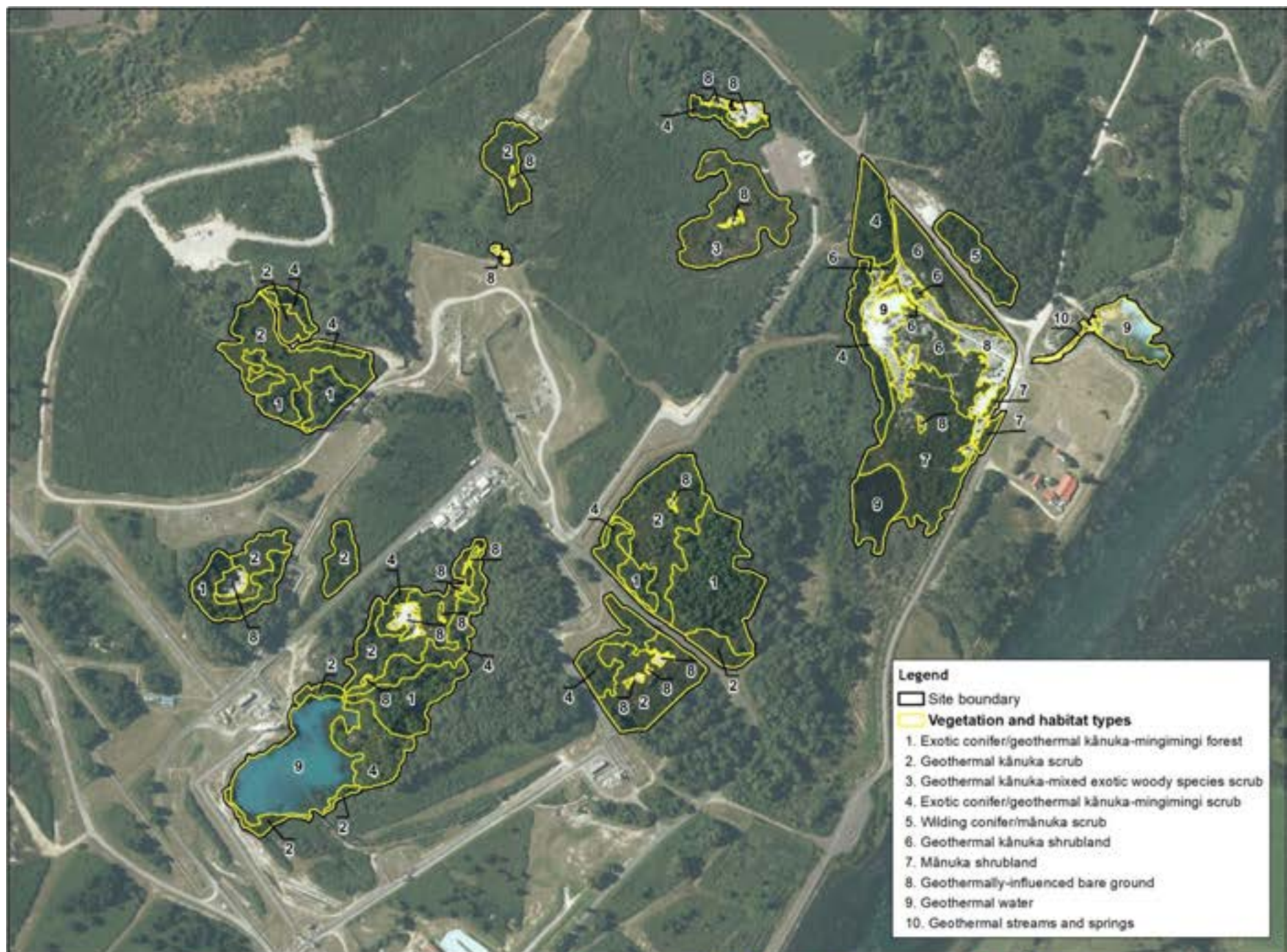
Beadel 1986; Burns 1997a; Given 1989a & 1996; Merrett and Burns 1998a; Merrett *et al.* 2003; Wildland Consultants 2000, 2004c 2012, 2014a, 2022b, 2022c.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 172 Run 1169 Photos 27-29, 1941.



Ohaaki Steamfield East, June 2022. NZTM E1889270, N5728963.



Data Acknowledgment Map contains data sourced from LINZ Crown Copyright Reserved © Waikato Regional Aerial Photography Service (WRAPS) 2021 Report: 1330d Client: Waikato Regional Council Ref: 1330 Path: E:\GIS\EW_Geothermal_Sites_2021\1330d\Figure1 File: Ohaaki Steamfield West.mxd	Ohaaki Steamfield West 0 100 200 m	Wildlands www.wildlands.co.nz 0800 910002 Scale: 1:5,000 Date: 4/05/2023 Cartographer: FM Format: A3

OHAAKI STEAMFIELD WEST

Ecological District:	Atiamuri	GPS Reference:	NZTM E1888672 N5731579
Geothermal System:	Ohaaki	Altitude:	320 m
Bioclimatic Zone:	Submontane	Local Authority:	Taupō
Extent of Geothermal Habitat:	c.15.0 ha		
Extent of Geothermal Vegetation:	c.13.1 ha		
Date of Most Recent Field Survey:	10, 11 February, 25 March 2022 and 6 March 2023		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic forest (01.02) Exotic conifers/geothermal kānuka-mingimingi forest (01.02.07) Abundant conifers (mostly maritime pine and radiata pine) almost form a complete canopy over indigenous woody species, most notably geothermal kānuka and mingimingi, with local blackberry, bracken, and broom. Local patches of pampas are present.	Flat, gently sloping, hill slope.	c.2.3 ha
2.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka ranging from 0.3 to 1.5 metres tall, with height decreasing with increasing proximity to geothermal surface features. Occasional emergent radiata pine and maritime pine up to c.10 m tall. Bracken, tūrutu, <i>Gleichenia microphylla</i> , <i>Paesia scaberula</i> , kiokio, and <i>Histiopteris incisa</i> are also present. Small patches of geothermally-influenced bare ground occur amongst this vegetation type which supports scattered <i>Lycopodiella cernua</i> , Spanish heath, broad-leaved fleabane, gorse, pampas, buddleia, and broom.	Low hills; hillslopes, flat	c.4.0 ha
3.	Geothermal kānuka-mixed exotic woody species scrub (04.01.11) A site that was historically dominated by geothermal kānuka scrub with abundant mingimingi, however exotic woody species such as blackberry and broom are becoming abundant. Local bracken fernland.	Flat, gently sloping, hillslope	c.0.8 ha
4.	Geothermal kānuka-mingimingi-dominant scrub (04.03) Exotic conifer/geothermal kānuka-mingimingi scrub (04.03.03) Geothermal kānuka and mingimingi dominates the canopy with occasional mānuka. Locally abundant emergent conifers especially maritime pine and radiata pine. Bracken, buddleia, Spanish heath, blackberry, gorse, whauwhaupaku, kōhūhū, and whekī are also present. Local patches of pampas are present.	Flat, hillslope	c.2.1 ha
5.	Mānuka scrub (04.04) Wilding conifer/mānuka scrub (04.04.08) An area of shrubland which becomes increasing taller and denser to the north away from the road. Part of this area may have been cleared in the past, although the substrate is sinter, or broken sinter, and pumice by road margins. On the part closest to the road,	Flat	c.0.3 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	mānuka is 1-4 m tall with occasional maritime pine, and radiata pine. Scattered Spanish heath/sinter occurs in small patches where mānuka and pines are not established. Patches of exotic grasses and bare ground are present on the immediate road margin. Pines and mānuka become taller to north of this area, with pines being up to 10 m tall. In the eastern end of this area, a patch of geothermal kānuka is present, which has a more geothermal character, and it is possible that some geothermal influence is still active in this area.		
6.	Geothermal kānuka-dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) This area comprises geothermal kānuka up c.0.75 m height, and areas of bare soil. Occasional pampas is present.	Flat, terrace	c.1.1 ha
7.	Mānuka-dominant shrubland (05.04) Mānuka shrubland (05.04.01) Mānuka-geothermal kānuka/lichen/sinter shrubland (near the ngawha at the north of the site). Mānuka and lesser amounts of geothermal kānuka are the most abundant species within this vegetation type, with occasional maritime pine, lodgepole pine, and kōhūhū present in the canopy. Occasional mingimingi and prickly mingimingi, as well as blackberry, cotoneaster, gorse, and Spanish heath are present. Scattered pampas occur locally. The understorey comprises <i>Drosera auriculata</i>, orchids (<i>Thelymitra longifolia</i> and <i>Microtis uniflora</i>), as well as mosses and liverworts, including <i>Chiloscyphus semiteres</i> and <i>Campylopus</i> spp. Extensive areas of sinter are mostly devoid of vascular plant species, with locally abundant patches of lichens and mosses. Abundant non-vascular species present on open sinter include <i>Racomitrium</i> spp., <i>Campylopus</i> spp. and several <i>Cladonia</i> species (including <i>C. confusa</i> and possibly <i>C. floerkeana</i>). On open areas of sinter the foliose lichen <i>Xanthoparmelia</i> sp. is particularly abundant.	Flat	c.1.2 ha
8.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Sinter clay, small sinter terraces (unmapped), steaming fumaroles, fissures, and bare ground with areas of geothermal kānuka, mānuka, <i>Lycopodiella cernua</i>, the moss <i>Campylopus capillaceus</i>, and exotic grasses (including narrow-leaved carpet grass and tall fescue). Around Ohaaki ngawha there are local patches of kānuka in association with mānuka and scattered Spanish heath, pampas, and blackberry with small, isolated areas of <i>Machaerina juncea</i>. This habitat type is characterised by sinter clay, small sinter terraces, steaming fumaroles, fissures, and bare ground with local areas of sparse low vegetation. Many areas of geothermally-influenced bare ground are too small to separately map, and as a result are included within the other geothermal vegetation types. Small local areas of geothermal kānuka, moss (often <i>Campylopus</i> sp.), and exotic grasses including narrow-leaved carpet and tall fescue are present within this habitat. Scattered patches of mānuka,	Flat, sinter terrace, hillslope.	c.1.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	Spanish heath, gorse, pampas, and blackberry are also present. One grey willow tree was present in the southernmost area of this vegetation type.		
9.	Water (22.01) Geothermal water (22.01.01) Geothermal pool (including the Ohaaki Ngawha). Geothermal stream, springs, and drain.	Open water	c.1.8 ha
10.	Geothermal streams and springs (22.01.03)	Gully	<0.1 ha

Indigenous Flora:

Geothermal kānuka (Threatened-Nationally Endangered), *Campylopus clavatus*, *Lycopodiella cernua*, mingimingi, prickly mingimingi, monoao, tūrutu, and *Drosera auriculata* are present at this site; these species are characteristic of geothermal sites.

Approximately 5-10 plants of *Dicranopteris linearis* (Threatened-Nationally Endangered) were present at Ohaaki Steamfield West in 2004 (Wildland Consultants 2004), but this species has not been recorded in subsequent surveys and is possibly extinct at this site.

Fauna:

Common indigenous and introduced bird species typical of the habitat are present and include pūtangitangi/paradise shelduck, kāhu/swamp harrier, pūkeko, spur-winged plover, poaka/pied stilt, pīpīwharau/roa/shining cuckoo, warou/welcome swallow, toutouwai/North Island robin (At Risk-Declining), pīwakawaka/North Island fantail, kōtare/sacred kingfisher, tūi, korimako/bellbird, riroriro/grey warbler, and tauhou/silvereye. Introduced species recorded include mallard, common pheasant, California quail, dunnoek, Eurasian blackbird, song thrush, yellowhammer, European greenfinch, European goldfinch, chaffinch, house sparrow, Australian magpie, and common starling.

Rabbits were also present at the site.

Geothermal Ecosystems:

Heated ground (dry), hydrothermally altered ground (now cool), fumaroles, geothermal streamsides and geothermal wetlands.

Current Condition:

Major changes to the vegetation and landform within this site have occurred over several years due to land subsidence as a result of groundwater extraction by the geothermal power station. This site has been fragmented by industrial activities and road works. No clearance was evident between 2011 and 2023. Overall, this site comprises a relatively large area of geothermal vegetation and habitat with significant human-induced disturbance and major pest plant infestations. However, the site still has significant ecological values. The geothermal character of the vegetation of much of the site is declining with a reduction in the area dominated by geothermal kānuka and increased vegetation height.

Wilding pines have been controlled in some areas but they remain prominent in other parts of the site.

Threats/Modification/ Vulnerability:

Invasive pest plants: Wilding pines (mostly maritime pine, radiata pine and some Douglas fir and lodgepole pine) are the most prominent invasive species, with a cover of c.20%. Scattered silver birch are present (c.1% cover). Other invasive pest plant species present are blackberry, broom, pampas, gorse, grey willow, crack willow, *Cotoneaster franchetii*, and ornamental cherry (each with 1-5% cover). Soil temperatures are cooling at this site which is resulting in increased opportunities for exotic species to invade. Some of the larger infestations of wilding pines and pampas had been controlled in and around the borefield by the Waikato Regional Council some years ago. Ongoing pest plant control is being undertaken within this site by Contact Energy (wilding pines and pampas) and Waikato Regional Council.

Human impacts: Geothermal extraction and related earthwork operations present ongoing threats to the geothermal features and vegetation of this site. Temperatures are cooling (D. Bowden, Contact Energy, pers. comm. 2011), wilding pines are continuing to establish, and geothermal vegetation has been cleared to make way for roads and infrastructure.

Grazing: Grazing is not an issue at this site.

Adjoining land use: Geothermal power plant operations, plantation forestry (some historical, not currently managed for any purpose), Waikato River.

Site Change:

Recent change: Several small additional areas were identified in the 2022/23 surveys, although none of these are likely to be new geothermal features, but a result of better aerial photography and knowledge of the site. Vegetation change as a result of land subsidence within the site has occurred but the full extent of change is not known. Some wilding pine control has been undertaken at the site since 2004, however wilding pine encroachment is continuing in many areas. The cover of wilding pines is an issue that should be addressed in throughout the Ohaaki Steamfield West site.

*Historical:*¹ In 1941² there was a larger area of bare ground and low shrubland in the vicinity of this site, which may have been geothermal vegetation and habitat, however these areas are now non-geothermal. Merrett and Burns (1998a) compared and interpreted aerial photographs from 1941 to 1996 and found that the total area of geothermal vegetation reduced between 1941 and 1981, with many areas colonised by wilding pines. In 1996, there was an increase in the extent of geothermal vegetation, probably as a consequence of fallen pines and recolonisation by geothermal kānuka. The density of weed species has steadily increased at this site over the last few decades.

The Ohaaki Power Station was commissioned in 1989. Prior to the development of field, the large boiling pool in the northeast of the site (Ohaaki Ngāwhā) was the most significant feature of the field, with its turquoise-blue water and extensive sinter terrace (Vaile 1939). When

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 172 Run 1167 Photos 7-9, 1941.

development commenced, the extraction of geothermal fluid made the water level at Ohaaki Ngāwhā drop. The change in water level within Ohaaki Ngāwhā changed the quality of the sinter terrace and allowed vegetation to establish on it. Most other features at Ohaaki have dried up because of the extraction of geothermal fluid. Before development, several types of geothermal features were present at Ohaaki including:

- Several mud pools heated by steam.
- Hot pools isolated from ground water by a layer of mineralised earth, also heated by steam.
- Hot springs producing chloride water and depositing sinter.

Most of these features have dried up and are now hot dry ground, however the area of steaming ground initially expanded, resulting in steam rising through the graves in the urupā to the northwest of the site, and the ground has opened up in places (<http://www.waikatoregion.govt.nz/Environment/Natural-resources/Geothermal-resources/Geothermal-systems-map/Ohaaki/>; Accessed 9 July 2014).

Other management activities have also had significant impacts at the site, and some features are threatened by flooding of, and inundation by, the Waikato River ([http://www.nzgeothermal.org.nz/nz_geo_fields.html#Ohaaki Broadlands](http://www.nzgeothermal.org.nz/nz_geo_fields.html#Ohaaki_Broadlands); Accessed 30 June 2011).

Environmental monitoring of this area over ten years prior to, and during, the development of the Ohaaki power project shows that significant changes to geothermal features have occurred in response to water draw-off for geothermal power generation. In the northwestern thermal area, all pools are now dry (other than Ohaaki Ngāwhā where the water level is artificially maintained) and geothermal vegetation is establishing on the exposed ground (Bromley *et al.* 1997). In some areas ground temperatures have decreased, but in others ground temperatures have increased, resulting in an increase in the extent of thermotolerant vegetation (Merrett and Burns 1998a).

Management Requirements:

Management of pest plants is a high priority. Contact Energy is undertaking control of wilding pines and pampas within this site. Waikato Regional Council has maintained the area next to the Ohaaki Marae free from pest plants since wilding pines were removed in 2011. Other pest plant control should also be undertaken.

Monitoring of steamfield management, and the vegetation response to changing temperatures should be ongoing. The impacts of land subsidence on geothermal vegetation should also be monitored.

Future infrastructure developments on the site should avoid clearing remaining areas of geothermal vegetation.

Significance Level:

Regional (Criteria 3, 5).

Significance Justification:

This site is of regional significance because it contains a relatively large area of geothermal habitat (a nationally uncommon habitat type).

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region. He ranked Ohaaki Ngawha, which occurs in this site, as Category C - the third highest category.

Merrett and Burns (1998a) suggest that the study area would rank in the Protected Natural Areas Programme as a level 2 priority for protection, and commented that “the conservation of thermotolerant vegetation at Ohaaki is moderately significant to the goal of maintaining adequate representative examples of the full range of natural vegetation present in the Atiamuri Ecological District.”

A restoration plan for the site has been prepared on behalf of Contact Energy and the landowners (Wildland Consultants 2021g).

References:

Beadel 1986; Bromley *et al.* 1997; Given 1996; Merrett and Burns 1998a; Merrett *et al.* 2003; Vaile 1939; Wildland Consultants 2000, 2004c, 2012, 2014a, 2017c, 2021, 2022b, 2022c.



The crater is surrounded by geothermal kānuka and mingimingi scrub and radiata pine forest. Pampas, maritime pine, gorse, and Spanish heath have established on the floor of the crater. E1887916 N5731342. 10 February 2022.



Geothermal kānuka scrub and shrubland, with scattered emergent wilding pines in background. NZTM E1887934 N5731337. 25 March 2022.



Ohaaki Ngāwhā. The pool is surrounded by sinter with scattered mānuka, geothermal kānuka and pampas. NZTM E1888649 N5731658. 25 March 2022.



Geothermal feature in the southern part of Ohaaki Steamfield West. June 2022. NZTM E1887771 N5729863.

LIST OF VASCULAR PLANT SPECIES RECORDED AT SURFACE
GEOTHERMAL SITES IN THE OHAAKI GEOTHERMAL SYSTEM

Scientific Name	Common Name	Ohaaki West	Ohaaki East
INDIGENOUS SPECIES			
Monocot. trees and shrubs			
<i>Cordyline australis</i>	Ti kōuka, cabbage tree		✓
Dicot. trees and shrubs			
<i>Coprosma robusta</i>	Karamū, kāramuramu		✓
<i>Dracophyllum subulatum</i>	Monoao	✓	✓
<i>Kunzea robusta</i>	Kānuka	✓	
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	
<i>Leptecophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi	✓	✓
<i>Leptospermum scoparium</i>	Mānuka	✓	✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	✓
<i>Leucopogon fraseri</i>	Pātōtara		✓
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓	
<i>Pseudopanax arboreus</i>	Whauwhaupaku, puahou, five finger	✓	
<i>Veronica stricta</i> var. <i>stricta</i>	Koromiko, kōkōmuka	✓	
Dicot. lianes			
<i>Calystegia sepium</i> subsp. <i>roseata</i>	Pōhue	✓	
<i>Muehlenbeckia australis</i>	Puka	✓	
Lycopods and psilopsids			
<i>Lycopodiella cernua</i>	Mātukutuku	✓	
Ferns			
<i>Asplenium flaccidum</i> subsp. <i>flaccidum</i>	Makawe, ngā makawe o raukatauri, drooping spleenwort	✓	✓
<i>Asplenium polyodon</i>	Petako, paratao, sickle spleenwort	✓	✓
<i>Blechnum minus</i>	Swamp kiokio	✓	
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio	✓	✓
<i>Dicksonia fibrosa</i>	Whekī-ponga, kurīpākā	✓	✓
<i>Dicksonia squarrosa</i>	Whekī	✓	✓
<i>Dicranopteris linearis</i>		✓	
<i>Diplazium australe</i>		✓	
<i>Gleichenia microphylla</i>	Waewaekākā, carrier tangle fern	✓	
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	
<i>Hiya distans</i>		✓	✓ *Burns 1997a
<i>Hypolepis ambigua</i>		✓	✓
<i>Paesia scaberula</i>	Mātātā, hard fern	✓	✓
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	✓
<i>Pyrrosia elaeagnifolia</i>	Leather-leaf fern	✓	
Orchids			
<i>Microtis unifolia</i> agg.		✓	
<i>Thelymitra longifolia</i>		✓	
Grasses			
<i>Austroderia fulvida</i>	Toetoe	✓	
<i>Lachnagrostis filiformis</i>		✓	
<i>Rytidosperma gracile</i>		✓	
Sedges			
<i>Carex virgata</i>	Pūrei	✓	
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata	✓	
<i>Isolepis prolifera</i>		✓	
<i>Lepidosperma australe</i>		✓	
<i>Machaerina juncea</i>		✓	
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā	✓	✓
<i>Schoenus maschalinus</i>		✓	
Rushes			
<i>Juncus edgariae</i>	Wi, wīwī		✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)			
<i>Dianella nigra</i>	Tūruru	✓	✓
<i>Phormium tenax</i>	Harakeke, flax	✓	
<i>Triglochin striata</i>	Arrow grass		✓
<i>Typha orientalis</i>	Raupō	✓	✓

Scientific Name	Common Name	Ohaaki West	Ohaaki East
Composite herbs			
<i>Pseudognaphalium luteoalbum</i> agg.	Pukatea	✓	
<i>Senecio bipinnatisectus</i>	Australian fireweed	✓	
Dicot. herbs (other than composites)			
<i>Drosera auriculata</i>	Sundew, wahu	✓	
<i>Gonocarpus micranthus</i>	Piripiri		✓
<i>Solanum americanum</i>	Raupeti		✓
NATURALISED AND EXOTIC SPECIES			
Gymnosperms			
<i>Larix decidua</i>	European larch	✓	
<i>Pinus contorta</i>	Lodgepole pine	✓	✓
<i>Pinus pinaster</i>	Maritime pine	✓	✓
<i>Pinus radiata</i>	Radiata pine	✓	✓
<i>Pseudotsuga menziesii</i>	Douglas fir	✓	
Dicot. trees and shrubs			
<i>Betula pendula</i>	Silver birch	✓	
<i>Buddleja davidii</i>	Buddleia	✓	
<i>Cotoneaster franchetii</i>		✓	
<i>Cytisus scoparius</i>	Broom	✓	✓
<i>Erica lusitanica</i>	Spanish heath	✓	✓
<i>Eucalyptus</i> sp.	Eucalyptus	✓	
<i>Leycesteria formosa</i>	Himalayan honeysuckle	✓	
<i>Ligustrum sinense</i>	Chinese privet	✓	
<i>Lupinus arboreus</i>	Lupin	✓	
<i>Prunus</i> sp.	Ornamental cherry	✓	
<i>Quercus robur</i>	English oak	✓	
<i>Rosa rubiginosa</i>	Sweet briar	✓	
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓
<i>Salix cinerea</i>	Grey willow	✓	✓
<i>Salix ×fragilis</i>	Crack willow	✓	
<i>Teline monspessulana</i>	Montpellier broom	✓	
<i>Ulex europaeus</i>	Gorse	✓	✓
Grasses			
<i>Agrostis capillaris</i>	Browntop	✓	✓
<i>Agrostis stolonifera</i>	Creeping bent	✓	
<i>Aira caryophyllea</i> subsp. <i>caryophyllea</i>	Silver hairy grass	✓	✓
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓	
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass	✓	✓
<i>Bromus diandrus</i>	Rippgut brome	✓	
<i>Cortaderia selloana</i>	Pampas	✓	✓
<i>Cynodon dactylon</i>	Indian doab	✓	✓
<i>Dactylis glomerata</i>	Cocksfoot	✓	
<i>Eragrostis brownii</i>	Bay grass	✓	✓
<i>Holcus lanatus</i>	Yorkshire fog	✓	✓
<i>Lolium arundinaceum</i> subsp. <i>arundinaceum</i>	Tall fescue	✓	
<i>Lolium perenne</i>	Rye grass	✓	
<i>Paspalum dilatatum</i>	Paspalum	✓	
Sedges			
<i>Cyperus eragrostis</i>	Umbrella sedge	✓	
Rushes			
<i>Juncus bufonius</i> var. <i>bufonius</i>	Toad rush	✓	
<i>Juncus tenuis</i> var. <i>tenuis</i>	Track rush	✓	
Composite herbs			
<i>Achillea millefolium</i>	Yarrow	✓	
<i>Cirsium vulgare</i>	Scotch thistle	✓	✓
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane	✓	✓
<i>Gamochaeta coarctata</i>	Purple cudweed	✓	
<i>Hypochaeris radicata</i>	Catsear	✓	✓
<i>Jacobaea vulgaris</i>	Ragwort	✓	
<i>Leontodon taraxacoides</i>	Hawkbit	✓	
Dicot. herbs (other than composites)			
<i>Centaurium erythraea</i>	Centaurry	✓	
<i>Digitalis purpurea</i>	Foxglove	✓	
<i>Galium aparine</i>	Cleavers	✓	
<i>Geranium molle</i>	Dovesfoot cranesbill	✓	
<i>Hypericum perforatum</i>	St John's wort	✓	

Scientific Name	Common Name	Ohaaki West	Ohaaki East
<i>Linum catharticum</i>	Purging flax	✓	✓
<i>Lotus pedunculatus</i>	Lotus	✓	✓
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	Scarlet pimpernel	✓	
<i>Ornithopus perpusillus</i>	Wild seradella	✓	✓
<i>Parentucellia viscosa</i>	Tarweed	✓	
<i>Persicaria maculosa</i>	Willow weed	✓	
<i>Plantago lanceolata</i>	Narrow-leaved plantain	✓	
<i>Plantago major</i>	Broad-leaved plantain	✓	
<i>Prunella vulgaris</i>	Selfheal	✓	✓
<i>Ranunculus repens</i>	Creeping buttercup	✓	✓
<i>Rumex acetosella</i>	Sheep's sorrel	✓	✓
<i>Rumex obtusifolius</i>	Broad-leaved dock	✓	
<i>Spergula arvensis</i>	Spurrey	✓	
<i>Trifolium arvense</i>	Haresfoot trefoil	✓	
<i>Trifolium dubium</i>	Suckling clover	✓	
<i>Trifolium pratense</i>	Red clover	✓	✓
<i>Verbascum thapsus</i>	Woolly mullein	✓	
<i>Verbena bonariensis</i>	Purple-top	✓	
<i>Wahlenbergia</i> sp.	Harebell	✓	

19. ORĀKEI KŌRAKO GEOTHERMAL SYSTEM



Legend

- Site boundary
- Vegetation and habitat types
- 1. Geothermal kānuka scrub
- 2. Wilding conifer/geothermal kānuka scrub



Data Acknowledgment

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Report: 22046
 Client: WRC
 Ref: 21-2108
 Path: E:\GIS\DM_Geothermal_Sites_2003-2022\road\figures
 File: Akatarewa East.mxd

Akatarewa East



Wildlands
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Scale: 1:2,500
 Date: 27/03/2023
 Cartographer: FM
 Format: A4

AKATAREWA EAST

Ecological District:	Atiamuri	GPS Reference:	NZTM E1876276 N5738860
Geothermal System:	Orākei Kōrako	Altitude:	400 m
Bioclimatic Zone:	Submontane	Local Authority:	Rotorua
Extent of Geothermal Habitat:	c.0.1 ha		
Extent of Geothermal Vegetation:	c.0.1 ha		
Date of Most Recent Field Survey:	18 January 2023		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	04.01 Geothermal kānuka (04.01) Geothermal kānuka scrub (04.01.01) 1a: Geothermal kānuka scrub to four metres tall covers an area of 5 × 5 metres. There is occasional <i>Pteris tremula</i> in the understorey. The ground cover comprises leaf litter and the liverwort <i>Chiloscyphus semiteres</i> . 1b: Geothermal kānuka to four metres with local karamū and <i>Pittosporum tenuifolium</i> present.	Hillslope	<0.1 ha
2.	Wilding conifer/geothermal kānuka scrub (04.01.03) A few emergent radiata pines (to 25 metres tall), and kōhūhū are present over geothermal kānuka scrub ranging in height from one to four metres. Occasional karamū and mamaku occur on the margins. A small amount of buddleia and blackberry are present in areas with lower geothermal influence.	Hillslope, gully	<0.1 ha

Indigenous Flora: Geothermal kānuka (Threatened-Nationally Endangered) is present throughout the observed geothermal areas. A small population of *Dicranopteris linearis* (Threatened-Nationally Endangered) was recorded at the site in 2011, but no plants were found in 2023.

Fauna: Common indigenous and introduced species typical of the habitats are present. In 2023 three indigenous avifauna species were recorded: korimako/bellbird, miromiro/North Island tomtit, and tauhou/silvereye. In the 2011 site visit, two introduced species were recorded from the site: European greenfinch and yellowhammer.

Geothermal Ecosystems: Heated ground (dry), hydrothermally altered ground (now cool).

Current Condition: This site comprises geothermal features and vegetation surrounded by pine plantation. This is a change since 2011 when it was surrounded by farmland. While the site is now not grazed by stock, there is the potential for damage to occur during harvesting, however most or all plantation forestry managers are responsible and avoid damage to adjacent natural areas when harvesting.

Threats/Modification/ Vulnerability:

Invasive pest plants: Radiata pine (5-25% cover) is present on the margins of the site with Spanish heath (1-5% cover) scattered throughout. Buddleia (1-5% cover) and blackberry (1-5% cover) are also present.

<i>Human impacts:</i>	Plantation forest (was farmland in 2011).
<i>Grazing:</i>	This site was unfenced and grazed in 2011, but stock no longer have access to the site due to changes to surrounding land use (now surrounded by plantation forest which is not grazed).
<i>Adjoining land use:</i>	Pine plantation.
Site Change:	
<i>Recent change:</i>	The surrounding farmland has been converted to plantation forestry since 2011. This has reduced the grazing impacts of farming at the site, allowing the geothermal vegetation to become denser and taller. This has reduced the area of geothermally influenced bare ground at the site, and the areas mapped as shrubland in 2011 are now scrub.
<i>Historical:</i> ¹	Site not assessed, no historical aerial photos found. Because the site is small and is in a gully it is unlikely that change would be able to be identified at this site through comparing historic and recent aerial photographs.
Management Requirements:	The forestry company should be made aware of the location of the geothermal vegetation and habitats, so these areas can be avoided. In the long-term a small, e.g. 20 metre buffer, should be established between the geothermal vegetation and forestry plantings.
Significance Level:	Local (Criteria 3, 5)
Significance Justification:	Akatarewa East is locally significant because it contains a nationally uncommon habitat type (geothermal).
Notes:	There may be more features and small geothermal areas in the surrounding vegetation at the site, but access is difficult. This site was identified based on a summary of known geothermal features in Hochstein (2007b)². The Hochstein study was based on summaries of geothermal features in the Orākei Kōrako and Te Kopia Geothermal Systems from Lloyd (1974) and Bignall (1994).
References:	Bignall 1994; Hochstein 2007b; Lloyd 1974; Wildland Consultants 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

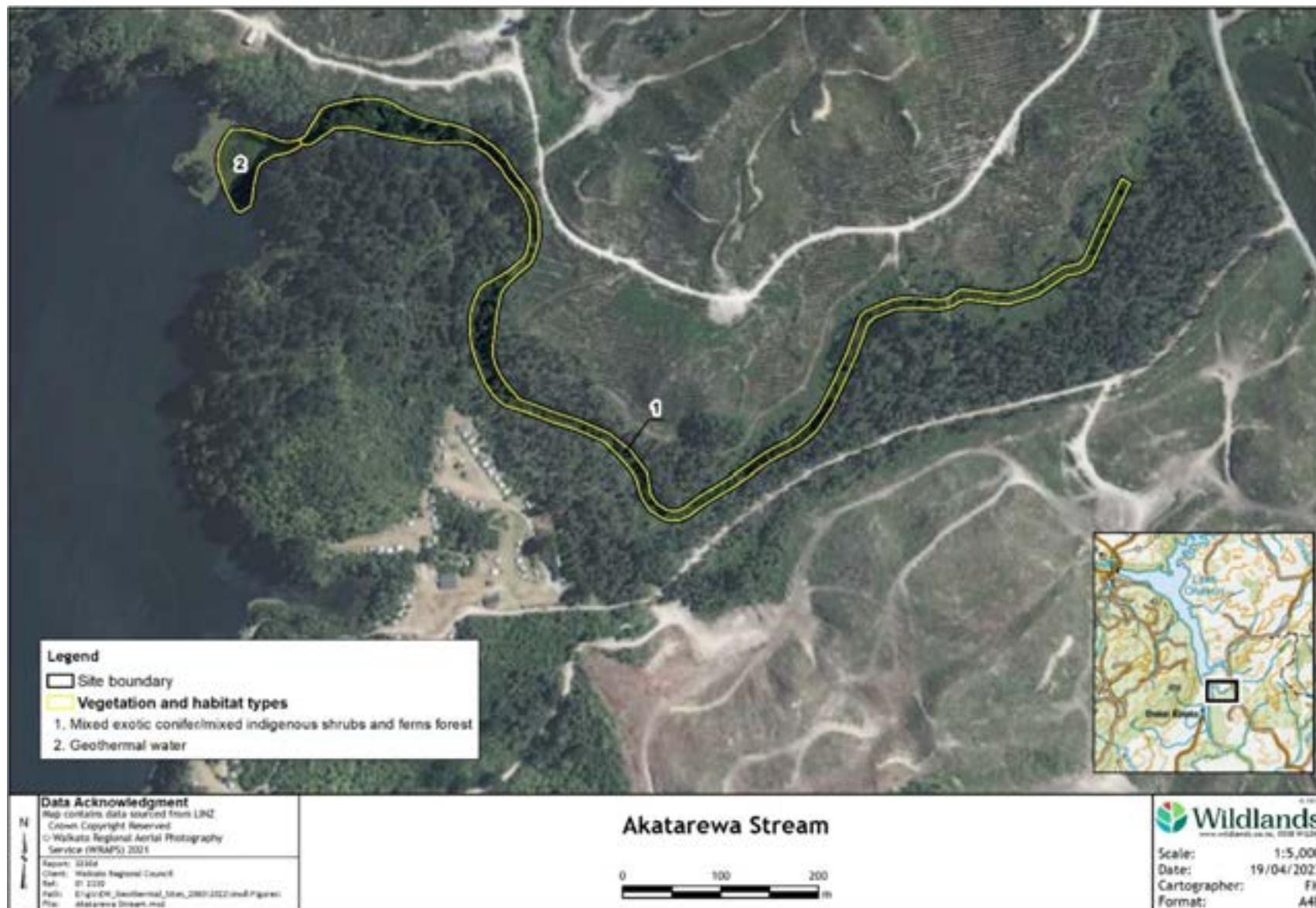
² Figure 4.1, Page 92.



Akatarewa East. A small geothermal patch by a forestry road.
18 January 2023. NZTM E1876057 N5738815



Akatarewa East. Geothermal kauri scrub on hillslope, surrounded by radiata pine plantation and small areas of non-geothermal scrub. A few emergent radiata pine are present. 18 January 2022. NZTM E1876271 N5738822.



AKATAREWA STREAM

Ecological District: Atiamuri **GPS Reference:** NZTM E1875142 N5737819
Geothermal System: Orākei Kōrako **Altitude:** c.300 m
Bioclimatic Zone: Lowland - Submontane **Local Authority:** Rotorua
Extent of Geothermal Habitat: c.2.1 ha
Extent of Geothermal Vegetation: c.1.8 ha
Date of Most Recent Field Survey: 17 November 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic forest (01.02) Mixed exotic conifer/mixed indigenous shrubs and ferns forest (01.02.01) Radiata pine-maritime pine/mixed indigenous broadleaved species and indigenous ferns forest and scrub Planted radiata pine forest, with some maritime pine to 20 metres tall, above a canyon. In places along the stream margins there is a narrow band of indigenous tree and shrub species of abundant mahoe, whauwhaupaku, kōhūhū whekī, whekī-ponga, rangiora, and scattered tī kōuka, buddleia, harakeke, karamū, and whekī. Abundant ferns and shrubs including kiokio, blackberry, bracken, and <i>Cyperus ustulatus</i> occur along the immediate stream margins. Creeping bent, Yorkshire fog, <i>Deparia petersenii</i> , <i>Histiopteris incisa</i> , <i>Paesia scaberula</i> , <i>Hypolepis ambigua</i> , creeping buttercup, pakau, <i>Carex secta</i> , and lotus are also common. There are scattered <i>Christella</i> aff. <i>dentata</i> (“thermal”) plants along the stream and a few <i>Lycopodiella cernua</i> are present. Springs, seepages, and occasional sinter are present along the entire length of the stream in Vegetation Type 1. These were too small to be mapped separately. Water temperatures of up to 63.8 °C were recorded from the stream in 2014. In 2022, access was limited in 2022 due to high water levels and temperature readings could not be obtained.	Riparian margins, canyon sides	c.1.8 ha
2.	Water (22.01) Geothermal water (22.01.01) Geothermal stream flowing into Lake Ōhakuri.	Stream, lake	c.0.3 ha

Indigenous Flora: The stream creates habitats for *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered). Three surveys have been undertaken in this area since 2007: 2007 (47 clumps were recorded), 2014 (six clumps), and 2022 (14 clumps). The latter two surveys did not access as many areas as the 2007 survey, so the population is likely to be stable.

Cyclosorus interruptus (At Risk-Declining) was recorded at this site in 2002 (Hobbs 2002) but was not observed in the 2007, 2014, and 2022 survey despite extensive searching. *C. interruptus* is a seasonal species in the central North Island and is not always visible during all seasons, so this species could still be present at this site.

Dicranopteris linearis (Threatened-Nationally Endangered), was also recorded from this site in 2002 (Hobbs 2002), but was not recorded in the 2007, 2014, or 2022 surveys.

Other species typical of geothermal sites present include *Lycopodiella cernua*, *Histiopteris incisa*, bracken, and *Cyperus ustulatus*.

Fauna: Common indigenous and introduced bird species typical of the habitat were present in 2022, including toutouwai/North Island robin, riroriro/grey warbler, pīwakawaka/North Island fantail, korimako/bellbird, miromiro/North Island tomtit, tūi, and kōtare/sacred kingfisher. Introduced species recorded include common pheasant, California quail, song thrush and European blackbird.

Geothermal Ecosystems: Geothermal streamsides, geothermal wetland.

Current Condition: Much of the site is in a poor to moderate ecological condition with plantation forestry occurring close to stream margins. The site provides good habitat for at least one ‘Threatened’ fern species.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Wilding conifers (50% cover), blackberry (25% cover), pampas (5% cover), buddleia (5% cover), Himalayan honeysuckle (5% cover), grey willow (<1% cover), , Spanish heath (<1% cover), ornamental cherry (<1% cover) and Montpellier broom (<1% cover) are present.

Human impacts: Several bridges and culverts. Bathing pools. Plantation forest harvesting operations nearby.

Grazing: Livestock have no access to the area.

Adjoining land use: Plantation forestry, indigenous vegetation, recreation tracks. The stream flows into Lake Ōhakuri. A camp ground is present near the stream at one point.

Site Change:

Recent change: Other than changes to the pest plant distribution, and fluctuations in fern numbers, no significant change has been observed at this site since 2007.

*Historical:*¹ In 2011, the 2007 aerial photographs were compared with those from 1949². It appears that the lower portion of the stream (in the order of c.50 m) was inundated when Lake Ōhakuri was raised. This is likely to have reduced habitat for fern taxa such as *Christella* aff. *dentata* (“thermal”). An area of raw-soilfield appears to be present in the upper stream catchment in 1949; this area is now in plantation forest. Overall, there was at least a 25% loss of geothermal vegetation and habitats at this site since between 1949 and 2007.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 358 Run 1074 Photos 92-94, 1949.

Management Requirements:

The stream margins are potential ecological restoration sites. Management should include the control of pest plant species (e.g. patches of dense blackberry scrub) and planting of suitable, locally-sourced indigenous species. Establishing a buffer of indigenous vegetation between the stream and plantation forestry would reduce the possibility of harvesting operations impacting on the *Christella* aff. *dentata* (“thermal”) populations.

Significance Level:

National (Criteria 3, 5).

Significance Justification:

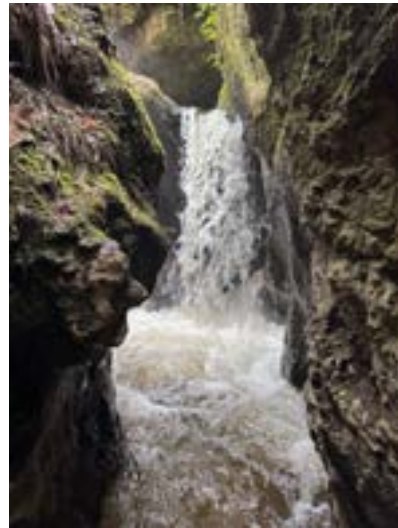
This site is of national significance because it contains an important population of a Threatened taxon *Christella* aff. *dentata* (“thermal”), and is one of the largest populations of this taxon in Aotearoa New Zealand.

References:

Beadel and Bill 2000; Given 1989a, 1995, & 1996; Hobbs 2002; Merrett and Burns 1999; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004c, 2007b, 2012, 2014a.



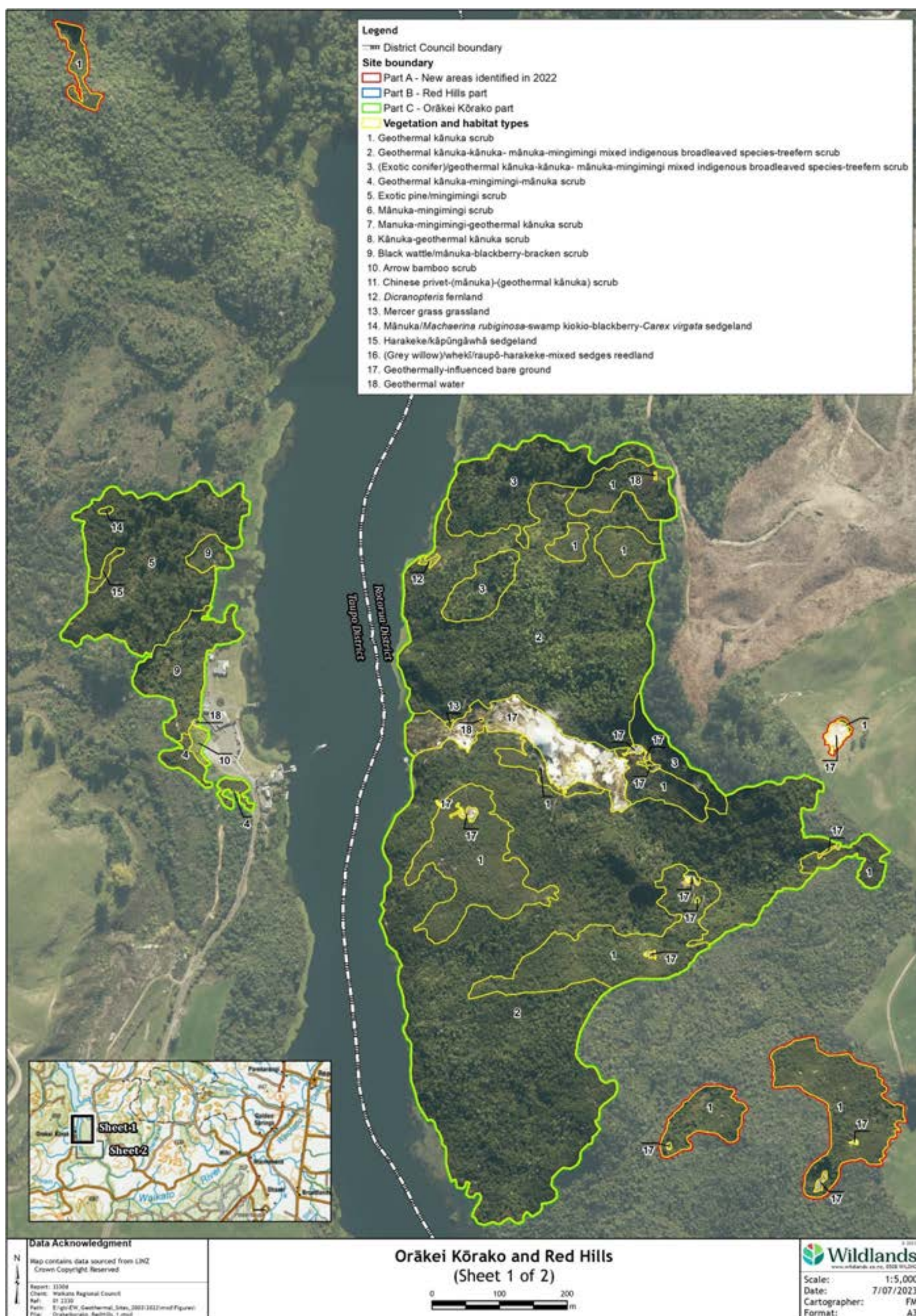
Akatarewa Stream. Most of the stream above the waterfall is gently flowing. NZTM E1874904 N5738017. 17 November 2022.

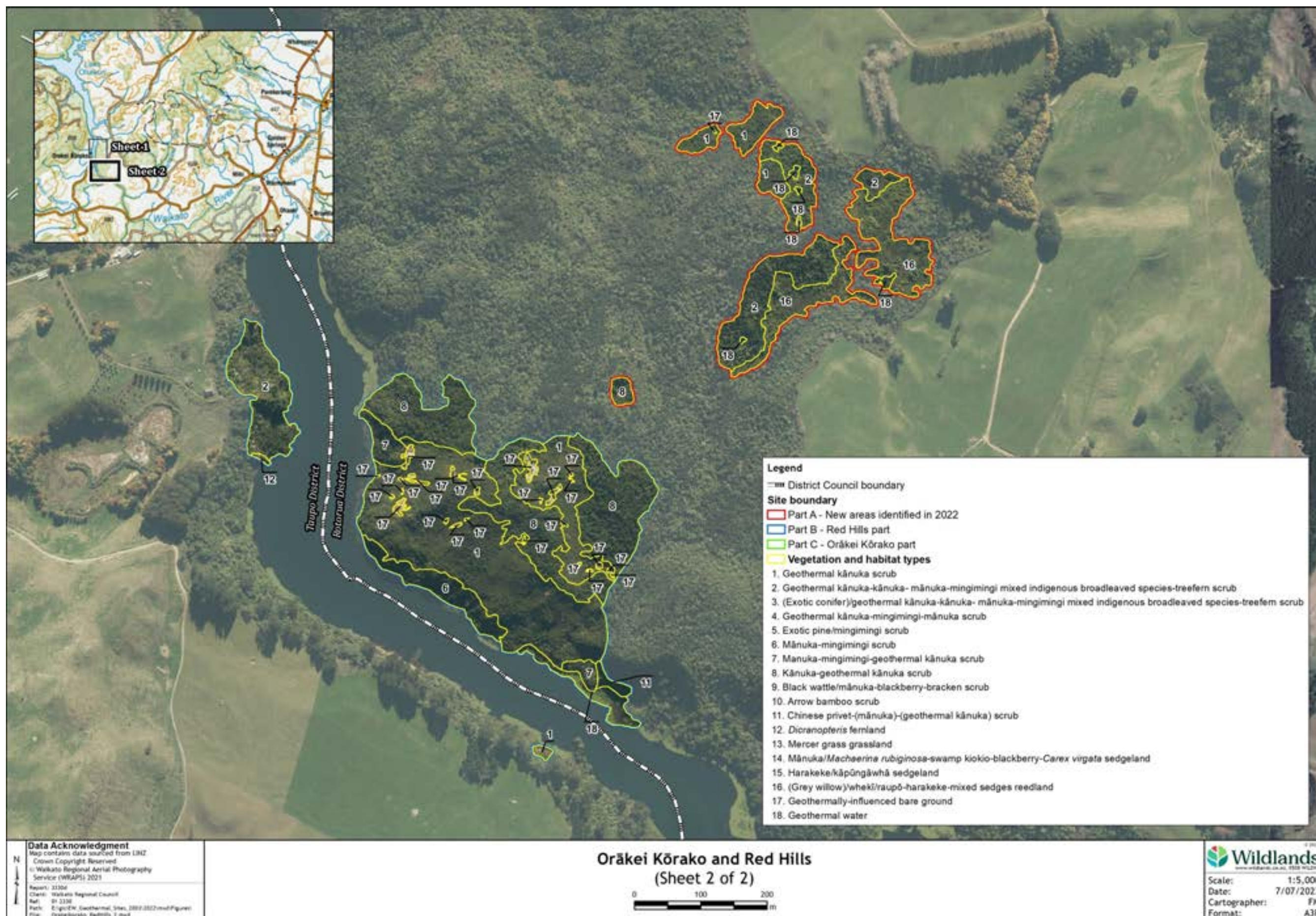


Akatarewa Stream. The geothermal pool below and above a waterfall is used for recreational bathing. NZTM E1874938 N5738136. 17 November 2022.



Akatarewa Stream. The steamy margins provide habitat for *Christella* aff. *dentata* (“thermal”). NZTM E1874937 N5738143. 17 November 2022.





ORĀKEI KŌRAKO AND RED HILLS¹

Ecological District: Atiamuri **GPS Reference:** NZTM E1874726 N5736937
Geothermal System: Orākei Kōrako **Altitude:** c.295-380 m
Bioclimatic Zone: Submontane – Lowland **Local Authority:** Rotorua
Extent of Geothermal Habitat: c.71.0 ha
Extent of Geothermal Vegetation: c.70.5 ha
Date of Most Recent Field Survey: 15, 17 November and 7 December 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka (0.3-3 m high) forms a dense canopy with mingimingi and mānuka scattered throughout. Prickly mingimingi, monoao, and karamū are also present with local patches of kāmahī and local infestations of wilding conifers. The groundcover comprises <i>Campylopus</i>, <i>Dicranoloma</i>, <i>Racomitrium</i>, <i>Leucobryum javense</i>, and <i>Sphagnum</i> mossfield, areas of fernland with <i>Gleichenia microphylla</i>, <i>Histiopteris incisa</i>, and bracken, and local <i>Lycopodiella cernua</i>, and <i>Dicranopteris linearis</i>. Exotic grasses such as Mercer grass, Indian doab, and narrow-leaved carpet grass, are scattered throughout along with tūrutu. <i>Trentepohlia</i>, an alga, is common on geothermal kānuka branches. Wilding pine control has recently been carried out in most of this area and some felled pine trees were observed. Fumaroles are scattered throughout, with occasional geysers, mudpools and hot springs. Also within this type is a steep-sided gully with a small geothermal stream near the far south of the Red Hills part. Vegetation along the stream margins includes occasional Chinese privet and whekī with scattered kiokio and occasional <i>Coprosma lucida</i> and <i>Austroderia fulvida</i>. <i>Cyperus ustulatus</i> is present around steam vents near the stream. <i>Christella</i> aff. <i>dentata</i> (“thermal”) is scattered along stream margins in the steamy habitat. Surface water temperatures within the stream of up to c.50 °C were recorded in 2014 (too small to map separately). In the Red Hills part, a small wetland is present in the base of a gully comprises a muddy geothermal pond surrounded by mingimingi with islands of geothermal kānuka in the pond. <i>Histiopteris incisa</i> is abundant on the margins with occasional patches of <i>Gleichenia microphylla</i> and <i>Hypolepis ambigua</i>. A patch of Vasey grass is present. Other small wetlands may be present within gullies within this type.	Hillslope, gully, crater	c.18.4 ha

¹ The Orākei Kōrako and Red Hills sites have been merged in this report.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
2.	Geothermal kānuka-kānuka-mānuka-mingimingi-mixed indigenous broadleaved species-treefern scrub (04.01.12). Mostly occurs on very steep hill country above Lake Ōhakuri with a canopy height ranging from 3 to 20 metres, with some areas approaching forest, while other areas are shorter shrubland. There are also a few small areas on the eastern side of Lake Ōhakuri. Extensive areas of geothermal kānuka and mānuka are present. Mānuka and mingimingi are present with scattered indigenous broadleaved species (e.g. karamū, kōhūhū, rewarewa, whauwhaupaku and kāmahī), treeferns (e.g. whekī, whekī-ponga, ponga and mamaku) and occasional rimu. Local patches of fernland (<i>Gleichenia microphylla</i>, bracken, <i>Paesia scaberula</i>, <i>Histiopteris incisa</i>, <i>Dicranopteris linearis</i> and kiokio) are present. There are scattered emergent wilding conifers. Pampas is often abundant in areas with open canopy and less geothermal influence. A few patches of Japanese honeysuckle are present near the boardwalk at the Orākei Kōrako tourist site, and in disturbed areas there is scattered Spanish heath. <i>Morelotia affinis</i>, kiokio, and tūrutu are common in the understorey. The groundcover comprises <i>Campylopus</i>, <i>Dicranoloma</i>, <i>Racomitrium</i>, <i>Leucobryum javense</i>, and <i>Sphagnum</i> mossfield, areas of fernland with <i>Gleichenia microphylla</i>, <i>Histiopteris incisa</i>, and bracken, and local <i>Lycopodiella cernua</i>, and <i>Dicranopteris linearis</i>. Exotic grasses such as Mercer grass, Indian doab, and narrow-leaved carpet grass are scattered throughout, with occasional tūrutu. Fumaroles are scattered throughout, and there are seepages adjacent to Lake Ōhākūri. Scattered populations of <i>Christella</i> aff. <i>dentata</i> (“thermal”) occur on banks near springs and heated streams near lake margins. Large areas of <i>Dicranopteris linearis</i> are present above the lake edge. At least one pohutukawa is present on the lake edge near the tourist boat jetty on the east side of the river.	Hillslope, gully	c.32.4 ha
3.	(Exotic conifer)/geothermal kānuka-kānuka-mānuka-mingimingi-mixed indigenous broadleaved species-treefern scrub (04.01.13) Similar to Type 04.01.12, but emergent wilding conifers (mostly maritime pine and radiata pine) to 30 metres tall are more common in Type 04.01.13.	Hillslope, gully	c.3.4 ha
4.	Geothermal kānuka-mingimingi scrub (04.02) Geothermal kānuka-mingimingi-mānuka scrub (04.02.02) There are small areas of heated soils (up to 30 °C in 2011) with geothermal kānuka, mingimingi, and mānuka scrub near the road. Other species present include bracken, maritime pine, broad-leaved fleabane, Japanese honeysuckle, silver birch, and Spanish heath.	Hillslope	c.0.3 ha
5.	Mingimingi-dominant scrub (04.03) Exotic pine/mingimingi scrub (04.03.03) Emergent radiata pine and maritime pine up to c.8 m tall are scattered to locally common over mingimingi and mānuka with occasional mamaku and māpou. Frequent boiling mud pools and fumaroles occur within depressions in this area. <i>Histiopteris incisa</i>, tūrutu, and occasional geothermal kānuka and blackberry are present on the margins of the mud pools.	Hillslope	c.4.2 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	Patches of geothermal kānuka and mānuka scrub are present within this type but are too small to map out separately. There are frequent fumaroles. In these areas, geothermal kānuka and mānuka form a moderately dense canopy up to c.4 m tall over a ground cover dominated by mosses, principally <i>Chiloschyphus semiteres</i> and <i>Dicranoloma billarderei</i> , with local patches of <i>Leucobryum javense</i> . Ferns (e.g. <i>Hypolepis ambigua</i> , <i>Asplenium flaccidum</i> , <i>A. polyodon</i> , kōwaowao/hound's tongue fern and <i>Dicranopteris linearis</i>) are present. Indigenous broadleaved species are scattered throughout. <i>Trentepohlia</i> , an alga, is abundant on branches of woody shrubs, particularly geothermal kānuka.		
6.	Mānuka-dominant scrub (04.04) Mānuka-mingimīngi scrub (04.04.02) Mānuka and mingimīngi form a dense scrub cover in the western part of this site, with scattered kānuka and geothermal kānuka, and occasional karamū and kōhūhū. The groundcover comprises <i>Gleichenia microphylla</i>, bracken, <i>Paesia scaberula</i>, <i>Histiopteris incisa</i>, kiokio, and tūrutu with large local patches of <i>Dicranopteris linearis</i>, and abundant <i>Dicranoloma</i> species. Fumaroles are scattered throughout and there are a number of seepages that flow directly into Lake Ōhākūri. Occasional emergent wilding pines (maritime pine and radiata pine) are present throughout, although most of the pines that were present in 2007 have been controlled and are dead or dying. Occasional Spanish heath and Chinese privet plants are present on the margins.	Hillslope, gully	c.0.7 ha
7.	Mānuka-mingimīngi-geothermal kānuka scrub (04.04.06) Occasional emergent maritime pines are present over scrub dominated by mānuka and geothermal kānuka with local patches of mingimīngi, local tōtara and indigenous broadleaved species such as karamū, kōhūhū, rewarewa, and whauwhaupaku. There are extensive patches of <i>Dicranopteris linearis</i>. This vegetation type occurs around a small example of sinter terrace, a geyser, and an outflow of hot water into the lake. A slip exposing bright red substrate is also present. Occasional <i>Christella</i> aff. <i>dentata</i> ("thermal") are present on the lake margins. Most wilding pines have been controlled since 2014.	Hillslope, gully	c.0.4 ha
8.	Kānuka scrub (04.06) Kānuka-geothermal kānuka scrub (04.06.01) Kānuka forms a canopy with geothermal kānuka up to c.6 m high over a shrub tier dominated by mingimīngi and prickly mingimīngi. Local indigenous broadleaved species such as karamū, kōhūhū, rewarewa, whauwhaupaku, and whekī-ponga are present. Groundcover within this area includes whekī-ponga and tūrutu, with local patches of <i>Dicranopteris linearis</i> and <i>Gleichenia microphylla</i>, and locally common <i>Chiloschyphus semiteres</i> (a moss).	Hillslope	c.4.3 ha
9.	Mixed exotic and indigenous species scrub (04.09) Black wattle/mānuka-blackberry-bracken scrub (04.09.04). Emergent black wattle and maritime pine occur over mānuka, blackberry, bracken and Japanese honeysuckle with small patches of raupō, mingimīngi, and geothermal kānuka (up to c.3 m tall). Blackberry occurs in large swathes and in places is the dominant	Wetland, gently sloping.	c.1.6 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	canopy cover. <i>Lycopodiella cernua</i> , <i>Paesia scaberula</i> , swamp millet, <i>Machaerina rubiginosa</i> , karamū, whekī, tūrutu, <i>Gleichenia microphylla</i> , greater bindweed, <i>Cyperus ustulatus</i> , buddleia, Mercer grass, and <i>Hypolepis</i> sp. are common. Large clumps of <i>Christella</i> aff. <i>dentata</i> (“thermal”) (with a total population of c.40 plants), <i>Cyclosorus interruptus</i> (c.50 plants), and <i>Dicranopteris linearis</i> are present. Mud pools occur throughout this type.		
10.	Exotic species-dominant scrub (04.10) Arrow bamboo scrub (04.10.06) An area of arrow bamboo with occasional maritime pine, black wattle, cotoneaster, and Japanese honeysuckle is present near the visitor carpark. The extent of this vegetation type has increased since 2010.	Hillslope	c.0.1 ha
11.	Chinese privet-(mānuka)-(geothermal kānuka) scrub (04.10.07) Chinese privet forms a canopy to c.2 m height with scattered mānuka and geothermal kānuka.	Hillslope, lake margin	c.0.1 ha
12.	Indigenous fernland (07.01) Dicranopteris fernland (07.01.01) Orākei Kōrako part: Small areas dominated by <i>Dicranopteris linearis</i> occur locally, often scattered amongst geothermal kānuka scrub and shrubland. Many of these areas were too small to identify on the aerial photograph and are not mapped separately (they are included in other geothermal vegetation types). Red Hills part: A small south-facing area on the western bank of the lake with a steaming fumarole. <i>Dicranopteris linearis</i> forms the main cover in this area. There are many small areas of <i>Dicranopteris</i> fernland within 04.04.02 which were almost completely dominated by <i>D. linearis</i> , but were too small to be mapped separately.	Hillslope	<0.1 ha
13.	Exotic grassland (08.01) Mercer grass grassland (08.01.03) A few small areas of grassland dominated by Mercer grass with local <i>Gleichenia microphylla</i> , <i>Histiopteris incisa</i> , <i>Paesia scaberula</i> and bracken. <i>Cyperus ustulatus</i> and <i>Machaerina juncea</i> occur around a small thermal seepage.	Sinter terrace	<0.1 ha
14.	Indigenous sedgeland (09.01) Mānuka/Machaerina rubiginosa-swamp kiokio-blackberry-Carex virgata sedgeland (09.01.03). A small patch of geothermally influenced wetland dominated by <i>Machaerina rubiginosa</i> is present on the western side of the farm track that bisects the site. Mānuka is scattered to common over sedgeland dominated by <i>M. rubiginosa</i> with locally common swamp kiokio, blackberry, and <i>Carex virgata</i> . Scattered emergent maritime pine and kōhūhū are also present.	Wetland, flat	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
15.	Harakeke/kāpūngāwhā sedgeland (09.01.08) A small patch of geothermally influenced wetland dominated by kāpūngāwhā occurs beside the farm track that bisects the northwestern part of this site. Harakeke is common with local patches of raupō. A geothermally influenced stream flows through this area. Other species present include swamp millet, lotus, swamp kiokio, and Japanese honeysuckle. This wetland is surrounded by exotic shrub species (including Spanish heath and blackberry) and bracken, which then grade into geothermal kānuka-mānuka scrub.	Wetland, flat	c.1.0 ha
16.	11.01 Reedland 11.01.07 (Grey willow)/whēkī/raupō-harakeke-mixed sedges reedland A wetland with geothermal influence, that had not been surveyed previously. The wetland vegetation is a mosaic of harakeke, raupō, mixed sedges and rushes such as <i>Carex secta</i>, and <i>Machaerina rubiginosa</i> and scattered tī kōuka. There are scattered areas dominated by whēkī, whēkī-ponga, mānuka, geothermal kānuka, and <i>Carex geminata</i> throughout the wetland, but because of the difficulty of safe access it was not possible to map these separately. The majority of the woody species are less than three metres tall. Kōhūhū, māhoe, whauwhaupaku, karamū and kānuka are often present on the margins of the wetland. In the southeast, there is frequent emergent grey willow to 15 metres tall. <i>Carex secta</i> is present in the north of the wetland. One part visited during the field inspection has a very active area of mud pools. The mudpools are surrounded by whēkī, whauwhaupaku, māhoe, with local blackberry, <i>Paesia scaberula</i> and an area of exotic grassland with abundant Yorkshire fog, paspalum, and <i>Histioglossis incisa</i>. There was significant pig damage on the edge of the wetland.	Wetland	c.2.0 ha
17.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Geothermally heated ground, in the form of a large sinter terrace at the main tourist site on the eastern side of the river. The sinter terrace comprises a range of scattered vegetation such as small areas of woody plants (e.g. geothermal kānuka and mānuka, and mingimingi), as well as local sea rush, oioi, and mossfield, Mercer grass and Indian doab. Other areas of sinter and geothermally heated bare ground, fumaroles, and mud pools are found scattered throughout the site.	Hillslope sinter terrace, flat, gully	c.2.4 ha
18.	Water (22.01) Geothermal water (22.01.01) Hot pools, cooler pools with some geothermal influence, geothermal springs, geysers, geothermal streams, and mud pools.	Open water, sinter terrace	c.0.5 ha

Indigenous Flora:

Extensive areas of geothermal kānuka (Threatened-Nationally Endangered) are present throughout the site. It is one of the largest areas of this type in Aotearoa/New Zealand.

The site supports probably the largest population of *Dicranopteris linearis* (Threatened-Nationally Endangered) in the North Island.

At least 50 plants of *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) are located on the eastern margins of Lake Ōhākūri. There are also good populations of *Christella* aff. *dentata* (“thermal”) alongside the lake edge and stream margins in the Red Hills part of the site. This site supports what is likely to be the third largest population of this species in Aotearoa/New Zealand. At least another 40 plants are located in the wetland behind the Orākei Kōrako tourist car park on the western side of the lake.

At least one pōhutukawa tree (Threatened-Nationally Vulnerable) is present on the lake edge near the sinter terrace at Orākei Kōrako.

A small population of *Cyclosorus interruptus* (At Risk-Declining) is located in a wetland near the Orākei Kōrako tourist car park on the western side of Lake Ōhākūri.

Lycopodiella cernua, sea rush, tūrutu, and *Campylopus* species, which are characteristic of geothermal areas, are also present.

Nephrolepis flexuosa (At Risk-Naturally Uncommon) *Schizaea dichotoma* (At Risk-Naturally Uncommon), *Calochilus robertsonii* (At Risk-Naturally Uncommon), *Psilotum nudum*, *Schizaea bifida*, and *Corunastylis pumila*¹ (At Risk-Naturally Uncommon) have been recorded from this site in previous surveys but were not observed in 2004, 2011, 2014, or 2022.

The site also contains interesting inland populations of arrow grass, oioi and sea rush.

Other species of interest that occur at Orākei Kōrako include *Microtis parviflora*, *Thelymitra carnea* (Bellingham 1985), *Thelymitra colensoi* (Data Deficient), *Thelymitra longifolia* (Ceroyd, 1985), *Thelymitra pauciflora*, *Limosella lineata*, and *Drosera binata* (Wildland Consultants 2009a).

Fauna:

Common indigenous and introduced bird species typical of the habitat are present, including māpunga/black shag (At Risk-Relict), kawaupaka/little shag (At Risk-Relict), kawau tūi/little black shag (At Risk-Naturally Uncommon), pāpango/New Zealand scaup, pārerā/grey duck (Threatened-Nationally Vulnerable²), tētē-moroiti/grey teal, kāhu/swamp harrier, karearea/New Zealand ‘bush’ falcon (Threatened-Nationally Increasing), pūkeko, spur-winged plover, karoro/southern black-backed gull, tarāpunga/red-billed gull (At Risk-Declining), kōtare/sacred kingfisher, pīpīwharau/shining cuckoo, warou/welcome swallow, pōpokotea/whitehead, toutouwai/North Island robin (At Risk-Declining), tūi, korimako/bellbird, riroriro/grey warbler, tauhou/silvereye, and pīwakawaka/fantail. The wetlands on the site are also likely to support a population of pūweto/spotless crane (At Risk-Declining) and forest habitats are likely to support koekoeā/long-tailed cuckoo (Threatened-Nationally Vulnerable) although they have not been observed in surveys to date.

¹ Formerly *Genoplesium pumilum*.

² Most of the New Zealand grey duck population is believed to be extensively hybridised with the introduced mallards to such an extent that few pure grey ducks may now exist (Williams, M.J. 2013 [updated 2022]. Grey duck | pārerā. In Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz: accessed: 29 March 2023.

Introduced species include mallard, turkey, California quail, common pheasant, Eastern rosella, dunnoek, Eurasian blackbird, song thrush, yellowhammer, European goldfinch, European greenfinch, redpoll, chaffinch, house sparrow, and Australian magpie.

Bird observations also include birds in open water habitats adjacent to the site between 2012 and 2019 (Wildland Consultant 2020d).

Vespula wasps were recorded from the western wetland in 2010.

A small population of long-tailed pekapeka/bats (Threatened-Nationally Critical) have been recorded in Ruatapu thermal cave (<http://related.springerprotocols.com/lp/de-gruyter/observations-of-a-cave-colony-of-the-long-tailed-bat-chalinolobus-sjZl2WehC4>; accessed 12 September 2011). Long-tailed bats have also been recorded from Tutukau Forest, adjacent to the northwestern part of this site. Long-tailed bats have been recorded at Orākei Kōrako since 1948 (W.J. Phillipps, Dominion Museum file): Dwyer (1962).

Pig and possum sign (scat) were observed within the site. Pigs were regularly seen during the field survey. Deer are also likely to utilise this site. Pig damage was particularly evident near farmland margins on the eastern side of the site in November 2022.

**Geothermal
Ecosystems:**

Heated ground (dry), geothermal streamsides, geothermal wetlands, fumaroles, hydrothermally-altered ground (now cool).

Current Condition:

Orākei Kōrako part:

Overall, most of the site is in excellent ecological condition. Removal of wilding pines since 2008/2009 improved the quality of the geothermal vegetation on the western side of this site markedly, with most tree stumps not visible to the naked eye from the car park on the eastern side in 2011. However, pampas has become established in places following pine control. Some pampas control has been undertaken within the site since 2011. There remains some small areas of wilding pines on the site that require control.

Invasive pest plant species are common within vegetation in the northwestern part of the site, and local patches of adventive weed species are present on the western side of the river. Control of maritime pine, radiata pine, black wattle, blackberry, Japanese honeysuckle, and arrow bamboo should be undertaken.

Red Hills part:

Generally the site is in excellent condition with large areas of indigenous geothermal vegetation with no pest plants present. Ongoing control of wilding radiata pines is needed to control reinvasion. Blackberry is often abundant on margins. Scattered grey willow occurs in a wetland in the southeast. Chinese privet is a threat in the southern part of the site. A few pampas and Montpellier broom are present.

Threats/Modification/ Vulnerability:

Invasive pest plants:

Orākei Kōrako part:

Wilding pines (maritime pine and radiata pine) have been removed from large parts of the site but are still present at c.1-5% cover in the main extent of the site and up to 10% cover in the northwestern part of this site. Other invasive pest plant species present include grey willow (<1% cover), Spanish heath (<1% cover), blackberry (1-5% cover), black wattle (<1% cover), broom (<1% cover), Montpellier broom (<1% cover), buddleia (<1% cover), Himalayan honeysuckle (<1% cover), Japanese honeysuckle (<1% cover), arrow bamboo (<1% cover), and narrow-leaved carpet grass (1% cover). The Mercer grass should be controlled on the sinter terrace in the main tourist part of the site. A few male fern have established on the eastern margins of the site. Pampas has increased in cover since wilding pine control was undertaken and is now present at 1-5% cover. The patch of arrow bamboo on the western side of the river near the Orākei Kōrako Geothermal Park and Cave carpark should be controlled. Since 2010 the infestation has invaded surrounding geothermal vegetation and has increased in extent. Grey willow is mainly confined to the western side of Lake Ōhākūri, although a small area is present in the geothermal wetland (described for the first time in 2022) to the northeast of Red Hills (see Type 11 on site map).

Waikato Regional Council undertook pampas control within this site in 2011 and 2014; further pampas control is still required. Two plants of royal fern were found at Orākei Kōrako on 11 March 2009 (Wildland Consultants 2009a), and these were removed. Royal fern was not seen in 2022.

Red Hills part:

Scattered wilding pines are present, although are now mostly seedlings as large trees have been controlled. Chinese privet (1% cover) is present at the camp/picnic area adjacent to the southern side of the site, and is continuing to invade the mānuka-mingimingi scrub. It could spread rapidly into geothermal habitats if it is not controlled. Other pest plant species present include Spanish heath (<1%), buddleia (<1%), and Himalayan honeysuckle (<1%). Wilding pines and pampas have been controlled within this site by Ngati Tahu-Ngati Whaoa and Waikato Regional Council respectively.

Human impacts:

Orākei Kōrako part:

This area is managed as a tourist facility and the geothermal features of the area are valued, with well-maintained tracks and viewing sites keeping further human impacts to a minimum. Most vegetation away from the tourist area is rarely visited.

Farm tracks are present within the northwestern part of this site.

Red Hills part:

Direct human impact is low, as the site is relatively inaccessible. A bath has been put into a geothermal stream near the south end of the site, and some litter is present in this area. Some wilding pine control has been undertaken

at the site. The vegetation at this site is very susceptible to damage by trampling.

Grazing:

The northeastern part of the site is farmed and geothermal features and vegetation are not currently fenced to exclude stock. Stock sign was present within some areas of geothermal vegetation. Some fencing also needs to be maintained on the eastern side of the site, although in most cases the stock have not roamed far from the site margins.

The main part of the site is not farmed and domestic stock do not have access to this area.

Adjoining land use:

Plantation forest, indigenous forest, Lake Ōhākūri (on the Waikato River), accommodation facilities, tourism, and farmland.

Site Change:

Recent change:

Orākei Kōrako part:

An additional area has been added to this site, north of the previously mapped area on the western side of Lake Ōhākūri. The addition of this area is not the result of new geothermal manifestations but is the result of new information since the previous survey of the site.

The boundaries of the site have been updated following wilding pine control, and better quality aerial photographs. The most significant real change to the site is the removal of pine trees on the eastern side of Lake Ōhākūri which has greatly improved the ecological condition of the site. This has resulted in some considerable updates to vegetation descriptions.

Red Hills part:

Some control of wilding pines and other pest plants has been undertaken at this site in the last ten years. No other changes to the extent and quality of geothermal activity are known to have occurred at this site. Any changes made to site boundaries are based on higher quality aerial photographs and field work, rather than any real change to geothermal extent.

*Historical:*¹

Orākei Kōrako part:

In 1961 the Waikato River was artificially dammed to form Lake Ōhākūri and c.75% of the geothermal features were destroyed by flooding (Lloyd 1972).

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

Comparison of 1949¹ and 2007 aerial photographs indicates a considerable reduction in the extent of geothermal vegetation and habitats at this site, particularly on the western side of Lake Ōhākūri. Extensive areas of raw-soilfield were evident in 1949. A large proportion of these areas of bare ground were presumably geothermal, however bare ground is virtually non-existent in 2007 aerial photographs. The advance of wilding pines into some areas on the eastern side of the river is evident in 1941 photographs. Large areas of indigenous vegetation on the western side of Lake Ōhākūri have been converted to farmland since 1941.

Considerable loss of geothermal habitat with the construction of Lake Ōhākūri is evident. Due to the steep nature of the landforms present an accurate measure of loss is impossible, however the previous estimates of 75% loss by Lloyd (1972) seems accurate. When assessing the areas not flooded in 1961, there was more bare ground present in the 1949 photographs in these areas than there was in 2007. Increased vegetation cover could be due to a number of factors including reduced heat from geothermal systems. Changes to the site since the 1949 photos also include a tourist operation and associated tracks.

Red Hills part:

The extent of geothermal vegetation and habitats within the site were considerably reduced in size since dam construction on the Waikato River in 1961 resulted in the formation of Lake Ōhākūri. An assessment of aerial photographs taken in 1949² showed significantly more bare soil on both sides of the Waikato River. The lower reaches of these were drowned when the river was dammed. The steep nature of bank margins means that the overall loss of geothermal habitat is difficult to determine, however it could be as high as 10-20%.

Management Requirements:

Orākei Kōrako part:

Ongoing wilding pine and black wattle control work on the western side of the site will further enhance biodiversity values. Blackberry, Japanese honeysuckle, and arrow bamboo control at the site would allow geothermal species such as geothermal kānuka, mingimingi, *Cyclosorus interruptus*, and *Christella* aff. *dentata* (“thermal”) populations to expand their range. On the eastern side of the river, further pampas control should be undertaken along with follow-up monitoring and control as necessary. Follow-up control of pines should also be undertaken on a regular basis. The site should be regularly checked for new pest plant species invasions, and when small populations of invasive pest plants such as royal fern are found, they should be promptly controlled.

Geothermal vegetation and features in the northwestern part of the site should be fenced to exclude domestic stock.

¹ Historical photos: SN 358 Run 1074 Photos 92-94, 1949.

² Historical photographs: SN 358 Run 1074 Photos 92-94, 1949.

Red Hills part:

Wilding pine control has been undertaken by Ngati Tahu-Ngati Whaoa. Pampas control has also been undertaken and regular follow-up monitoring and control of this species is advisable. Chinese privet should also be controlled.

Significance Level: National (Criteria 3, 5, 6, 7, 9, 10).

**Significance
Justification:**

This site is of national significance because it contains one of the best quality areas of geothermal vegetation in the Waikato Region. The site includes populations of Threatened and At Risk taxa including *Christella* aff. *dentata* (“thermal”), and one of the largest populations of *Dicranopteris linearis* in New Zealand. It supports a relatively high number of other notable geothermal plant species including sea rush and *Lycopodiella cernua*, and has a high diversity of geothermal features including steamfields, mud pools, fumaroles, geysers, hot springs, and sinter terraces.

Notes:

The 2022 field survey of the Orākei Kōrako and Red Hills areas found considerable previously unmapped areas of geothermal vegetation and habitats between the two sites, making it difficult to determine where the boundary should be between the two sites as mapped in Wildland Consultants (2014a). Because there are likely to be more features that are still unmapped in this area, the two sites have been mapped and described together in this report. The original areas mapped as Orākei Kōrako and Red Hills are shown on the site map. Some of the northwestern most areas of the site were not field checked, but were mapped based on assessment of aerial photographs.

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study the Orākei Kōrako part of the site was classed as Category A - the highest category.

A geophysical assessment of a selection of surface geothermal manifestations within the main part of this site is presented in Appendix 4.

Brodnax (2022) recorded mice, rats and possums at this site.

Macroinvertebrate taxa found in geothermally influenced streams here were in general typical of those recorded in non-geothermal streams, but which can tolerate high temperatures or unusual pH (Duggan and Boothroyd 2002).

References:

Beadel 1995b; Beadel and Bill 2000; Brodnax 2022; Duggan and Boothroyd 2002; Ecroyd 1986; Given 1986, 1989a & 1995; Spring-Rice 1996; Wildland Consultants 2004c, 2007b, 2009a&b, 2012, 2013b, 2014a, 2020d.



Overview of the main geothermal sinter terrace at Orākei Kōrako. The geothermal vegetation extends into the western side of Lake Ōhākūri in the background.
NZTM E1874768 N5736787.
7 December 2022.



The sinter terrace at Orākei Kōrako, the major tourist attraction at this site.
NZTM E1874429 N5736979.
15 November 2022.



Geothermal kānuka scrub on the western side of Lake Ōhākūri, opposite the Red Hills area. Note the scattered wilding pines.
NZTM E1874514 N5735839.
15 November 2022.



A geothermal wetland with small areas of harakeke flaxland, raupō reedland, whekī treefernland, mānuka-geothermal kānuka scrub, and grey willow forest.
NZTM N1875390 E5735687.
17 November 2022.



A view of the Red Hills part of Orākei Kōrako from farmland to the east of the site. This shows taller geothermal kānuka and kānuka on the upper hill slopes. NZTM E1875390 N5735687. 17 November 2022.



A geothermal stream at the Red Hills part of the Orākei Kōrako site is used for bathing. Scattered plants of *Christella* aff. *dentata* ("thermal") are present alongside stream margins. NZTM E1874916 N5735246. 15 November 2022.



WAIHUNUHUNU

Ecological District: Atiamuri **GPS Reference:** NZTM E1875248 N5738978
Geothermal System: Orākei Kōrako **Altitude:** 310 m
Bioclimatic Zone: Lowland - Submontane **Local Authority:** Rotorua
Extent of Geothermal Habitat: c.5.9 ha
Extent of Geothermal Vegetation: c.2.3 ha
Date of Most Recent Field Survey: 15 November 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic forest (01.02) Grey willow forest (01.02.03) Grey willow forest to c.10 metres tall. Grey willow have increased in cover markedly in this area since 2014. Abundant raupō is present in open areas and margins. A walk-through inspection was not made through this type in 2022.	Wetland	c.0.4 ha
2.	Mixed indigenous broadleaved species forest (01.04) Mixed indigenous broadleaved species forest (01.04.01) Steamy habitats present alongside a geothermal stream and lake margins. The canopy is a mixture of indigenous broadleaved species including kōhūhū, karamū, whauwhaupaku, māhoe and hangehange. Scattered treeferns are present with whekī the most abundant species, but some mamaku and whekī-ponga are present. The canopy height ranges from 3 to 15 metres. The lower tiers have abundant mingimingi. The immediate stream margins often have an abundant cover of the ferns, <i>Christella</i> aff. <i>dentata</i> (“thermal”) and <i>Nephrolepis flexuosa</i> . Blackberry, bracken and kiokio are locally common. Although access to the stream is very difficult due to the steep sides and very hot stream temperatures, the stream was viewed at several points along its length.	Stream gully	<0.1 ha
3.	Indigenous fernland (07.01) Bracken-mingimingi-blackberry fernland (07.01.02) Scattered emergent karamū, kōhūhū, mamaku, and whekī are present over bracken, mingimingi, and blackberry. On lake margins, patches of <i>Machaerina articulata</i> , <i>M. rubiginosa</i> , kāpūngāwhā, swamp kiokio, <i>Christella</i> aff. <i>dentata</i> (“thermal”), <i>Carex virgata</i> , and kiokio are common. A geothermal stream flows through this vegetation type.	Steep banks on lake margins, wetland	<0.1 ha
4.	<i>Christella</i> aff. <i>dentata</i> (“thermal”)-<i>Nephrolepis flexuosa</i>-blackberry fernland (07.01.09) This type is located on the banks above Lake Ōhakuri where hot geothermal water from a geothermal stream discharges into the lake. Here, patches of <i>Nephrolepis flexuosa</i> and bracken are common. <i>Christella</i> aff. <i>dentata</i> (“thermal”), blackberry, and mingimingi are also common, with scattered <i>Dicranopteris linearis</i> , Spanish heath, whekī, karamū, kōhūhū, and swamp kiokio.	Steep banks on lake margins	<0.1 ha
5.	Reedland (11.01) Raupō reedland (11.01.01) Raupō reedland is dominant with patches of <i>Carex virgata</i> and <i>Carex secta</i> common, and occasional grey willow, marsh bedstraw (<i>Galium palustre</i>), <i>Centella uniflora</i> , <i>Carex maorica</i> , lotus, <i>Eleocharis acuta</i> , whekī, swamp kiokio, <i>Juncus edgariae</i> , and <i>Machaerina articulata</i> .	Wetland	c.0.3 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
6.	(Tī kōuka)-(mānuka)/raupō-Cyperus ustulatus-kāpūngāwhā reedland (11.01.04) Scattered emergent tī kōuka and local patches of mānuka are present over raupō reedland. In places, <i>Cyperus ustulatus</i>, kāpūngāwhā, and <i>Eleocharis acuta</i> replace raupō as the dominant species. Small areas of bare soil are also present around hot springs. <i>Carex virgata</i>, whekī, swamp kiokio, and <i>Machaerina articulata</i> are locally common. Small areas of less wet habitats contain abundant exotic grasses with mercer grass in association with <i>Cyclosorus interruptus</i> and <i>Hypolepis ambigua</i>. Narrow-leaved plantain, blackberry, lotus, Spanish heath, Scotch thistle, broad-leaved fleabane, kōhūhū, <i>Histiopteris incisa</i>, <i>Cyperus ustulatus</i>, mānuka, and bracken are scattered throughout.	Wetland	c.1.2 ha
7.	Grey willow/raupō reedland (11.01.05) Grey willow to 10 metres tall is common over dense raupō (2-3 metres tall).	Wetland	c.0.2 ha
8.	Water (22.01) Geothermal water (22.01.01) Geothermally heated waters of the Waihunuhunu Arm of Lake Ōhākuri. Several hot springs feed this area, along with input from several hot streams.	Open water	c.3.6 ha

Indigenous Flora:

Nephrolepis flexuosa (At Risk-Naturally Uncommon) is common and *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) is scattered to locally common along stream margins throughout this site, and on lake margins.

One large population of *Cyclosorus interruptus* (At Risk-Declining) is present within the raupō reedland in the southern half of the site. This population comprises more than 50 clumps over c.50 m².

Two small populations of *Dicranopteris linearis* (Threatened-Nationally Endangered) were present near the hot springs along the unnamed hot water stream, and another population occurs near the outlet of this stream into Lake Ōhākuri.

Other species present that are typical of geothermal habitat include *Cyperus ustulatus*, tūrutu, *Histiopteris incisa*, raupō, mingimingi, and mānuka.

Thelypteris confluent (At Risk-Naturally Uncommon) has previously been recorded from this site (E. Miller pers. comm. in Hobbs 2002) but was not recorded in surveys in 2007, 2014 and 2022.

Fauna:

Mātātā/North Island fernbird (At Risk-Declining) and māpunga/black shag (At Risk-Relict) were recorded at the site in 2022. Other common indigenous species recorded include: black swan, pūtangitangi/paradise shelduck, pāpango/New Zealand scaup, pīpīwharau/shining cuckoo, pīwakawaka/fantail, kōtare/sacred kingfisher, riroriro/grey warbler, and warou/welcome swallow. Introduced species recorded include Canada goose, mallard, and Eurasian blackbird. Pūweto/spotless crane (At Risk-Declining), spur-winged plover, pūkeko, and kawaupaku/little shag (At Risk-Relict) have previously

been recorded from the site (Wildland Consultants 2007b). Bird surveys by one of the authors (CMB) have also recorded kawau tūi/little black shag (At Risk-Naturally Uncommon) in open water adjacent to the site.

Geothermal Ecosystems:

Geothermal streamside, geothermal wetland.

Current Condition:

This site is mainly in good ecological condition and provides good habitat for four threatened fern species. However, pest plants (e.g. grey willow, blackberry, and wilding radiata pines) are common within the site.

Threats/Modification/Vulnerability:

Invasive pest plants:

Blackberry (15% cover), radiata pine (5% cover), grey willow (5% cover), Spanish heath (<1% cover), Himalayan honeysuckle (<1% cover), pampas (1% cover) and buddleia (<1% cover) are present. *Carex lurida* was recorded at the site in 2023 (<1% cover). Mexican water lily is present in open water habitats (<1% cover).

Human impacts:

There are some tracks near geothermal streams close to the road access to the Waihunuhunu Arm of Lake Ōhākuri. Several pools have been used for swimming, and some geothermal features have been altered by pool users. The water to one hot pool has been piped to the site. During one site visit by the authors within the last five years, there was considerable rubbish such as broken bottles through the site, however the pool area was mostly tidy in 2022.

Grazing:

The site is not farmed. Some feral pig and possum sign was evident.

Adjoining land use:

Surrounded by indigenous vegetation and Lake Ōhākuri.

Site Change:

Recent change:

There has been little obvious change to the geothermal vegetation since 2007, though the density of blackberry has increased around the margins of the stream making access to the upper reaches and hot springs difficult. Forest regeneration is suppressing some of this blackberry. Grey willow has increased in cover in some wetland areas since 2014.

*Historical:*¹

The lower parts of the site were flooded when the Waikato River was dammed to form Lake Ōhākuri in 1961, and features were destroyed by flooding. The loss of terrestrial geothermal vegetation and habitats at this site since the raising of Lake Ōhākuri is likely to have been substantial. The geothermal activity in Waihunuhunu is now in the head of a bay that was previously a long valley (c.1 km in length)². Heated water in this arm of the lake indicates that there continues to be considerable geothermal activity beneath the lake (surface temperatures up to 25 °C were measured c.1 km from the Waihunuhunu site in 2014). Although significant terrestrial

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photograph: SN358 Run 1074 1944-49.

geothermal habitat was lost to flooding, the higher lake level may have expanded the area of geothermal wetland. The terrestrial part of the site has probably changed little over time, although wilding and plantation pines occur close to the site margins. We estimate that a loss of *c.* 75% of terrestrial geothermal habitats occurred with the raising of Lake Ōhakuri, of which about 25% became geothermal wetland, resulting in a total loss of geothermal habitats of *c.* 50% since between 1961 and 2007.

Management Requirements:	This site has high potential for ecological restoration through management of pest plants (e.g. grey willow and blackberry).
Significance Level:	National (Criteria 3, 4, 5, 6, 9).
Significance Justification:	This site is of national significance because it is a good quality, representative example of geothermal habitat, a nationally uncommon habitat type. It also contains a good example of an under-represented habitat type: geothermal wetland. It also contains good populations of four Threatened and At Risk taxa: <i>Cyclosorus interruptus</i> , <i>Christella</i> aff. <i>dentata</i> (“thermal”), <i>Dicranopteris linearis</i> , and <i>Nephrolepis flexuosa</i> . It contains one of the largest populations of <i>N. flexuosa</i> in the North Island.
References:	Beadel and Bill 2000; Given 1989, 1995 & 1996; Hobbs 2002; Merrett and Burns 1999; Smith-Dodsworth 1993; Wildland Consultants 2004c, 2007b, & 2012, 2014a.



Warm steaming geothermal waters in Waihunuhunu Inlet, Lake Ōhakuri. NZTM E1875197 N5739156. 15 November 2022.



Extensive area of wetland on margins of Lake Ōhakuri in Waihunuhunu Inlet. NZTM E1875156 N5739096. 15 November 2022.

VASCULAR PLANT SPECIES IN RECORDED AT SURFACE GEOTHERMAL SITES IN THE ORĀKEI KŌRAKO GEOTHERMAL SYSTEM

Scientific Name	Common Name	Waihunuhunu	Akatārewa Stream	Akatārewa East	Orākei Kōrako/ Red Hills
INDIGENOUS SPECIES					
Gymnosperms					
<i>Dacrydium cupressinum</i>	Rimu		✓		✓
<i>Podocarpus totara</i> var. <i>totara</i>	Tōtara	✓	✓		✓
Monocot. trees and shrubs					
<i>Cordyline australis</i>	Ti kōuka, cabbage tree	✓			✓
Dicot. trees and shrubs					
<i>Aristotelia serrata</i>	Makomako, wineberry		✓		
<i>Brachyglottis repanda</i>	Rangiora		✓		✓
<i>Coprosma lucida</i>	Karamū, kāramuramu, glossy karamū				✓
<i>Coprosma rhamnoides</i>					✓
<i>Coprosma robusta</i>	Karamū, kāramuramu	✓	✓	✓	✓
<i>Dracophyllum subulatum</i>	Monoao				✓
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taupuku				✓
<i>Geniostoma ligustrifolium</i> var. <i>ligustrifolium</i>	Hangehange	✓	✓		✓
<i>Griselinia littoralis</i>	Kāpuka		✓		✓
<i>Knightia excelsa</i>	Rewarewa	✓	✓		✓
<i>Kunzea robusta</i>	Kānuka	✓			✓
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	✓	✓	✓
<i>Leptecophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi				✓
<i>Leptospermum scoparium</i>	Mānuka	✓	✓	✓	✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	✓		✓
<i>Leucopogon fraseri</i>	Pātōtara				✓
<i>Meliczytus ramiflorus</i> subsp. <i>ramiflorus</i>	Māhoe	✓	✓		✓
<i>Metrosideros excelsa</i>	Pōhutukawa				✓
<i>Myrsine australis</i>	Māpou, matipou, māpau				✓
<i>Pittosporum eugenioides</i>	Tarata; lemonwood				✓
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓	✓	✓	✓
<i>Pomaderris amoena</i>	Tauhinu				✓
<i>Pseudopanax arboreus</i>	Whauwhaupaku, puahou, five finger	✓	✓		✓
<i>Pterophylla racemosa</i>	Kāmahi	✓	✓		✓
<i>Schefflera digitata</i>	Patē		✓		
<i>Veronica stricta</i> var. <i>stricta</i>	Koromiko, kōkōmuka		✓		✓
Dicot. lianes					
<i>Clematis forsteri</i>	Poananga, puawānanga		✓		✓
<i>Metrosideros diffusa</i>	Rātā		✓		✓
<i>Muehlenbeckia australis</i>	Puka		✓		✓
<i>Lycopodium volubile</i>	Waewaekoukou, climbing clubmoss		✓		✓
<i>Lycopodiella cernua</i>	Mātukutuku				✓
<i>Psilotum nudum</i>	Fork fern				✓ (WC 2000 & Bellingham, 1985)
<i>Tmesipteris elongata</i>					✓
Ferns					
<i>Adiantum cunninghamii</i>	Huruhuru tapairu, maidenhair fern		✓		
<i>Asplenium bulbiferum</i>	Mouku, mouki, mauku, hen and chicken fern		✓		✓

Scientific Name	Common Name	Waihunuhunu	Akatārewa Stream	Akatārewa East	Orākei Kōrako/ Red Hills
<i>Asplenium oblongifolium</i>	Huruhuru whenua, shining spleenwort				✓
<i>Asplenium polyodon</i>	Petako, paratao, sickle spleenwort				✓
<i>Asplenium bulbiferum</i> × <i>A. hookerianum</i>					✓
<i>Azolla rubra</i>	Kārearea, rotoreto, returetu				✓
<i>Blechnum chambersii</i>	Rereti, nini, lance fern		✓		✓
<i>Blechnum membranaceum</i>			✓		
<i>Blechnum minus</i>	Swamp kiokio	✓			✓
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio	✓	✓		✓
<i>Blechnum parrisiae</i>	Pukupuku				✓
<i>Blechnum deltoides</i>	Korokio		✓		
<i>Christella</i> aff. <i>dentata</i> (b) (AK 126902 "thermal")		✓	✓		✓
<i>Cyathea dealbata</i>	Ponga, silver fern	✓			✓
<i>Cyathea medullaris</i>	Mamaku, black tree fern		✓		✓
<i>Cyathea smithii</i>	Kātote, soft tree fern				✓
<i>Cyclosorus interruptus</i>		✓			✓
<i>Deparia petersenii</i> subsp. <i>congrua</i>		✓	✓		✓
<i>Dicksonia fibrosa</i>	Wheki-ponga, kuripākā	✓	✓		✓
<i>Dicksonia squarrosa</i>	Wheki	✓	✓		✓
<i>Dicranopteris linearis</i>		✓	✓	✓	✓
<i>Diplazium australe</i>			✓		✓
<i>Gleichenia microphylla</i>	Waewaekākā, carrier tangle fern				✓
<i>Histiopteris incisa</i>	Mātātā, water fern	✓			✓
<i>Hymenophyllum demissum</i>	Irirangi, pipiri, drooping filmy fern		✓		
<i>Hymenophyllum flabellatum</i>	Mauku, fan-like filmy fern				✓ (Bellingham, 1985)
<i>Hymenophyllum rarum</i>	Mauku, tufted filmy fern				✓
<i>Hymenophyllum sanguinolentum</i>	Piripiri, filmy fern		✓		✓
<i>Hypolepis ambigua</i>		✓			✓
<i>Hypolepis dicksonioides</i>	Giant hypolepis				✓ (Bellingham, 1985)
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pāharaha, hound's tongue fern	✓			✓
<i>Lecanopteris scandens</i>	Mokimoki, fragrant fern	✓			
<i>Lastreopsis hispida</i>	Tuakura		✓		✓
<i>Leptopteris hymenophylloides</i>	Heruheru, single crepe fern		✓		✓
<i>Nephrolepis flexuosa</i>	Indigenous ladder fern	✓			✓
<i>Ophioglossum coriaceum</i>	Adder's tongue				✓
<i>Paesia scaberula</i>	Mātātā, hard fern	✓	✓	✓	✓
<i>Pakau pennigera</i>	Piupiu, pākauroharoha, feather fern, gully fern		✓		✓
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	✓	✓	✓
<i>Pteris tremula</i>	Turawera, shaking brake			✓	
<i>Pyrosia elaeagnifolia</i>	Leather-leaf fern				✓
<i>Schizaea bifida</i>					✓ (old record)
<i>Schizaea dichotoma</i>					✓
<i>Schizaea fistulosa</i>					✓ (Bellingham, 1985)
Orchids					
<i>Calochilus robertsonii</i>					✓ (Bellingham, 1985)

Scientific Name	Common Name	Waihunuhunu	Akatārewa Stream	Akatārewa East	Orākei Kōrako/ Red Hills
<i>Corunastylis pumila</i>					✓
<i>Microtis parviflora</i>					✓ (Bellingham, 1985)
<i>Orthoceras novae-zeelandiae</i>	Māikaika				✓ (Bellingham, 1985)
<i>Prasophyllum colensoi</i>					✓ (Bellingham, 1985)
<i>Pterostylis trullifolia</i>					✓ (Bellingham, 1985)
<i>Pterostylis</i> sp.			✓		✓
<i>Thelymitra carnea</i>					✓ (Bellingham, 1985)
<i>Thelymitra colensoi</i>					✓
<i>Thelymitra longifolia</i>					✓ (Ecroyd, 1979)
<i>Thelymitra pauciflora</i>	Slender sun orchid				✓ (Bellingham, 1985)
Grasses					
<i>Austroderia fulvida</i>	Toetoe				✓
<i>Lachnagrostis filiformis</i>					✓
<i>Microlaena stipoides</i>	Pātiti, meadow rice grass		✓		✓
<i>Opismenus hirtellus</i> subsp. <i>imbecillis</i>			✓		✓
<i>Pentapogon avenoides</i>					✓
<i>Rytidosperma gracile</i>					✓
Sedges					
<i>Carex geminata</i> agg.	Rautahi				✓
<i>Carex maorica</i>		✓			
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio	✓			✓
<i>Carex uncinata</i>	Kamu matau a Maui, kamu	✓	✓		✓
<i>Carex virgata</i>	Pūrei	✓	✓		✓
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata	✓			✓
<i>Eleocharis acuta</i>	Spike sedge	✓			✓
<i>Eleocharis sphacelata</i>	Giant spike sedge, ngāwhā, kuta.kutakuta, paopao				✓
<i>Lepidosperma australe</i>					✓
<i>Machaerina articulata</i>		✓			✓
<i>Machaerina juncea</i>					✓
<i>Machaerina rubiginosa</i>		✓			✓
<i>Machaerina tenax</i>					✓ (Bellingham, 1985)
<i>Morelotia affinis</i>					✓
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā	✓			✓
Rushes					
<i>Apodasmia similis</i>	Oioi				✓
<i>Juncus edgariae</i>	Wi, wīwī	✓			
<i>Juncus kraussii</i> var. <i>australiensis</i>	Wi, wīwī sea rush				✓
<i>Juncus sarophorus</i>	Wi, wīwī				✓ (Bellingham, 1985)
Monocot. herbs (other than orchids, grasses, sedges, and rushes)					
<i>Astelia fragrans</i>	Kakaha		✓		✓
<i>Dianella nigra</i>	Tūrutu	✓			✓
<i>Lemna disperma</i>	Karearea				✓
<i>Phormium tenax</i>	Harakeke, flax				✓
<i>Potamogeton suboblongus</i>	Rerewai				✓
<i>Triglochin striata</i>	Arrow grass				✓
<i>Typha orientalis</i>	Māhoe	✓			✓
Composite herbs					
<i>Euchiton audax</i>					✓ (Bellingham, 1985)
<i>Senecio bipinnatisectus</i>	Australian fireweed			✓	
Dicot. herbs (other than composites)					
<i>Drosera auriculata</i>	Sundew, wahu				✓
<i>Drosera binata</i>	Sundew, wahu				✓ (Bellingham, 1985)

Scientific Name	Common Name	Waihunuhunu	Akaterewa Stream	Akaterewa East	Orākei Kōrako/ Red Hills
<i>Galium propinquum</i>	Mawe	✓			
<i>Geranium potentilloides</i> var. <i>potentilloides</i>			✓ (Bellingham, 1985)		
<i>Haloragis erecta</i> subsp. <i>erecta</i>	Toatoa		✓		✓
<i>Hydrocotyle dissecta</i>			✓		
<i>Hydrocotyle microphylla</i>					✓ (Bellingham, 1985)
<i>Hydrocotyle moschata</i> var. <i>moschata</i>					✓
<i>Limosella lineata</i>	Mudwort				✓
<i>Lobelia angulata</i>	Pānakenake	✓			✓
<i>Nertera depressa</i>					✓
<i>Ranunculus reflexus</i>	Maruru		✓		
<i>Stellaria parviflora</i>	Kohukohu		✓		
NATURALISED AND EXOTIC SPECIES					
Gymnosperms					
<i>Pinus pinaster</i>	Maritime pine		✓		✓
<i>Pinus radiata</i>	Radiata pine		✓	✓	✓
<i>Pseudotsuga menziesii</i>	Douglas fir		✓		
Monocot. trees and shrubs					
<i>Acacia mearnsii</i>	Black wattle		✓		✓
<i>Betula pendula</i>	Silver birch		✓		✓
<i>Buddleja davidii</i>	Buddleia	✓	✓	✓	✓
<i>Cotoneaster glaucophyllus</i>	Cotoneaster		✓		✓
<i>Erica lusitanica</i>	Spanish heath	✓	✓	✓	✓
<i>Leycesteria formosa</i>	Himalayan honeysuckle	✓	✓		✓
<i>Ligustrum sinense</i>	Chinese privet				✓
<i>Prunus</i> sp.	Ornamental cherry		✓		✓
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓	✓	✓
<i>Salix cinerea</i>	Grey willow	✓	✓		✓
<i>Teline monspessulana</i>	Montpellier broom		✓		✓
<i>Ulex europaeus</i>	Gorse				✓
Dicot. lianes					
<i>Lonicera japonica</i>	Japanese honeysuckle				✓
Ferns					
<i>Azolla pinnata</i>	Ferny azolla				✓
<i>Dryopteris affinis</i>	Male fern				✓
Grasses					
<i>Agrostis capillaris</i>	Browntop		✓	✓	✓
<i>Agrostis stolonifera</i>	Creeping bent	✓			✓
<i>Aira caryophyllea</i> subsp. <i>caryophyllea</i>	Silver hairy grass		✓		
<i>Aira praecox</i>	Early hair grass		✓ (Bellingham, 1985)		
<i>Anthoxanthum odoratum</i>	Sweet vernal		✓	✓	✓
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass				✓
<i>Cortaderia selloana</i>	Pampas	✓	✓		✓
<i>Cynodon dactylon</i>	Indian doab		✓		
<i>Dactylis glomerata</i>	Cocksfoot		✓		✓
<i>Eragrostis brownii</i>	Bay grass				✓
<i>Glyceria maxima</i>	Reed sweetgrass				✓
<i>Holcus lanatus</i>	Yorkshire fog	✓	✓	✓	✓
<i>Lolium arundinaceum</i> subsp. <i>arundinaceum</i>	Tall fescue	✓			✓
<i>Paspalum dilatatum</i>	Paspalum	✓	✓	✓ (2010)	✓
<i>Paspalum distichum</i>	Mercer grass		✓		✓
<i>Paspalum urvillei</i>	Vasey grass				✓
<i>Pseudosasa japonica</i>	Arrow bamboo		✓		✓
<i>Sporobolus africanus</i>	Ratstail				✓ (Bellingham, 1985)
Sedges					
<i>Carex lurida</i>	Sallow sedge	✓			
<i>Cyperus esculentus</i>	Yellow nut grass		✓		
Rushes					
<i>Juncus tenuis</i> var. <i>tenuis</i>	Track rush	✓			

Scientific Name	Common Name	Waihunuhunu	Akatārewa Stream	Akatārewa East	Orākei Kōrako/ Red Hills
Monocot. herbs (other than orchids, grasses, sedges, and rushes)					
<i>Egeria densa</i>	Egeria		✓		
Composite herbs					
<i>Carduus tenuiflorus</i>	Winged thistle		✓ (Bellingham, 1985)		
<i>Cirsium vulgare</i>	Scotch thistle	✓	✓		
<i>Crepis capillaris</i>	Hawksbeard		✓		
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane	✓	✓	✓	
<i>Hypochaeris radicata</i>	Catsear		✓		
<i>Mycelis muralis</i>	Wall lettuce		✓		✓
<i>Senecio sylvaticus</i>	Wood groundsel		✓		
<i>Sonchus oleraceus</i>	Puha, sow thistle		✓		
Dicot. herbs (other than composites)					
<i>Cerastium fontanum</i> subsp. <i>vulgare</i>	Mouse-ear chickweed		✓		
<i>Ceratophyllum demersum</i>	Hornwort		✓		
<i>Digitalis purpurea</i>	Foxglove	✓	✓		
<i>Galium aparine</i>	Cleavers		✓		
<i>Galium palustre</i>	Marsh bedstraw	✓			
<i>Lotus pedunculatus</i>	Lotus	✓	✓		
<i>Ludwigia palustris</i>	Water purslane		✓		
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	Scarlet pimpernel		✓		
<i>Myosotis scorpioides</i>	Water forget-me-not		✓		
<i>Nymphaea mexicana</i>	Mexican water lily	✓	✓		
<i>Phytolacca octandra</i>	Inkweed	✓			
<i>Plantago australis</i>	Swamp plantain		✓		
<i>Plantago lanceolata</i>	Narrow-leaved plantain	✓	✓		
<i>Ranunculus repens</i>	Creeping buttercup		✓		
<i>Solanum nigrum</i>	Black nightshade		✓	✓	

20. REPOROA GEOTHERMAL SYSTEM



GOLDEN SPRINGS

Ecological District:	Atiamuri	GPS Reference:	NZTM E1888850 N5737187
Geothermal System:	Reporoa	Altitude:	300 m
Bioclimatic Zone:	Lowland	Local Authority:	Rotorua
Extent of Geothermal Habitat:	c. 0.9 ha		
Extent of Geothermal Vegetation:	c. 0.8 ha		
Date of Most Recent Field Survey:	26 January 2023		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Mixed exotic and indigenous species scrub (04.09) Mixed exotic and indigenous species scrub (04.09.02) A diverse range of vegetation occurs as a narrow band alongside the stream that flows through the Golden Springs camp ground. Along the stream margins, overhanging conifers (e.g. radiata pine, Douglas fir) and scattered indigenous and exotic species such as karamū, whēkī, ponga, whēkī-ponga, Chinese privet, silver birch, crack willow, and ornamental cherry are locally emergent over the stream. The stream sides are a mixture of ferns, small shrubs, exotic herbs and grasses and local bamboo. The heated stream creates suitable habitat for <i>Christella</i> aff. <i>dentata</i> (“thermal”) with c.30 clumps observed during the 2023 survey. Other fern species common along the stream margin include kiokio, <i>Hypolepis ambigua</i>, <i>Deparia petersenii</i>, bracken, <i>Histiopteris incisa</i>, shaking brake, <i>Hypolepis ambigua</i>, swamp kiokio and the exotic <i>Pteris comans</i>. Scattered planted and ornamental garden plant species are common in places such as montbretia, <i>Abelia grandiflora</i>, various <i>Veronica</i> (<i>Hebe</i>) species, hydrangea, agapanthus, and <i>Begonia</i> ‘semperflorens-cultorum hybrids’, with some of these species spreading from original plantings (e.g. agapanthus and montbretia). Blackberry, ivy, periwinkle, Spanish heath, Japanese honeysuckle and <i>Selaginella kraussiana</i> are locally common particularly under shrubs and trees. Blackberry becomes more abundant to the south of this type. Mown and rank grasses are common in other areas with abundant sweet vernal, annual poa, and white clover, in association with black nightshade, broad-leaved fleabane, and Scotch thistle. <i>Cyperus ustulatus</i>, <i>Carex secta</i>, <i>Cyperus eragrostis</i>, harakeke, and kāpūngāwhā are occasionally present on damp margins. There are several patches of bamboo near the stream including arrow bamboo. Bamboo threatens to dominate the cover of stream margins. One individual kiwifruit plant was present in January 2023. A few individual geothermal kānuka plants are present.	Stream margins	c.0.1 ha
2.	Exotic species dominated scrub (04.10) Blackberry scrub (04.10.01) Chinese privet and whēkī are locally emergent over stream margins dominated by blackberry scrub on the true right of the stream. A few scattered <i>Christella</i> aff. <i>dentata</i> (“thermal”) are present in the upstream part of this vegetation type. Rank grasses (including Yorkshire fog, sweet vernal, and ryegrass) are locally common. Periwinkle is often also abundant on stream margins.	Stream margins	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
3.	Mixed indigenous and exotic trees and shrubs/ blackberry scrub (04.10.08) (Radiata pine)-(grey willow)-(kānuka)/blackberry-Japanese honeysuckle-pōhue scrub <i>Eastern side of State Highway 5:</i> Emergent radiata pine to 25 metres and scattered grey willow, kānuka and ornamental cherry to eight metres are present over scrub dominated with blackberry, local Japanese honeysuckle, and <i>Calystegia sepium</i>. Several small areas of raupō and occasional kāpūngāwhā and harakeke are present in wet areas. Ivy is abundant around stream margins closest to the highway. The stream temperature near the highway was 38 °C. <i>Western side of State Highway 5:</i> Emergent grey willow (to 10 metres), Chinese privet, hawthorn, cotoneaster, silver birch, tī kōuka, kōhūhū, and whekī are abundant over blackberry, bracken, Japanese honeysuckle, and rank exotic grasses. Raupō is abundant in drains. The cover of Chinese privet, cotoneaster, and hawthorn has increased since 2014 (Chris Bycroft pers. obs). Several <i>Christella</i> aff. <i>dentata</i> (“thermal”) plants were present at the south end of the drain in 2007, however none were seen in 2014 or 2023. Other species present include <i>Cyperus ustulatus</i>, kiokio, pampas, and <i>Carex virgata</i>. A geothermal pool (NZTM E1888861 N5737260) has abundant raupō, <i>Carex virgata</i> and <i>Cyperus ustulatus</i> on its margins and is surrounded by abundant grey willow, hawthorn and blackberry. The vegetation in these areas has changed markedly since the area was fenced and stock excluded in the 2000s.	Flat, drain margins.	c.0.4 ha
4.	Exotic grassland (08.01) (Grey willow)-(pampas)/tall fescue-Cyperus ustulatus-Carex virgata-blackberry grassland (08.01.13) There are scattered grey willow over grassland alongside geothermal streams/drains in the northeastern part of the site. Pampas is locally abundant with occasional silver birch. The grassland is dominated by cockfoot, tall fescue with common Yorkshire fog, Mercer grass, and sweet vernal and herbs such as creeping buttercup and American fireweed. Sedges are occasionally present on stream margins (<i>Carex virgata</i> and <i>Cyperus ustulatus</i>), along with occasional creeping buttercup, broad-leaved fleabane, <i>Paesia scaberula</i>, and water purslane. These habitats have been fenced to exclude stock since 2007. Some harakeke has been planted in places and the grasses have been sprayed with herbicide in some areas. Poplars are planted around the pools in the eastern part of this type.	Wetland	c.0.2 ha
5.	Raupō-dominant reedland (11.01) Raupō reedland (11.01.01) A small area of wetland dominated by raupō with occasional Kāpūngāwhā, harakeke and rank exotic grasses such as cocksfoot and Yorkshire fog, and occasional blackberry on margins.	Wetland	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
6.	Water (22.01) Geothermal water (22.01.01) Geothermal hot springs and open water habitats surrounded by rank grassland species and sedgeland species. The surface temperature of the pool in the northern part of the site (NZTM E18888848 N5737470) was 40 °C in 2014.	Open water	<0.1 ha

Indigenous Flora:

Christella aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) is scattered along stream margins throughout the eastern part of this site. A few plants of *Christella* aff. *dentata* (“thermal”) were present in a roadside ditch on the western side of state highway in 2007 (Bycroft and Beadel 2007), but none were found here during the 2014 or 2023 surveys. Surveys of the entire site found 45 clumps in 2007, 28 clumps in 2014, and 30 clumps in 2023. The cover and distribution of *Christella* aff. *dentata* (“thermal”) at this site appears similar between each of the surveys.

A small population of geothermal kānuka (Threatened-Nationally Endangered) is present along stream margins on the eastern side of State Highway 5.

Fauna:

The site provides habitat for common indigenous and introduced bird species including pūkeko, spur-winged plover kōtare/sacred kingfisher, korimako/bellbird, pīwakawaka/North Island fantail, and tauhou/silvereye. Introduced species recorded from the site include mallard, Eurasian blackbird, yellowhammer, European greenfinch, house sparrow, and common myna. An indigenous butterfly, kahukura/red admiral butterfly (*Vanessa gonerilla*), was also seen at the site.

Mosquito fish (*Gambusia affinis*) are present in the geothermal streams and drains, along with a tropical aquarium fish species and snail.

Geothermal Ecosystems:

Geothermal streamsides, geothermal wetlands.

Current Condition:

This site is generally in a relatively poor ecological condition, and pest plants are common on both sides of State Highway 5. The condition on the western side of State Highway 5 has improved since the 2007 survey - the geothermal springs and wetland areas have been fenced to exclude stock. The fencing was well maintained in 2023. The parts on the eastern side of the road are within a camping ground, and their condition is directly affected by management of recreational activities and aesthetic plantings. The downstream (southern) end of the site is overrun with blackberry and has been lightly grazed by stock in the past. Exotic plantings are common along the length of the stream.

Threats/Modification/Vulnerability:

Invasive pest plants:

Western side of State Highway 5: Grey willow (10% cover), Chinese privet (10% cover), blackberry (25% cover), cotoneaster (<1% cover), pampas (1% cover), and Japanese honeysuckle (1% cover).

Eastern side of State Highway 5: Blackberry (35% cover), Chinese privet (15% cover), ivy (5% cover), periwinkle (2% cover), *Clematis flammula* (1% cover), *Selaginella kraussiana* (1% cover), montbretia (1% cover), Japanese honeysuckle (1% cover), ornamental cherry (1% cover), arrow bamboo and other bamboo species (5% cover), agapanthus (2% cover), crack willow (1% cover), Himalayan honeysuckle (1% cover), grey willow (1% cover), aluminium plant (<1% cover), *Calystegia silvatica* subsp. *disjuncta* (<1% cover), Douglas fir (<1% cover), silver birch (<1% cover), kiwifruit (<1% cover), *Cyperus eragrostis* (<1% cover), arum lily (<1% cover), elephants ear (<1% cover), and *Pteris comans* (<1% cover).

Some pest plants such as bamboo, is increasing in area, and will potentially smother streamside vegetation without management.

Human impacts:

Western Part

Although the western part of the site is farmed, most of the geothermal features were fenced to exclude stock prior to the 2014 survey. Some pools on the western side are used for swimming, but the impacts on vegetation from recreational use are minor. Some pest plants have become abundant in fenced areas since stock have been excluded, but the condition of features has improved. Drains are present alongside State Highway 5, and these areas on occasion have provided habitat for geothermal ferns.

Eastern Part

The eastern part is negatively impacted by recreation use and aesthetic plantings as part of the campground facilities. Impacts on the stream and margins include concreted sections, water wheels, and damming of the stream for swimming holes. Exotic plantings are abundant on stream margins, and mowing has occurred close to stream margins in some sections.

Grazing:

Western Part

The western part of the site is surrounded by farmland, however the geothermal features were fenced around the time of the 2014 survey to exclude stock, and stock are now having no direct grazing impacts on geothermal vegetation. The fencing appeared well maintained in 2023.

Eastern Part

The eastern part of the site is a camping ground. In the past, the manager occasionally would lightly graze this area with goats, although there was no evidence of any grazing by domestic stock in 2023.

Adjoining land use:

Farmland, camping ground, state highway, residential.

Site Change:

Recent change:

The general extent of geothermal vegetation appeared similar in 2023 to the previous survey in 2014, although the extent and abundance of pest plants has increased.

*Historical:*¹

This site is too small for any evidence of change to be identified on aerial photographs (Historical photos: SN 172 Run 1165 Photos 3-4, 1941).

Management Requirements:

The fences should be inspected and maintained regularly on the western side of State Highway 5. A planting plan within the fenced area would be beneficial in reducing pest plant issues around geothermal features.

A management plan should be prepared to provide guidelines for the manager(s) of the camping ground to maintain and enhance the population of *Christella* aff. *dentata* ("thermal"). Abundant weeds are present alongside stream margins which threaten both the *Christella* aff. *dentata* ("thermal") populations at the site as well as the remaining indigenous components of stream margins. In the past a previous camp ground manager has tried to control weeds at the site by using goats, however this is likely to also impact on *Christella* populations. Pest plants should be controlled in the wetland on the western side of State Highway 5, including grey willow, pampas, and Chinese privet. Bamboo should be controlled as it could become dense along stream margins. There are significant opportunities for ecological restoration around stream margins, in areas of open geothermal water, and within geothermal wetlands.

Significance Level:

Regional (Criterion 3, 5, 6).

Significance Justification:

This part of the site is of regional significance as it is an important site for the conservation of a Threatened taxon - *Christella* aff. *dentata* ("thermal").

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region classed Golden Springs as Category B - the second highest category.

Macroinvertebrate taxa found in geothermally influenced streams here was in general typical of those recorded in non-geothermal streams, but which can tolerate high temperatures or unusual pH (Duggan and Boothroyd 2002). Leeches have been recorded at Golden Springs, along with two introduced aquarium species (a fish and snail) which have likely been released into the stream from a tropical aquarium and are surviving in the warm water (Duggan and Boothroyd 2002).

References:

Beadel and Bill 2000; Bycroft and Beadel 2007; Duggan and Boothroyd 2002; Given 1989a, 1995 & 1996; Spring-Rice 1996; Wildland Consultants 2004c, 2007b, 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



Stream margins near the Golden Springs campsite. The ferns in the photograph are a mixture of *Christella* aff. *dentata* ("thermal") and *Deparia petersenii*. Note the weeds on stream margins (including agapanthus). NZTM E1888732 N5736958. 26 January 2023.



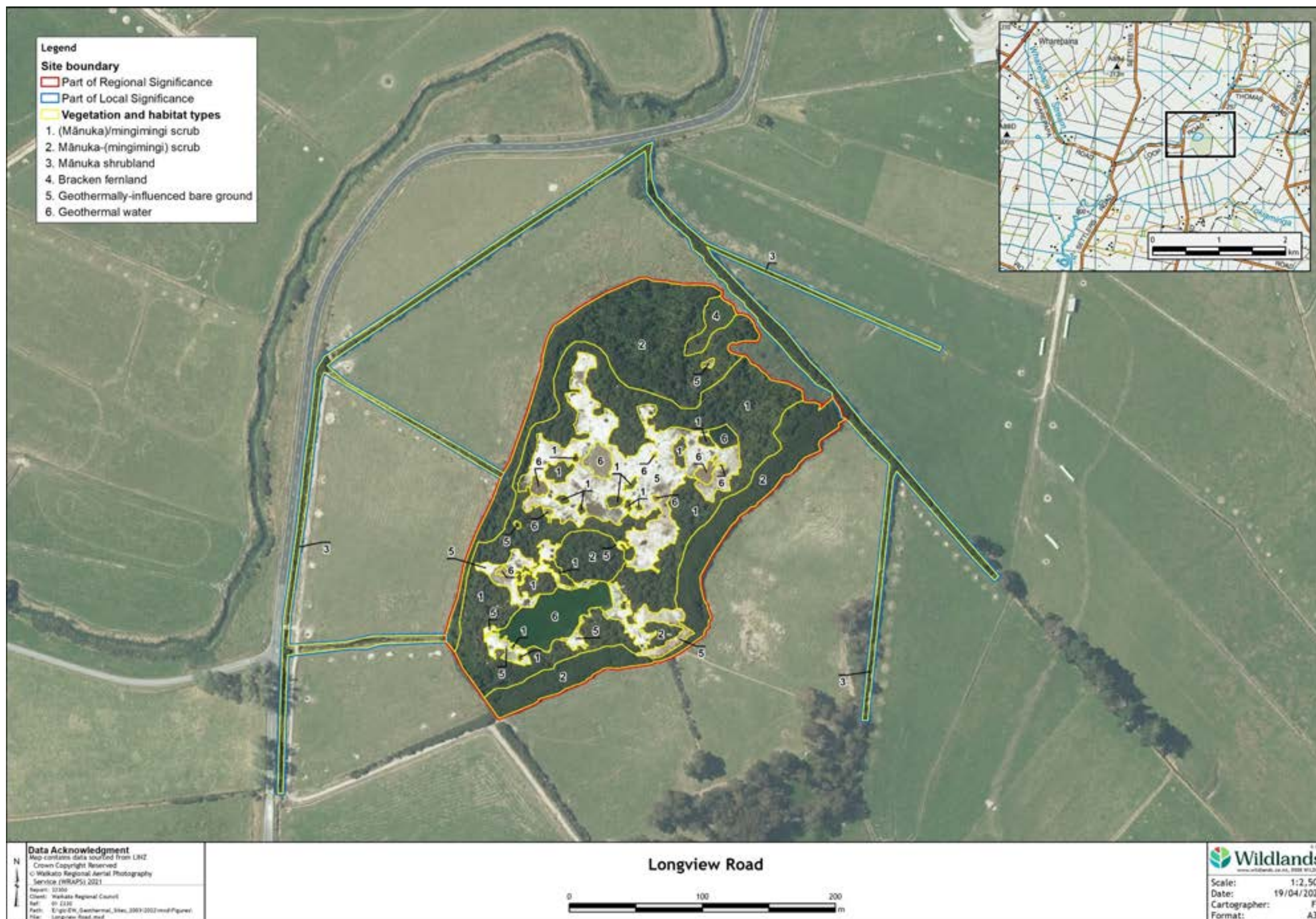
A geothermal spring on the western side of State Highway 5. There are patches of raupō and *Carex virgata* on the spring margin. The vegetation surrounding the geothermal springs and stream are fenced, but abundant pest plants are present. NZTM E1888861 N5737260. 26 January 2023.



A fenced geothermal drainage ditch surrounded by farmland on the west side of State Highway 5, Golden Springs. NZTM E1888895 N5737378. 26 January 2023



A geothermal pool, west side of State Highway 5 at Golden Springs. NZTM E1888863 N5737379. 26 January 2023.



LONGVIEW ROAD

Ecological District: Atiamuri	GPS Reference: NZTM E1893489 N5742976
Geothermal System: Reporoa	Altitude: 295 m
Bioclimatic Zone: Lowland	Local Authority: Rotorua
Extent of Geothermal Habitat: c. 6.3 ha	
Extent of Geothermal Vegetation: c. 6.0 ha	
Date of Most Recent Field Survey: 29 November 2022	

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Mingimingi-dominant scrub (04.03) (Mānuka)/mingimingi scrub (04.03.05) Occasional emergent mānuka (up to four metres tall) are present over mingimingi between 0.3 and 1.5 m tall with occasional blackberry, tūrutu, and bracken present in the understorey. Some small patches of dense bracken are present. A dense cover of non-vascular plants dominates much of the groundcover with the liverwort <i>Chiloscyphus semiteres</i> common to abundant, and the mosses <i>Campylopus clavatus</i> and <i>Leucobryum javense</i> also common. Occasional <i>Histiopteris incisa</i> , occurs on banks above steaming hot springs. The alga <i>Trentepohlia</i> sp. is common in its orange form on mānuka and mingimingi stems throughout.	Flat	c.2.0 ha
2.	Mānuka-dominant scrub (04.04) Mānuka scrub (04.04.01) Most of the area mapped as this type comprises dense mānuka scrub, with occasional mingimingi, tūrutu and bracken in the understorey. Mānuka forms a canopy up to eight metres tall, but in most areas the height is 3-5 metres tall. Areas with a dense mānuka canopy contain very few other species, with dense mānuka leaf litter on the ground. <i>Trentepohlia</i> sp. is common on mānuka. In the northwest corner of this vegetation type, blackberry becomes common in the understorey; elsewhere the blackberry is mostly present on margins with a cover of <1%. The most common non-vascular species is the liverwort <i>Chiloscyphus semiteres</i> . Small patches of mingimingi scrub are present within this type but are too small to map out separately. <i>Asplenium flaccidum</i> subsp. <i>flaccidum</i> , kōwaowao, and local <i>Hiya distans</i> are present but very infrequent.	Flat	c.2.0 ha
3.	Mānuka-dominant shrubland (05.04) Mānuka shrubland (05.04.01) Narrow bands of mānuka shrubland are present alongside a stream, drains, and geothermal springs. Mānuka forms a canopy up to c.6 metres tall over rank grasses and pasture dominated by Yorkshire fog, with scattered blackberry. Occasional <i>Histiopteris incisa</i> , <i>Hypolepis ambigua</i> , <i>Carex virgata</i> , and <i>Cyperus ustulatus</i> are also present. Geothermal springs are present in some of the drains that are bordered by this type, with the surface water temperature of one spring (NZTM E1893741 N5742957) measuring 57 °C in 2014. In most areas the surface water temperature in drains range from 30 °C to 40 °C (temperatures measured in 2022); these drains are located outside the covenant boundary. Many of the sides of drains comprise exotic grasses such as Yorkshire fog, occasional patches of <i>Hypolepis ambigua</i> , blackberry, and patches of bare soil.	Flat	c.0.8 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
4.	Indigenous fernland (07.01) Bracken fernland (07.01.19) Bracken forms a dense cover up to c.1.5 metres tall, interspersed with occasional blackberry vines, tūrutu, and <i>Muehlenbeckia complexa</i> . Scattered dead treefern stumps (c.1 metre tall), and several emergent mānuka up to c.4 metres tall, are also present. Blackberry forms dense patches in some areas, particularly on the northern margin of this vegetation and habitat type, adjacent to the surrounding farmland. Some of this blackberry is dead (probably a result of herbicide spray).	Flat	<0.1 ha
5.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Bare ground with scattered branches of mingimingi and mānuka present. Contains many hot springs too small to map out separately. The surface is often pumiceous rock, and brittle silicified gravelly soils and clays. Mud sediments are common on the surface, indicating higher water levels in the recent past.	Flat	c.1.1 ha
6.	Water (22.01) Geothermal water (22.01.01) Small geothermal lakes and hot springs. The maximum surface temperature recorded was 65.9 °C (NZTM E1893625 N5743064, temperature measured in 2014) however temperatures were only recorded from safe vantage points and surface temperatures are likely to exceed this measurement in other parts of the site.	Open water	c.0.4 ha

Indigenous Flora: No Threatened or At Risk species recorded from this site.

Fauna: Common indigenous and exotic bird species typical of the habitat are present and include pūkeko, pīpīwharau/roa/shining cuckoo, warou/welcome swallow, matuku moana/white-faced heron, kāhu/swamp harrier, and poaka/pied stilt. Introduced species include California quail and chaffinch.

Possum sign was present.

Geothermal Ecosystems: Geothermal streamsides, heated ground (dry), hydrothermally altered ground (now cool).

Current Condition: Overall, the covenanted part of the site is in good condition considering its long history of disturbance from fire, cattle grazing, and drainage channel development (see Spring-Rice 1996). The most significant geothermal features are well buffered with indigenous vegetation, and few weeds are present, apart from in the narrow bands of mānuka shrubland alongside drains outside the protected area. The drains and geothermal springs outside the covenanted area are vulnerable to farming activities.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Blackberry (15% cover on site margins and <1% cover in the site interior) was the only significant pest plant species found at the site. Blackberry does

not appear to have increased in cover since 2014 (Mitchell West pers. obs. 2022).

Human impacts:

The site is vulnerable to the further development of drainage channels on neighbouring farmland which would further lower the water table and alter ground temperatures. No evidence was found of recent drain excavation at the site. Trampling damage to vegetation is currently low at the site, but the vegetation and features present are susceptible to recreational use (e.g. trampling of geothermal vegetation and use of the site during duck shooting season).

Grazing:

While no stock (or stock sign) were recorded from the covenanted area, the fencing in many places is poor or completely ineffective. Repair of the covenant fence should be a high priority.

Adjoining land use:

Farmland.

Site Change:

Recent change:

The quality of fencing surrounding the site has declined since the 2014 survey, although stock impacts within the site are minimal. The cover of pest plants (mostly blackberry) appears similar to the 2004 and 2014 assessments. The geothermal vegetation present at this site appears to be similar in condition and overall extent as in 2004 and 2014, although a small change to site size has occurred due to better refinement of boundaries in 2022 as a result of better quality aerial photographs.

*Historical:*¹

It appears that the surrounding land use (farming) has intensified since 1941². It also appears that the site was unfenced in 1941 and stock had access to the site. The size of the site has been approximately halved since 1941, with what is likely to have been geothermal wetland, having been converted to pasture, and drained. Some of the raw-soilfield vegetation to the south of the site has been converted to pasture. In 1941, the scrub (probably dominated by mānuka) is more than double the size of the current area, based on 2007 aerial photographs. Most of the change to this site appears to be the result of land drainage and development into pasture.

Management Requirements:

Fencing is in a poor condition around most of the covenanted site. Repair of these fences is recommended. While the current state of the fences is ineffective, the drains on the boundaries of the covenanted area are keeping most stock out of this site. Drains are likely to have lowered water tables within parts of this site (both within the covenanted area and in adjacent farmland). The decreased water table may have provided suitable habitat for blackberry to establish at this site. No further drainage channels should be created. It is also recommended that the margins of the geothermal creeks and drains in neighbouring farmland are fenced to exclude stock. Possum control in the covenanted area is recommended. Trampling of vegetation and geothermal features should be kept to a minimum.

Significance Level:

R: Regional (Criteria 1, 3, 5)

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.
² Historical photos: SN 172 Run 1162 Photos 5-6, 1941.

L: Local (Criterion 5)

**Significance
Justification:**

R: Most of this site is of regional significance because it is protected by a conservation covenant and contains a nationally uncommon habitat type (geothermal). It is also the best example of geothermal vegetation associated with the Reporoa Geothermal System. A feature of this site is that the site interior has a relatively low pest plant cover compared with most mānuka and mingimingi-dominant geothermal sites in the Waikato Region.

L: The remainder of the site is locally significant because it contains small lower quality areas of a nationally uncommon habitat type (geothermal).

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and classed Longview Road as Category C - the third category.

Brodnax (2022) recorded mice, rats and possums at this site.

Much of this site is very unstable with very thin crusts and scorching water temperatures. Care should be taken during site inspections. It is not safe to access parts of the site on foot.

References:

Beadel and Bill 2000; Brodnax 2022; Given 1995 & 1996; Spring-Rice 1996; Wildland Consultants 2004c, 2012, 2014.



A large area of geothermal water in southwestern corner of the Longview Road site. Approximate location NZTM E1893519 N5742919. 29 November 2022.



Areas of geothermally influenced bare ground (foreground), pools of geothermal water (midground), and (mānuka)/mingimingi scrub (background) in the centre of the Longview Road site. Approximate location NZTM E1893605 N5743002. 29 November 2022.



WHAREPAPA ROAD¹

Ecological District: Atiamuri **GPS Reference:** NZTM E1890738 N5743011
Geothermal System: Reporoa **Altitude:** 300 m
Bioclimatic Zone: Lowland - Submontane **Local Authority:** Rotorua
Extent of Geothermal Habitat: c. 4.4 ha
Extent of Geothermal Vegetation: c. 4.3 ha
Date of Most Recent Field Survey: 24 January 2017

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) A small area of geothermal kānuka scrub to 3 metres tall. Occasional blackberry, Mercer grass, Chinese privet seedlings, and sheep's sorrel in the understorey.	Gentle slope	<0.1 ha
2.	Mānuka-dominant scrub (04.04) Mānuka scrub (04.04.01) Mānuka-dominant scrub (1-4 metres tall) surrounds geothermal features, with scattered blackberry and occasional geothermal kānuka and mingimingi. Radiata pine are occasionally emergent at the margins, particularly in the most eastern area. Chinese privet is locally present in the western area.	Flat	c.1.0 ha
3.	Mānuka-mingimingi scrub (04.04.02) Mānuka (2-5 metres tall) with abundant mingimingi. Patches of mingimingi-bracken scrub, Yorkshire fog grassland, and occasional geothermal kānuka. Radiata pine, several oaks (<i>Quercus</i> sp.) and silver birch are present on the margins.	Flat	c.0.4 ha
4.	Mānuka-geothermal kānuka-exotic species scrub (04.04.04) Mānuka, geothermal kānuka, and Chinese privet scrub to 7 metres tall. Open areas dominated by mingimingi. Common understorey species include Yorkshire fog, Himalayan honeysuckle, blackberry, Chinese privet seedlings, and <i>Cotoneaster franchetii</i> .	Flat	c.0.9 ha
5.	Exotic species dominated scrub (04.10) Silver birch-Chinese privet/blackberry-(geothermal kānuka) scrub (04.10.02) Occasional to local silver birch and Chinese privet are emergent over blackberry scrub, with scattered broom and patches of geothermal kānuka. Browntop and Yorkshire fog are present in the understorey. Fumaroles and small mud pools present in parts of this type.	Flat/gently rolling	<0.1 ha
6.	Exotic grassland (08.01) Yorkshire fog grassland (08.01.01) Several drains have flowing geothermal water, sometimes on an ephemeral basis, often draining areas of geothermal terraces and springs. There may be geothermal springs and seepages in the	Farm drains	c.0.3 ha

¹ Stevens *et al.* (2003) refers to this site as Opaheke

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	drain system. The margins are often dominated by exotic grassland species including Yorkshire fog, tall fescue, sweet vernal, paspalum, and broad-leaved dock. A few exotic trees and shrubs are present including grey willow, crack willow, radiata pine and broom, and local patches of blackberry. There are scattered populations of arrow grass on the bottom of the drain at several locations. Sinter deposition is often evident in sections of the drain. Mosquito fish were observed in the drain system in 2017.		
7.	(Geothermal kānuka)/rank exotic grasses grassland (08.01.08) Occasional geothermal kānuka over mixed exotic grassland species, including Indian doab, wild seradella, hawksbeard, browntop, Mercer grass, catsear, and lotus. Soil temperature was 15 °C at 5 cm depth on a winter morning in 2010.	Flat	<0.1 ha
8.	Mixed exotic grassland (08.01.15) Two adjacent areas of geothermal vegetation and features separated by a fence, drain and narrow band of pasture, comprising scattered fumaroles, small mud pools, and steaming ground. The northern area has two areas of silicified pumice rocks (the largest of these features is 2.5 m tall and approximately 5 m wide, while the smaller one is 2 m tall and c.3 m wide). The total area of geothermal activity in this area covers an area of c.50 × 20 m and several small fumaroles are present. Surface temperatures in these holes in July 2010 ranged from 51-85 °C (Wildland Consultants 2014). The area with geothermal activity is mostly a short grazed area of rushes, grasses and other herbs including soft rush, browntop, sheep's sorrel, paspalum and c.20% bare ground. Occasional patches of <i>Gonocarpus micranthus</i> occur near geothermal fumaroles. The southern area comprises small mud pools, steaming ground, and fumaroles covering c.30 × 50 m. In July 2010 the temperatures in these pools ranged from c.30 to 90 °C, with the largest pool being 35 °C and measuring 3 × 5 m. Extensive areas of geothermally-influenced bare ground are present with local areas of silicified pumice outcrops. Towards the margins of this feature the cover of vegetation increases with the most abundant species being <i>Juncus effusus</i>, Yorkshire fog, sheep's sorrel, <i>Gonocarpus micranthus</i>, and <i>Cladonia</i> sp. Occasional geothermal kānuka is present. Both of these features are currently grazed by stock, which is detrimental to the establishment of indigenous geothermal species around these features.	Gently sloping/flat	c.0.6 ha
9.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) (i) Sinter terrace, hot pools, occasional geothermal kānuka and mānuka. Scattered patches of Indian doab and hawksbeard. (ii) Bare ground and mud with extensive patches of arrow grass on sediments from geothermal springs. Overflow from geothermal springs was 98 °C during field survey in 2010. (iii) Bare ground, geothermal water and extensive areas of arrow grass. Scattered mānuka seedlings, and <i>Lachnagrostis</i> sp. are present.	Flat	c.1.0 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	(iv) Geothermally-influenced bare ground and several mud pools. The largest mud pool had a temperature of 72 °C in 2010. The bare ground which has a silicified crust is covered with pine needles. Yorkshire fog, and soft rush are present on downstream overflow margins of the mud pool. (v) Geothermally influenced bare ground with mingimingi abundant on margins. (vi) An area of steaming ground that comprises of at least three fumaroles (five were recorded in 2010). The vents (the largest was 0.5 metres wide), were too deep to see the base of, but bubbling was evident in the ground. The fumaroles are surrounded by bare ground (80% of the area described) with increasing cover of vegetation as geothermal influence decreases. Species present include patches of wild portulaca, scattered narrow-leaved carpet grass and a few sheep's sorrel and paspalum.		
10.	Water (22.01) Geothermal water (22.01.01) Several features are present. Several large pools are present in the western part of the site, but are not described separately. These are briefly described below with their location shown on the map. (vii) Hot pool. A pool 2-3 metres wide is surrounded by bare ground with a few emergent geothermal kānuka (to 2 metres tall) and herbaceous species e.g. browntop, sheep's sorrel, dead blackberry, paspalum, Yorkshire fog and bare areas. The temperature in the pool in 2010 was 90 °C with a pH of 7.6. An outcrop of silicified pumice rock appears to have some sinter structure. Stock had access to the pool in 2017. (viii) Geothermal pool (5m²) which in 2010 had a blue colouration (colloidal silica) with a temperature of 99 °C. The water discharges through a dug drain that has probably lowered the original height/depth of the pool. The pool is surrounded by a small sinter apron, which in turn is surrounded by varied vegetation including local patches of <i>Campylopus</i> mossfield, <i>Cladonia</i> lichenfield, <i>Histiopteris incisa</i>, paspalum, and <i>Gonocarpus micranthus</i>. Scattered geothermal kānuka, creeping bent and sheep's sorrel are also present. A small area of mostly geothermally-influenced bare ground occurs to the north of the pool site. (ix) Geothermal spring in ditch surrounded by rank exotic grasses, particularly reed sweetgrass and Yorkshire fog. The temperature was c.47 °C in 2010 with green and orange algae present near the spring outflow and drainage channel. (x) This feature is 1.5m² mud pool, c.1 metre deep. The pool is surrounded by pasture with abundant sheep's sorrel and narrow-leaved carpet grass.	Open water, streams, springs	<0.1 ha

Indigenous Flora:

Small populations of both geothermal kānuka (Threatened – Nationally Endangered) and *Campylopus* sp. are present; both are endemic species restricted to geothermal areas. Other species characteristic of geothermal habitat present include mingimingi, mānuka, and *Histiopteris incisa*. The presence of *Machaerina arthropophylla* at this site is of botanical interest, although it was not recorded in the 2010 or 2017 surveys.

Fauna:	A common and typical range of indigenous and introduced bird species have been recorded from adjacent farm and geothermal habitats at Wharepapa Road in surveys between 2004 and 2017. Indigenous species include little shag (At Risk-Relict), matuku moana/white-faced heron, pūkeko, kāhu/swamp harrier, poaka/pied stilt, spur-winged plover, pīhoihoi/New Zealand pipit (At Risk-Declining), warou/welcome swallow, riroriro/grey warbler, pīwakawaka/North Island fantail, and tauhou/silvereye. Introduced species include mallard, Eurasian skylark, European goldfinch, European greenfinch, yellowhammer, chaffinch, house sparrow, Australian magpie, and common starling. Mosquitofish were recorded in drains in 2017.
Geothermal Ecosystems:	Heated ground (dry), hydrothermally altered ground (now cool), geothermal streamsides, fumaroles, geothermal wetlands.
Current Condition:	Most of the site comprises small and isolated geothermal areas surrounded by farmland. The geothermal areas have been highly modified by dairy farming and the dumping of rubbish and are in poor condition. Most of the site are fenced to exclude stock and have geological features of high significance (see Appendix 4 for a geophysical assessment of features at this site). Pest plants are common, but there is good potential habitat for indigenous geothermal plants to increase their cover and diversity in these areas with appropriate management. The values of the site are likely to improve if the unfenced geothermal features are fenced to exclude stock.
Threats/Modification/Vulnerability:	
<i>Invasive pest plants:</i>	Several exotic species occur within the site and are likely to increase in extent under current management. Key weed species present are rank pasture grasses (26-50% cover), <i>Cotoneaster franchettii</i> (1-5% cover), blackberry (6-25% cover), oaks (1-5% cover), silver birch (1-5% cover), and pine species (including radiata pine, maritime pine, lodgepole pine) (5-25% cover). Silver birch and pines could damage geothermal features if they fall into them.
<i>Human impacts:</i>	Rubbish disposal is the main human-related threat to these areas. Rubbish, which includes litter, fencing material, white-ware, and garden refuse, has been dumped on the sinter terraces and geothermal sediments. Several drainage channels from the hot pools extend across the farmland, and these have lowered the water table and altered ground temperatures. Several geothermal baths are present at the site. One of the pools was used by pig hunters to clean their pigs. Harvesting of trees has caused considerable damage to geothermal features at one location. Many features are threatened by farming activities (see below).
<i>Grazing:</i>	Most of the areas are currently fenced but the fences may not necessarily keep all stock out. Fencing should be upgraded and maintained to ensure livestock are excluded from all geothermal areas.
<i>Adjoining land use:</i>	Dairy farming.

Site Change:

Recent change: Not assessed, most recent survey was in 2017.

*Historical:*¹ Historical photos of the site from 1941² were compared with 2007 aerial photographs to assess long-term change at this site. The development of farmland around these geothermal sites was less intense in 1941, with areas of shrubland linking most of the features. The geothermal activity in the northeast of the site appears to have become more active. The area that currently comprises mud pools and bare ground appears to have been dominated by shrubland in 1941 (there may have been geothermal features), and the area of bare ground present in 2010 is about five times the size it was in 1941. The large area of geothermal habitat in the southwest of the site appears to comprise a larger area of bare ground in 1941 than in 2007. Taking into account shrubland masking geothermal surface features in the 1941 photographs and the subsequent conversion of the site to pasture, a best estimate is that geothermal habitat in 1941 would have been about three times larger than that currently present (and mapped) at Wharepapa Road.

Management Requirements:

Stock access to some areas and dumping of rubbish should be prevented. Planting of exotic species around geothermal features should be discontinued, and the impacts of the drainage channels should be monitored. Consideration should be given to fencing to exclude stock from all geothermal features within this site. Pest plants (particularly trees that could fall into features) should be controlled.

Significance Level: Local (Criteria 3, 5,6)

Significance Justification: The site is of local significance because it is an example of a habitat type that is nationally uncommon (geothermal).

Notes: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category B - the second highest category.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4.

References: Given 1995 & 1996; Spring-Rice 1996; Stephens *et al.* 2003, Waikato Regional Council (undated); Wildland Consultants 2000, 2004c, 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 172 Run 1162 Photos 2-3, 1941.



The largest and highest quality areas of geothermal vegetation at the Wharepapa Road Site (western-area). It contains wetland dominated by arrow grass and is surrounded by mānuka scrub. NZTM E1890820 N5743010. 24 January 2017.



This pool is c.5 m², and stock can access some of the geothermal vegetation through the existing fence. NZTM E1890852 N5742780. 24 January 2017.



A 1.5 m² isolated geothermal mud pool, unfenced and surrounded by pasture. NZTM E1891092 N5742911. 24 January 2017.



A large mud pool with areas of bare ground surrounded by mingimingi-mānuka scrub with emergent pines and oaks. NZTM E1891134 N5743013. 24 January 2017.

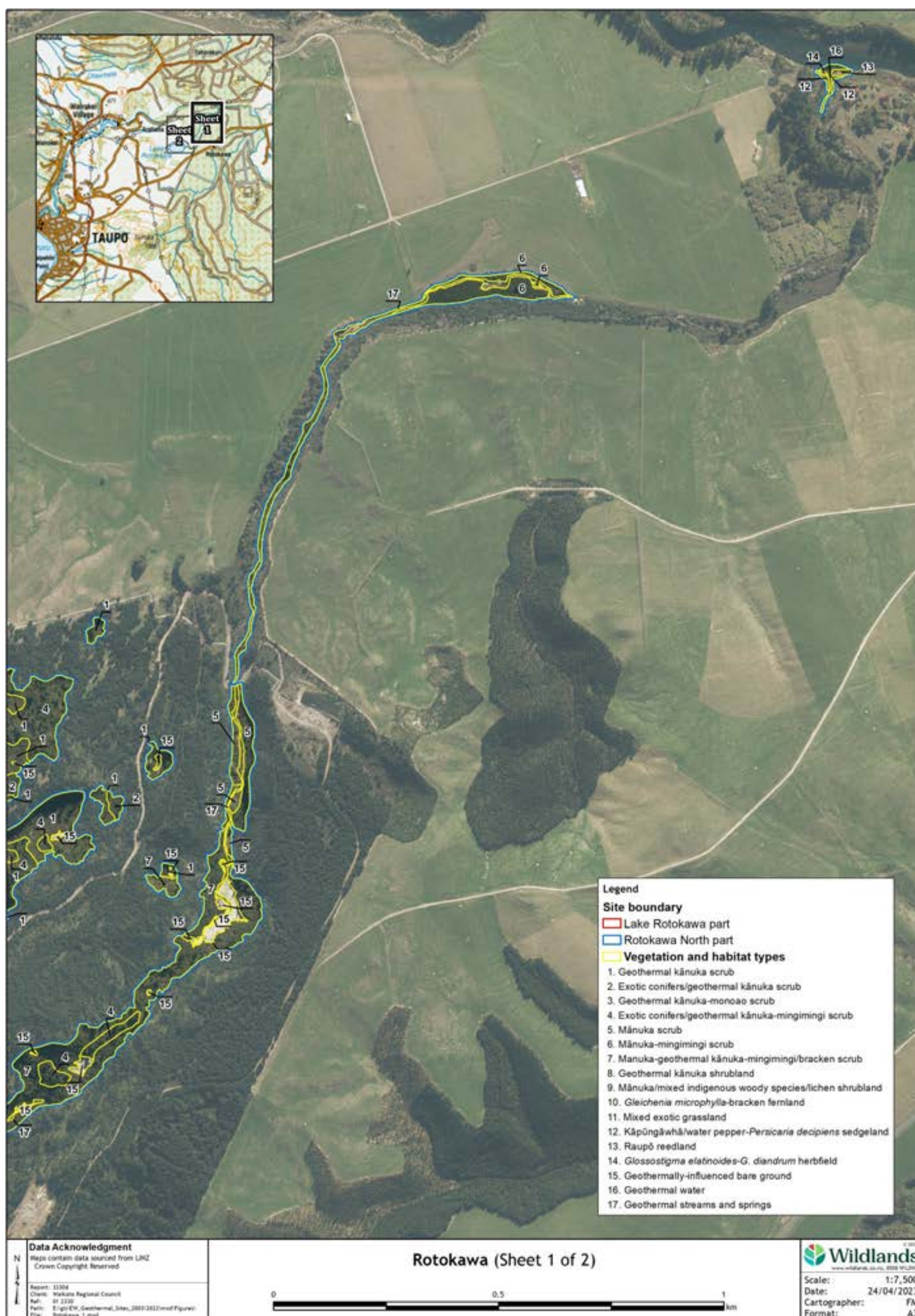
VASCULAR PLANT SPECIES RECORDED AT SURFACE GEOTHERMAL SITES IN THE REPOROA GEOTHERMAL SYSTEM

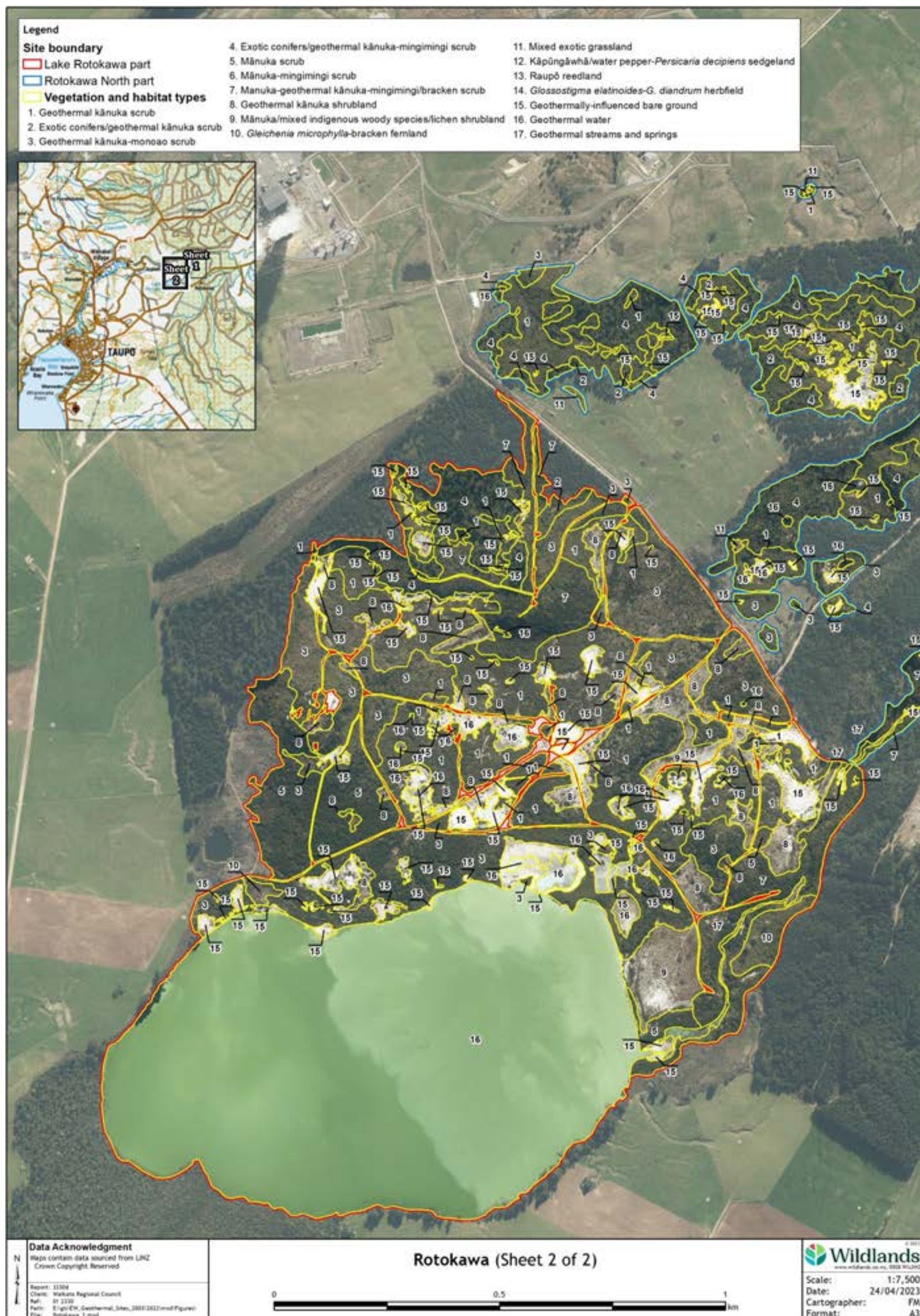
Scientific Name	Common Name	Longview	Golden Springs	Wharepapa
INDIGENOUS SPECIES				
Monocot. trees and shrubs				
<i>Cordyline australis</i>	Ti kōuka, cabbage tree		✓	✓
Dicot. trees and shrubs				
<i>Kunzea robusta</i>	Kānuka		✓	
<i>Kunzea tenuicaulis</i>	Geothermal kānuka		✓	✓
<i>Leptospermum scoparium</i>	Mānuka	✓		✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓		✓
Dicot. lianes				
<i>Calystegia sepium</i> subsp. <i>roseata</i>	Pōhue		✓	✓
<i>Muehlenbeckia australis</i>	Puka	✓		
<i>Muehlenbeckia complexa</i>	Pōhuehue	✓		
Ferns				
<i>Asplenium flaccidum</i> subsp. <i>flaccidum</i>	Makawe, ngā makawe o raukatauri, drooping splenwort	✓	✓	
<i>Blechnum minus</i>	Swamp kiokio		✓	✓
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio		✓	✓
<i>Christella</i> aff. <i>dentata</i> (b) (AK 126902 "thermal")			✓	
<i>Cyathea dealbata</i>	Ponga, silver fern		✓	
<i>Deparia petersenii</i> subsp. <i>congrua</i>			✓	
<i>Dicksonia fibrosa</i>	Wheki-ponga, kuripākā		✓	
<i>Dicksonia squarrosa</i>	Wheki	✓	✓	✓
<i>Diplazium australe</i>			✓	
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	✓	✓
<i>Hiya distans</i>		✓		
<i>Hypolepis ambigua</i>		✓	✓	
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pāraharaha, hound's tongue fern	✓		
<i>Pellaea rotundifolia</i>	Tarawera, button fern		✓	
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	✓	
<i>Pteris tremula</i>	Turawera, shaking brake		✓	
Grasses				
<i>Lachnagrostis</i> sp.				✓
Sedges				
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio		✓	✓
<i>Carex virgata</i>	Pūrei	✓	✓	
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata	✓	✓	
<i>Machaerina arthropophylla</i>				✓
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā		✓	
Monocot. herbs (other than orchids, grasses, sedges, and rushes)				
<i>Dianella nigra</i>	Tūrutu	✓		
<i>Lemna disperma</i>	Karearea			✓
<i>Phormium tenax</i>	Harakeke, flax		✓	✓
<i>Triglochin striata</i>	Arrow grass	✓		
<i>Typha orientalis</i>	Raupō	✓	✓	
<i>Wolffia australiana</i>			✓	
Composite herbs				
<i>Senecio bipinnatisectus</i>	Australian fireweed		✓	
Dicot. herbs (other than composites)				
<i>Gonocarpus micranthus</i>	Piripiri			✓
NATURALISED AND EXOTIC SPECIES				
Gymnosperms				
<i>Chamaecyparis lawsoniana</i>	Lawson's cypress			✓
<i>Cryptomeria japonica</i>	Japanese cedar			✓

Scientific Name	Common Name	Longview	Golden Springs	Wharepapa
<i>Cupressus macrocarpa</i>	Macrocarpa		✓	
<i>Pinus pinaster</i>	Maritime pine			✓
<i>Pinus radiata</i>	Radiata pine	✓	✓	✓
<i>Pseudotsuga menziesii</i>	Douglas fir		✓	✓
<i>Sequoia sempervirens</i>	Coast redwood			✓
Monocot. trees and shrubs				
<i>Trachycarpus fortunei</i>	Chinese windmill palm			✓*planted
Dicot. trees and shrubs				
<i>Abelia ×grandiflora</i>			✓	
<i>Alnus</i> sp.			✓	
<i>Berberis glaucocarpa</i>	Barberry	✓		
<i>Betula pendula</i>	Silver birch		✓	✓
<i>Cotoneaster franchetii</i>				✓
<i>Crataegus monogyna</i>	Hawthorn		✓	
<i>Cytisus scoparius</i>	Broom		✓	✓
<i>Eucalyptus</i> sp.	Eucalyptus			✓
<i>Hydrangea macrophylla</i>	Hydrangea		✓	
<i>Ligustrum sinense</i>	Chinese privet		✓	✓
<i>Mahonia lomariifolia</i>	Mountain grape		✓*planted	
<i>Populus</i> sp.			✓	✓
<i>Prunus</i> sp.	Ornamental cherry		✓	
<i>Quercus robur</i>	English oak			✓
<i>Quercus</i> sp.	oak		✓	
<i>Rosa</i> sp.	Climbing rose			✓
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓	
<i>Salix cinerea</i>	Grey willow		✓	✓
<i>Salix ×fragilis</i>	Crack willow		✓	✓
Dicot. lianes				
<i>Actinidia deliciosa</i>	Kiwifruit		✓	
<i>Calystegia silvatica</i>	Greater bindweed		✓	
<i>Hedera helix</i>	Ivy		✓	
<i>Lonicera japonica</i>	Japanese honeysuckle		✓	
<i>Vinca major</i>	Periwinkle		✓	
Lycopods and psilopsids				
<i>Selaginella kraussiana</i>	Creeping clubmoss, selaginella		✓	
Grasses				
<i>Agrostis capillaris</i>	Browntop		✓	✓
<i>Agrostis stolonifera</i>	Creeping bent			✓
<i>Anthoxanthum odoratum</i>	Sweet vernal			✓
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass			✓
<i>Bromus willdenowii</i>	Prairie grass	✓		
<i>Cortaderia selloana</i>	Pampas		✓	
<i>Cynodon dactylon</i>	Indian doab			✓
<i>Dactylis glomerata</i>	Cocksfoot		✓	✓
<i>Glyceria maxima</i>	Reed sweetgrass			✓
<i>Holcus lanatus</i>	Yorkshire fog	✓	✓	✓
<i>Lolium arundinaceum</i> subsp. <i>arundinaceum</i>	Tall fescue		✓	✓
<i>Lolium perenne</i>	Ryegrass		✓	
<i>Paspalum dilatatum</i>	Paspalum		✓	✓
<i>Paspalum distichum</i>	Mercer grass			✓
<i>Poa annua</i>	Annual poa		✓	
<i>Pseudosasa japonica</i>	Arrow bamboo		✓	
Sedges				
<i>Carex longibrachiata</i>	Australian sedge		✓	
<i>Cyperus eragrostis</i>	Umbrella sedge		✓	
Rushes				
<i>Juncus acuminatus</i>	Sharp-fruited rush			✓
<i>Juncus effusus</i> var. <i>effusus</i>	Soft rush, leafless rush	✓		✓
<i>Juncus tenuis</i> var. <i>tenuis</i>	Track rush			✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)				
<i>Agapanthus praecox</i>	Agapanthus		✓	
<i>Crocodymia ×crocodymiflora</i>	Montbretia		✓	
Composite herbs				
<i>Achillea millefolium</i>	Yarrow			✓
<i>Bellis perennis</i>	Lawn daisy		✓	
<i>Bidens frondosa</i>	Beggars' ticks			✓

Scientific Name	Common Name	Longview	Golden Springs	Wharepapa
<i>Cirsium arvense</i>	Californian thistle			✓
<i>Cirsium vulgare</i>	Scotch thistle		✓	✓
<i>Crepis capillaris</i>	Hawksbeard		✓	
<i>Erechtites hieraciifolia</i>	American fireweed		✓	
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane		✓	
<i>Gamochaeta coarctata</i>	Purple cudweed			✓
<i>Hypochaeris radicata</i>	Catsear		✓	✓
<i>Jacobaea vulgaris</i>	Ragwort			✓
<i>Lactuca serriola</i>	Prickly lettuce		✓	
<i>Leucanthemum vulgare</i>	Oxeye daisy			✓
<i>Sonchus oleraceus</i>	Puha, sow thistle			✓
<i>Taraxacum officinale</i>	Dandelion			✓
Dicot. herbs (other than composites)				
<i>Begonia</i> 'semperflorens-cultorum hybrids'			✓*planted	
<i>Centaurea erythraea</i>	Centauray			✓
<i>Cerastium fontanum</i> subsp. <i>vulgare</i>	Mouse-ear chickweed			✓
<i>Chenopodium album</i>	Fathen			✓
<i>Digitalis purpurea</i>	Foxglove		✓	
<i>Fumaria muralis</i>	Scrambling fumitory		✓	
<i>Galeobdolon luteum</i>	Aluminium plant		✓	
<i>Geranium molle</i>	Dovesfoot cranesbill		✓	
<i>Lotus pedunculatus</i>	Lotus	✓	✓	✓
<i>Ludwigia palustris</i>	Water purslane		✓	✓
<i>Modiola caroliniana</i>	Creeping mallow			✓
<i>Myosotis</i> sp.	Forget-me-not		✓	
<i>Nasturtium officinale</i>	Watercress			✓
<i>Ornithopus perpusillus</i>	Wild seradella			✓
<i>Persicaria maculosa</i>	Willow weed			✓
<i>Petroselinum crispum</i>	Parsley		✓	
<i>Plantago lanceolata</i>	Narrow-leaved plantain		✓	✓
<i>Plantago major</i>	Broad-leaved plantain		✓	✓
<i>Polygonum aviculare</i>	Wireweed			✓
<i>Portulaca oleracea</i>	Wild portulaca			✓
<i>Prunella vulgaris</i>	Selfheal		✓	✓
<i>Ranunculus flammula</i>	Spearwort	✓		✓
<i>Ranunculus repens</i>	Creeping buttercup		✓	✓
<i>Rumex acetosella</i>	Sheep's sorrel			✓
<i>Rumex obtusifolius</i>	Broad-leaved dock		✓	✓
<i>Solanum nigrum</i>	Black nightshade		✓	
<i>Stellaria media</i>	Chickweed		✓	
<i>Trifolium pratense</i>	Red clover		✓	
<i>Trifolium repens</i>	White clover		✓	✓
<i>Viola</i> sp.			✓	

21. ROTOKAWA GEOTHERMAL SYSTEM





ROKOKAWA¹

Ecological District: Atiamuri
Geothermal System: Rotokawa
Bioclimatic Zone: Submontane
Extent of Geothermal Habitat: c.217.8 ha
Extent of Geothermal Vegetation: c.144.8 ha
Date of Most Recent Field Survey: 6 October 2021, 14 March 2023

GPS Reference: NZTM E1877887 N5719763
Altitude: 300-385 m
Local Authority: Taupō

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka scrub forms a more or less continuous canopy with a cover of greater than 80% to a height of between 0.3 to 2.0 metres. This scrub often grades into shrubland near areas of geothermally-influenced bare ground or disturbed areas. Emergent wilding pines (mostly radiata pine with some maritime pine) are scattered throughout the northern part of the site. Extensive wilding pine control has been undertaken on the northern side of the lake (part previously mapped as Lake Rotokawa). Local mingimingi, monoao, prickly mingimingi, rārahu/bracken and tūrutu are often present. Tāwiniwini, <i>Lycopodiella cernua</i> , and <i>Paesia scaberula</i> are present. Soil temperatures of up to 80 °C at 0-10 centimetres depth have been recorded in this habitat type. Kānuka and mānuka are locally common on cooler soils. As well as pines there is local gorse, buddleia, broom, and blackberry. Some recent invasion of narrow-leaved carpet grass was evident in 2021 in the northern parts of the site. Fumaroles, thermal springs, and gas vents are scattered throughout this vegetation type.	Flat and gentle hillslopes	c.40.1 ha
2.	Exotic conifers/geothermal kānuka scrub (04.01.03) This type is similar to Vegetation and Habitat Type 1, but with scattered emergent wilding conifers (predominantly radiata pine and maritime pine). Wilding pines are more abundant in the northern part of the site. <i>Lycopodiella cernua</i> , mingimingi, narrow-leaved carpet grass, Mercer grass, prickly mingimingi, bracken, tangle fern, <i>Paesia scaberula</i> , and <i>Hiya distans</i> are scattered throughout. Mingimingi and blackberry become more common towards the margins. Sheep's sorrel and wild serradella occur in disturbed sites.	Flat and gentle hillslopes	c.1.8 ha
3.	Geothermal kānuka-monoao scrub (04.01.06) Geothermal kānuka, monoao and mānuka are all locally dominant with scattered wilding pines (radiata pine and maritime pine). Canopy height varies between 0.3 metres (often geothermal kānuka) to c.4 metres (often mānuka). Monoao often forms extensive patches, particularly within the central part of the area on the northern side of the lake (previously mapped as Lake Rotokawa). Prickly mingimingi, rārahu (bracken), tāwiniwini, gorse, <i>Paesia scaberula</i> and tūrutu are locally abundant.	Flat and gentle hillslopes	c.31.1 ha

¹ The site Rotokawa is an amalgamation of two sites described in Wildland Consultants 2014a: Rotokawa North and Lake Rotokawa.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
4.	Geothermal kānuka-mingimingi scrub (04.02) Exotic conifers/geothermal kānuka-mingimingi scrub (04.02.03) Wilding conifers (mostly radiata pine and maritime pine) are scattered to common, above geothermal scrub dominated by geothermal kānuka, mingimingi, and mānuka. The scrub is between 0.3 and two metres tall, with small patches of monoao, bracken, and geothermally-influenced bare ground. Tūrutu is scattered throughout. Prickly mingimingi, tāwiniwini, gorse, <i>Lycopodiella cernua</i>, and <i>Paesia scaberula</i> are also present.	Flat and gentle hillslopes	c.17.6 ha
5.	Mānuka-dominant scrub (04.04) Mānuka scrub (04.04.01) This type is mostly located on the margins of geothermal areas. The western-most area comprises mānuka scrub and mixtures of mānuka, mingimingi, local whekī-ponga, rārahu (bracken), and tāwiniwini with occasional toetoe. The average canopy height is 2-5 metres. Geothermal kānuka is occasionally present on road margins. Scattered indigenous shrubs (mostly mānuka, mingimingi and some prickly mingimingi and monoao) are present over lichen and patches of bare ground within this vegetation type. Bare patches with a pumice substrate are also present. Soil temperatures were cool in this area during the 2021 field survey. While this vegetation has some similarity to geothermally-influenced scrub and shrubland, cool soils and the low occurrence of geothermal kānuka indicates that the low fertility pumice soils are more likely to be the main factor that has led to the formation of this vegetation type here. On the margins of Parariki Stream, mānuka occurs over an understorey dominated by mingimingi and rārahu/bracken. <i>Lycopodiella cernua</i>, <i>Histiopteris incisa</i>, and <i>Hypolepis ambigua</i> are locally common. There are local patches of gorse and occasional emergent radiata pine, eucalyptus, and Douglas fir. Small patches of geothermal kānuka, blackberry, and pampas form a canopy up to five metres in height over bare soil on some moderate to steep slopes within this scrub. Local patches of umbrella sedge, <i>Cyperus ustulatus</i>, and <i>Eleocharis gracilis</i> occur close to the stream edge.	Flat, riparian margins, and gentle hillslopes	c.9.5 ha
6.	Mānuka-mingimingi scrub (04.04.02) Mānuka and mingimingi form a scrub canopy, 1-5 metres tall alongside the northern section of Parariki Stream. Surface water temperatures of up to 29 °C were recorded in this section of the stream in 2014. <i>Lycopodiella cernua</i>, <i>Histiopteris incisa</i>, and <i>Hypolepis ambigua</i> are locally common. Patches of bracken fernland are present within this type, within local patches of gorse and occasional emergent radiata pine, eucalyptus, and Douglas fir. Small patches of geothermal kānuka, blackberry, and pampas form a canopy up to c.5 metres tall over bare ground on some moderate to steep slopes within this type. Local patches of umbrella sedge, <i>Cyperus ustulatus</i>, and <i>Eleocharis gracilis</i> occur close to the stream edge.	Riparian margins	c.1.3 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
7.	Mixed indigenous species scrub (04.08.01) Mānuka-geothermal kānuka-mingimingi/bracken scrub (04.08.01) This scrub vegetation type is similar to Vegetation and Habitat Type 3, but is generally taller (c.4 metres tall), with mānuka, geothermal kānuka, mingimingi, and rārahu/bracken. Predominant wilding pines (radiata pine and maritime pine) are scattered throughout.	Flat, hillslopes, and riparian margins	c.18.9 ha
8.	Geothermal kānuka-dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Geothermal kānuka shrubland occurs near areas of geothermally-influenced bare ground or disturbed areas, geothermal kānuka forms 20-80% of the cover to a height of up to 1.5 metres. Mānuka, mingimingi, monoao, prickly mingimingi, rārahu/bracken, gorse, and tūrutu are often present locally. Soil temperatures of up to 80 °C at 0-10 centimetres depth have been recorded in this habitat type. Between the shrubs there is bare ground and local patches of lichens (<i>Cladonia</i> and <i>Cladia</i> species) and pātōtara. Fumaroles, thermal springs, and gas vents are scattered throughout this habitat type. These areas encompass a relatively wide diversity of vegetation, mainly associated with variations in the intensity of past human disturbance from mining.	Flat and gentle hillslopes	c.8.8 ha
9.	Mānuka-dominant shrubland (05.04) Mānuka/mixed indigenous woody species/lichen shrubland (05.04.07) This area near Parariki Stream was mapped as lichenfield in earlier assessments. This change from lichenfield to an increasing cover of indigenous woody species, is a slow ongoing process following a history of mining disturbance. Scattered woody species (mostly mānuka, mingimingi with some prickly mingimingi and monoao) are present over extensive lichens and bare ground. Bare patches of pumice substrate are also present. Soil temperatures were cool in this area at the time of the 2021 field survey. The vegetation has elements of geothermal influence, although its structure may also be due to the pumice soils that typically have low fertility. The flat landform within this vegetation and habitat type may reflect historic disturbance from sulphur mining activities.	Flat	c.2.9 ha
10.	Indigenous fernland (07.01) Mixed fernland (07.01.07) <i>Gleichenia microphylla</i>-bracken fernland There are two areas of fernland on the northern side of the lake. The area on the western side of the lake is dominated by tangle fern and the area alongside an access road on the eastern side of the lake is dominated by rārahu/bracken. The height of the fernland is c.0.75 metres tall. Woody shrubs such as broom and mānuka are often present. <i>Histiopteris incisa</i> is also present.	Flat and gentle hillslopes	c.1.5 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
11.	Exotic grassland (08.01) Mixed exotic grassland (08.01.15) Exotic grassland dominated by narrow-leaved carpet grass, paspalum and Indian doab with occasional geothermal kānuka. Wild serradella and wild portulaca are common. Narrow-leaved carpet grass has become more abundant in the area since 2017.	Gentle slope, and gully	c.0.2 ha
12.	Indigenous sedgeland (09.01) Kāpūngāwhā/water pepper-<i>Persicaria decipiens</i> sedgeland (09.01.06) Sedgeland dominated by kāpūngāwhā occurs on a small geothermally-influenced river flat adjacent to the Waikato River. Water pepper and <i>Persicaria decipiens</i> are present throughout, with local umbrella sedge.	River margin	<0.1 ha
13.	Reedland (11.01) Raupō reedland (11.01.01) Reedland dominated by raupō occurs on a small geothermally-influenced river flat adjacent to the Waikato River. <i>Calystegia tuguriorum</i> is common, kāpūngāwhā is locally common, and <i>Carex secta</i> is scattered throughout. A small area of scrub dominated by geothermal kānuka, blackberry, <i>Juncus acuminatus</i> , and <i>Carex geminata</i> with occasional grey willow, occurs on the landward side of the reedland (too small to map separately).	River margin	<0.1 ha
14.	Herbfield (13.01) <i>Glossostigma elatinoides</i>-<i>G. diandrum</i> herbfield (13.01.03) Submerged indigenous turfs dominated by <i>Glossostigma elatinoides</i> and <i>G. diandrum</i> occur on the margins of the Waikato River around geothermal springs. Water temperatures of 63.8 °C were recorded here in 2014. Water purslane, <i>Callitriche petriei</i> , and <i>Myriophyllum pedunculatum</i> are present in cooler areas.	River margin	<0.1 ha
15.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Areas of heated pumice soils with no vegetation, or very limited vegetation present, including sinter and fumaroles. Small areas of lichenfield and mossfield are included within this type. Local sinter deposits are present alongside Parariki Stream. Occasional patches of geothermal kānuka and broom are present. Local areas which have been mined for sulphur are present throughout.	Flat, gently sloping	c.11.0 ha
16.	Water (22.01) Geothermal water (22.01.01) This habitat type comprises geothermal water, springs, and mudpools. These include Lake Rotokawa itself and the heated pools on its margins. There are also geothermal springs on the margins of the Waikato River (up to c.15 metres from the river margins).	Lake, riparian gully, craters	c.70.7 ha
17.	Geothermal streams and springs (22.01.03) Geothermal streams including Parariki Stream.	Gully	c.2.3 ha

Indigenous Flora:

Geothermal kānuka (Threatened-Nationally Endangered) and *Lycopodiella cernua* are present.

Small populations of the ferns, *Dicranopteris linearis* (Threatened-Nationally Endangered) (c.10 plants) and *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) (c.2 plants), were present in 2004 on the sides of a hot spring in the northern part of the site at GPS reference: E1877709 N5721043, but are probably no longer present.

The terrestrial orchid *Calochilus robertsonii* (At Risk-Naturally Uncommon) occurs on the flats on the northern side of Lake Rotokawa; a total of c.36 plants were recorded in November 2019 (Wildland Consultants 2020) and c.70 plants were recorded in 2006 (Bycroft 2008).

Other indigenous species typical of geothermal habitat that are present include monoao, tāwiniwini, mānuka, prickly mingimingi, mingimingi, *Gleichenia microphylla*, *Histiopteris incisa*, tūrutu, and bracken.

Brownsey and Perrie (2022b) note an outlying population of *Thelypteris confluenta* (At Risk-Naturally Uncommon) is present at Lake Rotokawa near Taupō. We have not seen this species at this site; it is most likely to be present in the wetland at the southern end of Lake Rotokawa, outside of the areas mapped as geothermal habitat.

Fauna:

Avifauna species recorded during recent visits by the authors include: pīhoihoi/New Zealand pipit (At Risk-Declining), mātātā/North Island fernbird (At Risk-Declining), kārearea/New Zealand ‘bush’ falcon (Threatened-Nationally Increasing), korimako/bellbird, kāhu/Australasian harrier, spur-winged plover, pīwakawaka/North Island fantail, riroriro/grey warbler, tūi, kuruwhegi/Australasian shoveler, kōtare/sacred kingfisher, and warou/welcome swallow. Introduced species present include Australian magpie, common myna, California quail, and common pheasant.

Tūturiwhatu/banded dotterel and tarāpuka/black-billed gull (both At Risk-Declining) have been recorded breeding around Lake Rotokawa (Merrett and Burns 1997, Wildland Consultants 2014a). Poaka/pied stilts, nesting karoro/black-backed gulls, and other water birds are also present on and around the lake.

Geothermal water in Lake Rotokawa is highly acidic (NIWA 2002). There have been several surveys of the aquatic biota. *Chironomus zealandicus* is the only chironomid midge to have been recorded from Lake Rotokawa (NIWA 2002). Other invertebrates recorded from the lake include the water boatman bug *Sigara arguta* and mosquito *Culex rotoruae* (Forsyth 1977), the water bug *Saldula stoneri* and fly *Neoscatella* sp. (Duggan and Boothroyd 2002), a diving beetle *Liodessus* sp., a lacewing *Kempynus* sp., and mites (Acari) (James and Kolb 2009).

Parariki Stream provides good habitat for *Chironomus zealandicus* and other insects including *Culex rotoruae*, *Ephydrella thermarum*, and *Microvelia macgregori* (Forsyth 1977).

Possum and rabbit sign was observed in 2023. Pig sign (scat) was observed during the 2014 survey. Some trapping of small pest animals is undertaken within part of this site.

**Geothermal
Ecosystems:**

Hydrothermally altered ground (now cool), heated ground (dry), geothermal wetlands, geothermal streamsides, fumaroles.

Current Condition:

This area and its surrounds have been modified by forestry operations and pastoral farming, resulting in a reduction in extent of geothermal vegetation and habitats. Areas near Lake Rotokawa have also been extensively modified during more than 20 years of sulphur mining (in the 1960s to 1980s), resulting in vegetation clearance and alteration of contours. However, indigenous geothermal vegetation has now re-established on much of these areas.

Pest plant control, particularly of wilding pines, has markedly improved the ecological condition of geothermal vegetation and habitats near the lake in recent years.

Invasive exotic plant species form a large component of the vegetation in the northern part of the site, in particular wilding pines (mainly radiata pine and maritime pine), which in some areas dominate the canopy over a lower tier of indigenous vegetation dominated by species characteristic of geothermal areas. However, geothermal vegetation remains relatively intact around several craters and areas of geothermally-influenced bare ground. Two areas of geothermally-influenced bare ground within the farmland have declined in condition since 2004 and now support exotic grassland with occasional geothermal kānuka.

Near the Waikato River, pest plants are common and the site is likely to be disturbed on an intermittent basis during duck hunting season (a maimai is present within the site).

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Rotokawa North part:

Wilding pines (6-80% cover) are visually dominant, and are a serious threat to plant communities, particularly on cooler ground. In many areas pines are dominant over a lower indigenous tier comprising geothermal kānuka and mingimingi. Some wilding pine control has been undertaken along the margins of the geothermal stream. Other invasive pest plant species present include broom (5% cover), pampas (3% cover), gorse (2% cover), blackberry (2% cover), silver birch (2% cover), Spanish heath (1% cover), umbrella sedge (1% cover), Himalayan honeysuckle (1% cover), buddleia (1% cover), pasture grasses (including narrow-leaved carpet grass, creeping bent, browntop, sweet vernal, Yorkshire fog, paspalum, Indian doab, and ryegrass) (1% cover), Montpellier broom (1% cover), tree lucerne (<1% cover), and grey willow (<1% cover).

Lake Rotokawa part:

Extensive wilding pine control has been undertaken in recent years, and pines are no longer visually dominant within the site (c.1% total cover). However, local patches of wilding pines continue to be a serious threat to indigenous plant communities on cooler ground in the western area. Other invasive pest plant species present include silver birch (<1% cover), broom (1% cover),

Himalayan honeysuckle (<1% cover), loquat (<1% cover), buddleia (<1% cover), gorse (1% cover), blackberry (<1% cover), Montpellier broom (<1% cover), pampas (1% cover), and pasture grasses (including creeping bent, browntop, sweet vernal, Yorkshire fog, and ryegrass) (1-5% cover).

Human impacts:

Two geothermal power stations (Rotokawa A and Ngā Awa Pūrua) have been installed in close proximity to the site. The ecological effects of extraction of geothermal energy are being monitored.

Rotokawa North part:

Forestry and pastoral farming occurs between areas of indigenous geothermal vegetation. A maimai is present on the lower hillslope above the lake kāpūngāwhā sedgeland immediately beside Parariki Stream near the Waikato River.

Lake Rotokawa part:

Historical human impacts on this area have been significant and mainly associated with the extraction of sulphur, however this has now ceased. Control of wilding pines has been undertaken over large parts of this site.

Grazing:

Rotokawa North part:

Livestock have access to some of the smaller areas of geothermal vegetation.

Lake Rotokawa part:

The site is fenced to exclude stock.

Adjoining land use:

Geothermal power station and infrastructure, plantation forest and farmland, riparian margins, and Waikato River.

Site Change:

Recent change:

Rotokawa North part:

An additional area of geothermal vegetation was added to this site, between the central north-south access track and Parariki Stream, based on recent field surveys and the better-quality aerial photographs available in 2023 compared with previous years. The cover and abundance of wilding pines has increased markedly since 2014. Other changes are generally based on better site information and aerial photograph quality rather than real change in the total extent of geothermal vegetation.

Lake Rotokawa part:

The extent of this part of the site has increased because areas of mānuka scrub, mixed fernland, and geothermal kānuka-monoao scrub have been added to the site since 2014, based on recent field surveys. The vegetation is continuing to improve in quality over time as it re-establishes after a history of mining and road construction throughout this site. Pest plant control, particularly wilding pines, has improved the ecological quality of this part of the site in recent years. Geothermal kānuka shrubland has established on several areas that were previously geothermally-influenced bare ground and lichenfield.

Historical:¹

Rotokawa North part:

Comparison of 1941 aerial photographs² and 2007 aerial photographs was undertaken. In the 1941 photo the areas of indigenous vegetation around the geothermal features were smaller than they are now. However by 2007, extensive areas had been planted in pine plantation. The extent of wilding pines in geothermal habitats appear to be minimal in 1941. While more bare ground was present in 1941, it is difficult to determine if these areas reflect surface geothermal activity or clearance caused by farming activities (e.g. stock).

Lake Rotokawa part:

Comparison of 2007 and 1941³ aerial photographs show dramatic change in this site. In 1941, it appears that the site was farmed, and there were few wilding pines amongst geothermal vegetation and habitat. More bare ground appears to have been present in 1941, but this may be non-geothermal bare ground rather than geothermal bare ground.

Extensive sulphur mining was undertaken at this site between the 1960s to 1980s, stripping large areas of hot ground, destroying contours and geothermal vegetation in the vicinity.

**Management
Requirements:**

Monitoring should continue to assess the ecological effects of extraction of geothermal energy, in concordance with resource consent conditions.

Rotokawa North part:

A management plan for pest plant control, particularly wilding conifers, should be prepared and implemented for this site. The spread of wilding pines and other exotic trees needs to be contained, with emphasis on those areas which are still predominantly indigenous. Pest plant control within this site should complement the work that has already been undertaken within the Lake Rotokawa part of the site. Pampas and grey willow control should be undertaken within the part of this site near the Waikato River.

Lake Rotokawa part:

Follow-up control of wilding pines should be undertaken on a regular basis. Pampas, silver birch and grey willow should also be controlled.

Significance Level:

National (Criteria 1, 3, 5, 6, 7, 9).

**Significance
Justification:**

This site is of national significance because it comprises a large, relatively good quality area of geothermal vegetation, a nationally uncommon vegetation habitat type. The site includes a wide diversity of geothermal habitats, and provides habitat for several Threatened and At Risk plant and bird species. It is one of the largest areas of geothermal kānuka scrub and shrubland, and is one of the biggest known populations of *Calochilus robertsonii* in Aotearoa New Zealand. While the site has a long history of modification, the quality of the site is noticeably improving following the

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photo: SN 172 Run 1173 Photos 10-13, 1941.

³ Historical photos: SN 172 Run 1173 Photos 10-13, 1941.

implementation of ecological management by the Department of Conservation.

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category C - the third highest category.

Merrett and Burns (1997) note that the geothermal area on the northern shore of Lake Rotokawa is of biological significance for both the geothermal vegetation growing there, and as a breeding site for banded dotterel and black-billed gulls.

References:

Bycroft 2008; Clarkson *et al.* 1989; Department of Conservation 1998; Duggan and Boothroyd 2002; Forsyth 1977; James and Kolb 2009; Merrett and Burns 1997; Merrett and Clarkson 1999; Milich and Hunt 2007; NIWA 2002; Singers and Bayler 2016; Spring-Rice 1996; Wildland Consultants 2000, 2004c, 2012, 2014a, 2015b, 2018c, 2020e, & 2021d.



Geothermal kākūka scrub around a fumarole, northern part of Rotokawa site. Note the dense cover of wilding pines in the surrounding area. NZTM E1878311 N5720421. 14 March 2023.



Scattered emergent wilding radiata and maritime pine over geothermal kākūka-mingimīngi scrub, northern part of Rotokawa site, with Lake Rotokawa visible in the distance. NZTM E1878325 N5720603. 14 March 2023.



Parariki Stream, northern part of Rotokawa site. NZTM E1878568 N5720039. 14 March 2023.



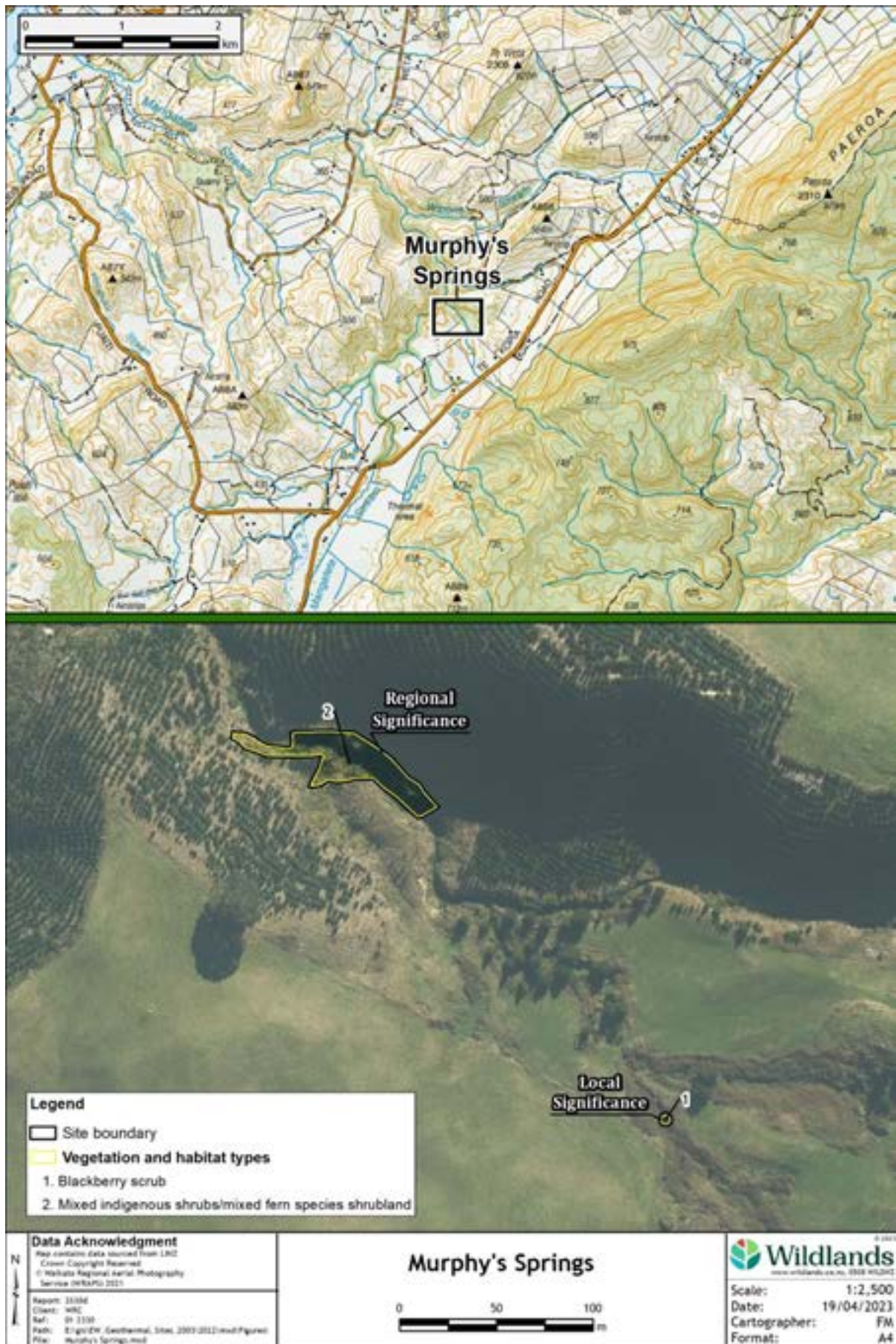
View over geothermal vegetation with steam emerging from fumaroles, and lake visible on right-side of photograph. NZTM E1877318 N5720056. 6 October 2021.

VASCULAR PLANT SPECIES RECORDED FROM SURFACE GEOTHERMAL HABITAT IN THE ROTOKAWA GEOTHERMAL SYSTEM

Scientific Name	Common Name	Rotokawa
INDIGENOUS SPECIES		
Monocot. trees and shrubs		
<i>Cordyline australis</i>	Ti kōuka, cabbage tree	✓
Dicot. trees and shrubs		
<i>Coprosma ×cunninghamii</i>		✓
<i>Coprosma lucida</i>	Karamū, kāramuramu, glossy karamū	✓
<i>Coprosma robusta</i>	Karamū, kāramuramu	✓
<i>Dracophyllum subulatum</i>	Monoao	✓
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taupuku	✓
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓
<i>Leptecophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi	✓
<i>Leptospermum scoparium</i>	Mānuka	✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓
<i>Leucopogon fraseri</i>	Pātōtara	✓
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓
<i>Pseudopanax arboreus</i>	Whauwhaupaku, puahou, five finger	✓
<i>Pterophylla racemosa</i>	Kāmahi	✓
Dicot. lianes		
<i>Calystegia tuguriorum</i>	Pōwhiwhi, native bindweed	✓
Lycopods and psilopsids		
<i>Lycopodium volubile</i>	Waewaekoukou, climbing clubmoss	✓
<i>Lycopodiella cernua</i>	Mātukutuku	✓
Ferns		
<i>Blechnum discolor</i>	Piupiu, petipeti, crown fern	✓
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio	✓
<i>Blechnum penna-marina</i> subsp. <i>alpina</i>	Little hard fern	✓
<i>Dicksonia fibrosa</i>	Wheki-ponga, kuripākā	✓
<i>Dicksonia squarrosa</i>	Wheki	✓
<i>Gleichenia microphylla</i>	Waewaekākā, carrier tangle fern	✓
<i>Histiopteris incisa</i>	Mātātā, water fern	✓
<i>Hiya distans</i>		✓
<i>Hypolepis ambigua</i>		✓
<i>Paesia scaberula</i>	Mātātā, hard fern	✓
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓
<i>Schizaea bifida</i>		✓
Orchids		
<i>Calochilus robertsonii</i>		✓
<i>Microtis unifolia</i> agg.		✓
<i>Thelymitra longifolia</i>		✓
Grasses		
<i>Austroderia fulvida</i>	Toetoe	✓
<i>Microlaena stipoides</i>	Pātiti, meadow rice grass	✓
<i>Pentapogon avenoides</i>		✓
<i>Rytidosperma gracile</i>		✓
Sedges		
<i>Carex geminata</i> agg.	Rautahi	✓
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio	✓
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata	✓
<i>Eleocharis gracilis</i>		✓
<i>Morelotia affinis</i>		✓
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā	✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)		
<i>Dianella nigra</i>	Tūrutu	✓
<i>Typha orientalis</i>	Raupō	✓
Dicot. herbs (other than composites)		
<i>Acaena anserinifolia</i>	Piripiri, hutiwai	✓
<i>Callitriche petriei</i>		✓
<i>Drosera auriculata</i>	Sundew, wahu	✓
<i>Geranium homeanum</i>	Pinakitere	✓
<i>Glossostigma diandrum</i>		✓
<i>Glossostigma elatinoides</i>		✓
<i>Gonocarpus micranthus</i>	Piripiri	✓
<i>Myriophyllum pedunculatum</i> subsp. <i>novae-zelandiae</i>		✓
<i>Persicaria decipiens</i>	Tutunawai	✓

Scientific Name	Common Name	Rotokawa
NATURALISED AND EXOTIC SPECIES		
Gymnosperms		
<i>Pinus contorta</i>	Lodgepole pine	✓
<i>Pinus pinaster</i>	Maritime pine	✓
<i>Pinus radiata</i>	Radiata pine	✓
<i>Pseudotsuga menziesii</i>	Douglas fir	✓
Dicot. trees and shrubs		
<i>Betula pendula</i>	Silver birch	✓
<i>Buddleja davidii</i>	Buddleia	✓
<i>Chamaecytisus palmensis</i>	Tree lucerne	✓
<i>Cytisus scoparius</i>	Broom	✓
<i>Erica lusitanica</i>	Spanish heath	✓
<i>Eriobotrya japonica</i>	Loquat	✓
<i>Eucalyptus</i> sp.	Eucalyptus	✓
<i>Leycesteria formosa</i>	Himalayan honeysuckle	✓
<i>Prunus</i> sp.	Ornamental cherry	✓
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓
<i>Salix cinerea</i>	Grey willow	✓
<i>Teline monspessulana</i>	Montpellier broom	✓
<i>Ulex europaeus</i>	Gorse	✓
Grasses		
<i>Agrostis capillaris</i>	Browntop	✓
<i>Agrostis stolonifera</i>	Creeping bent	✓
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass	✓
<i>Cortaderia selloana</i>	Pampas	✓
<i>Cynodon dactylon</i>	Indian doab	✓
<i>Dactylis glomerata</i>	Cocksfoot	✓
<i>Eragrostis brownii</i>	Bay grass	✓
<i>Festuca rubra</i> subsp. <i>rubra</i>	Red fescue	✓
<i>Holcus lanatus</i>	Yorkshire fog	✓
<i>Lolium perenne</i>	Rye grass	✓
<i>Paspalum dilatatum</i>	Paspalum	✓
<i>Paspalum distichum</i>	Mercer grass	✓
<i>Poa annua</i>	Annual poa	✓
Sedges		
<i>Cyperus eragrostis</i>	Umbrella sedge	✓
Rushes		
<i>Juncus acuminatus</i>	Sharp-fruited rush	✓
Composite herbs		
<i>Achillea millefolium</i>	Yarrow	✓
<i>Crepis capillaris</i>	Hawksbeard	✓
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane	✓
<i>Gamochaeta coarctata</i>	Purple cudweed	✓
<i>Hypochaeris radicata</i>	Catsear	✓
<i>Jacobaea vulgaris</i>	Ragwort	✓
<i>Mycelis muralis</i>	Wall lettuce	✓
Dicot. herbs (other than composites)		
<i>Centaureum erythraea</i>	Centaury	✓
<i>Cerastium fontanum</i> subsp. <i>vulgare</i>	Mouse-ear chickweed	✓
<i>Cymbalaria muralis</i>	Ivy-leaved toad flax	✓
<i>Digitalis purpurea</i>	Foxglove	✓
<i>Geranium molle</i>	Dovesfoot cranesbill	✓
<i>Lotus pedunculatus</i>	Lotus	✓
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	Scarlet pimpernel	✓
<i>Mentha pulegium</i>	Penny royal	✓
<i>Ornithopus perpusillus</i>	Wild seradella	✓
<i>Persicaria hydropiper</i>	Water pepper	✓
<i>Plantago lanceolata</i>	Narrow-leaved plantain	✓
<i>Plantago major</i>	Broad-leaved plantain	✓
<i>Portulaca oleracea</i>	Wild portulaca	✓
<i>Rumex acetosella</i>	Sheep's sorrel	✓
<i>Solanum tuberosum</i>	Potato	✓
<i>Stellaria media</i>	Chickweed	✓
<i>Trifolium pratense</i>	Red clover	✓
<i>Trifolium repens</i>	White clover	✓
<i>Verbascum thapsus</i>	Woolly mullein	✓
<i>Verbena bonariensis</i>	Purple-top	✓
<i>Verbena officinalis</i>	Vervain	✓

22. TE KOPIA GEOTHERMAL SYSTEM



MURPHY'S SPRINGS

Ecological District:	Atiamuri	GPS Reference:	NZTM E1880740 N5745787
Geothermal System:	Te Kopia	Altitude:	380 m
Bioclimatic Zone:	Submontane	Local Authority:	Rotorua
Extent of Geothermal Habitat:	c.0.1 ha		
Extent of Geothermal Vegetation:	c.0.1 ha		
Date of Most Recent Field Survey:	25 January 2023		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic species dominant scrub (04.10) Blackberry scrub (04.10.01) A steaming hot gully with a small area of steam rising with abundant blackberry. This area, although almost certainly present, was not found in the 2010 site survey.	Gully	<0.1 ha
2.	Mixed indigenous shrubland (05.07) Mixed indigenous shrubs/mixed fern species shrubland (05.07.01) Karamū-Spanish heath-koromiko-buddleia-blackberry-toetoe/<i>Histiopteris incisa</i>-<i>Christella</i> aff. <i>dentata</i> (“thermal”) shrubland A variable mixed indigenous and exotic shrubland with abundant karamū (to three metres), Spanish heath, koromiko, buddleia and toetoe with local kōhūhū. Occasional emergent tī kōuka. Blackberry is abundant in areas of lower geothermal influence. Alongside springs and steamy stream margins there is abundant <i>Histiopteris incisa</i> , <i>Christella</i> aff. <i>dentata</i> (“thermal”), <i>Carex virgata</i> , and <i>Cyperus ustulatus</i> , with kiokio becoming more abundant in less steamy habitats. There are small local areas of exotic grasses and herbs including Yorkshire fog, sweet vernal, paspalum, browntop, yarrow, and catsear. Pines have been harvested within this site since the previous site visit in 2010.	Gully	c.0.1 ha

Indigenous Flora: *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered), is common alongside geothermally heated stream margins. An estimated 100 plants are present. Other species typical of geothermal habitats are present and include *Carex virgata*, bracken, *Histiopteris incisa*, and tūrutu.

Fauna: Common bird species typical of the habitat are present and include tauhou/silvereye, and the introduced species, dunnock, Australian magpie, European goldfinch, European greenfinch and yellowhammer. Pīwakawaka/North Island fantail was recorded at the site in 2010.

In 2010 cattle sign was present in parts of this site. The site is now fenced. Possum sign was noted in 2010.

Geothermal Ecosystems: Geothermal streamsides, geothermal wetlands.

Current Condition: The site is in an improved condition since it was previously visited in 2010. There is now a buffer between forestry and the site. The area is fenced to

exclude stock. However, the area is subject to weed invasion, and blackberry and other woody weeds have established on geothermal margins.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Pest plants are having an impact on site margins. Blackberry 25% cover, Spanish heath (10% cover), radiata pine (1% cover), buddleia (1% cover).

Human impacts: None noted.

Grazing: None noted in 2023, site is fenced. Cattle grazing was evident in 2010.

Adjoining land use: Riparian margin, plantation forest, farmland.

Site Change:

Recent change: The site has been fenced to exclude stock since the last visit. One additional geothermal area was found in a gully in a nearby farm paddock in 2023.

*Historical:*¹ Site not assessed, no historical photos found. The surrounding margins have previously been plantation forest and geothermal features are in a steep sided gully that is unlikely to be visible on historical black and white aerial photographs.

**Management
Requirements:**

A restoration plan should be prepared to guide the management of weeds and enhance indigenous vegetation along the riparian margins around the springs and the thermal stream. Fences should be maintained to continue to exclude stock, and buffers between forestry operations and geothermal vegetation should be maintained.

Significance Level:

R: Regional (Criteria 3, 5)
L: Local (Criteria 5)

**Significance
Justification:**

R: Murphy's Springs is a regionally significant site because it is a habitat of importance for a 'Threatened – Nationally Endangered' taxon, *Christella* aff. *dentata* ("thermal").

L: This area is locally significant because it comprises an example of a nationally uncommon habitat type (geothermal).

Notes:

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.

References:

Wildland Consultants 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



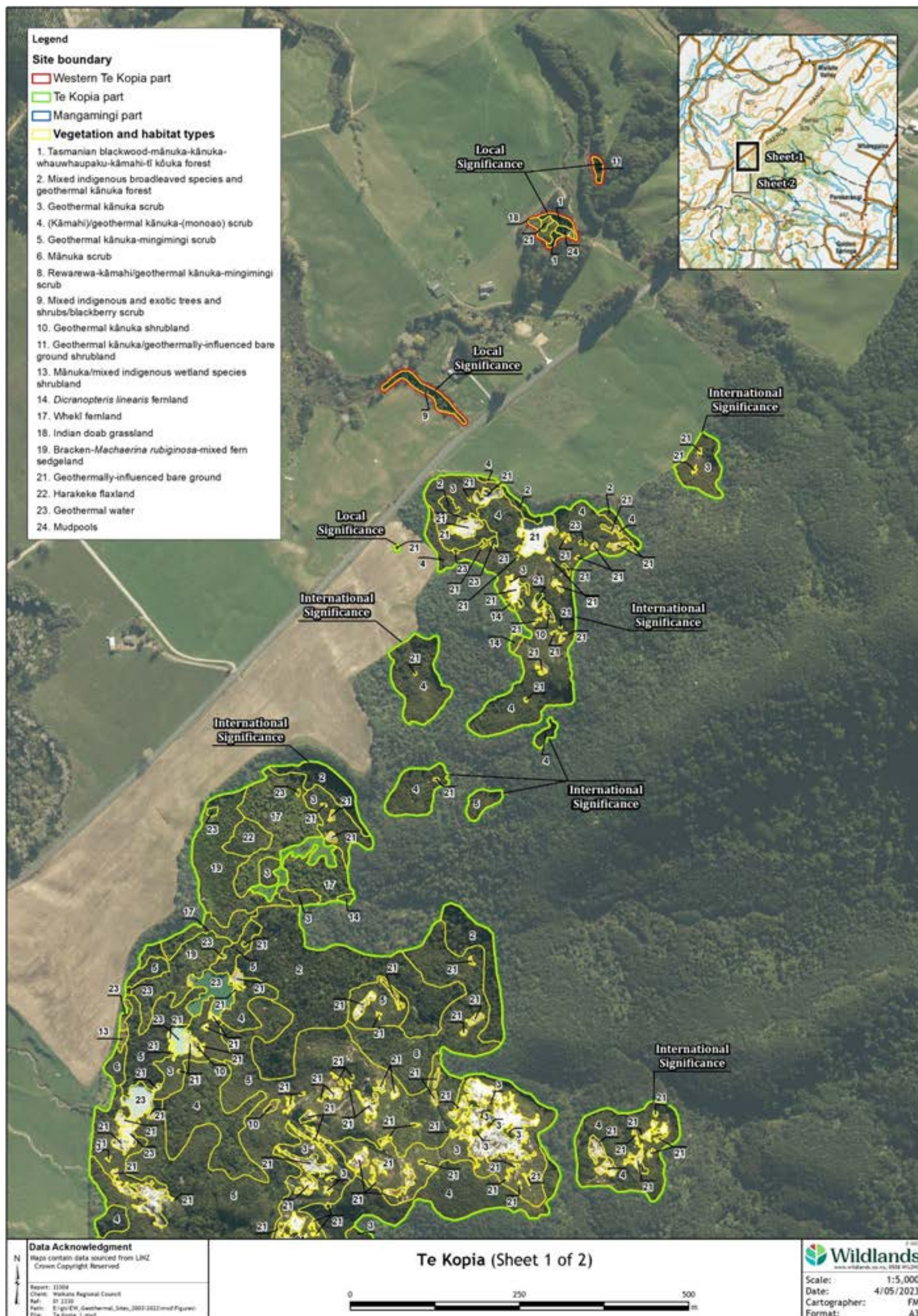
Murphy's Springs. Several hot springs are present on the true right side of the stream in the Waione Stream Catchment in a steep sided gully.
NZTM E1880749 N5745750. 25 January 2023.

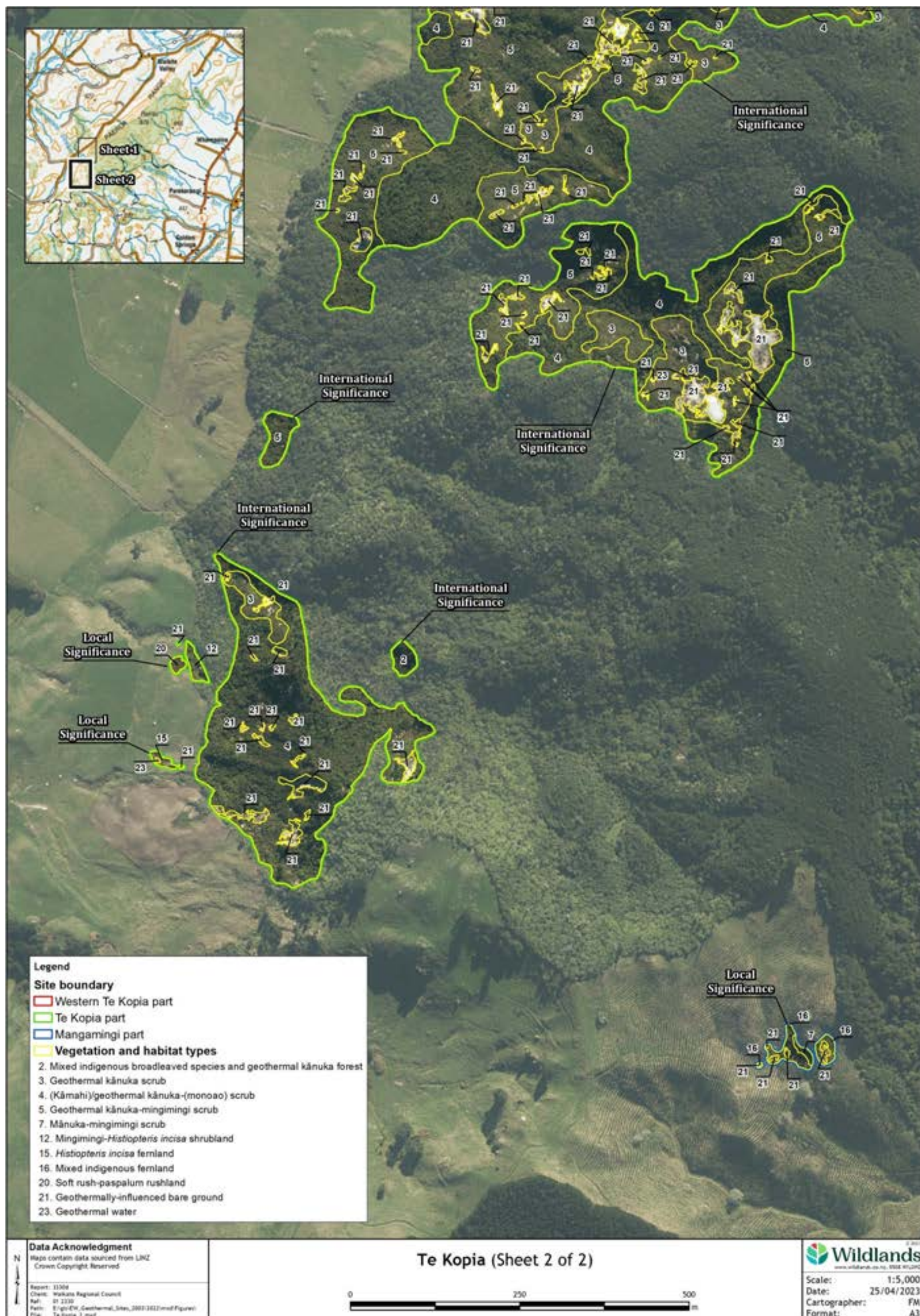


Murphy's Springs. The steamy stream and spring margins support a population of *Christella* aff. *dentata* ("thermal"). NZTM E1880749 N5745750. 25 January 2023.



A steam vent was found amongst farmland, near Murphy's Springs. This was not mapped previously. NZTM E1880871 N5745594. 25 January 2023.





TE KOPIA ¹

Ecological District: Atiamuri **GPS Reference:** NZTM E1880502 N5743445
Geothermal System: Te Kopia **Altitude:** 400-640 m
Bioclimatic Zone: Submontane **Local Authority:** Rotorua
Extent of Geothermal Habitat: c. 69.3 ha
Extent of Geothermal Vegetation: c. 68.5 ha
Date of Most Recent Field Survey: 17, 18, 20 January 2023

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic species forest (01.02) Tasmanian blackwood-mānuka-kānuka-whauwhaupaku-kāmahi-tī kōuka forest (01.02.04) Three mud pools (previously known as the Te Kopia Mud Pools). A Tasmanian blackwood plantation, in poor health, surrounds the pools, often to c. 7 metres tall, in association with indigenous tree species, including whauwhaupaku, and kāmahi. Tūrutu, <i>Hypolepis ambigua</i> , and bracken are common in the understorey. A notable feature of the kāmahi beside the eastern pool is the burnt foliage in the line of steam that arises from the pool. A thin layer of mud from mud pool activity coats many of the trees and other vegetation around the hot pools. Indian doab is common on heated soils to the south of the southern pool. Dead blackberry present here indicates a recent increase in surface geothermal activity in this area.	Terrace above mudpool	<0.1 ha
2.	Mixed indigenous broadleaved species forest (01.04) Mixed indigenous broadleaved species and geothermal kānuka forest (01.04.02) This type is often present either as enclaves within the wider geothermal habitat, or on margins and often contains vegetation that is of geothermal character. The most abundant canopy species are kāmahi, rewarewa, <i>Coprosma lucida</i> , geothermal kānuka, tarata, kōhūhū, and mānuka. The ground cover can often contain populations of fern species typical of geothermal habitats including <i>Dicranopteris linearis</i> and <i>Nephrolepis flexuosa</i> . There are a number of hot pools and fumaroles present beneath the canopy. There are many small areas of geothermal activity hidden beneath a canopy. These are not mapped as they are not visible on aerial photographs and are only found when walking through this area. Other species often present in the understorey include mingimingi, prickly mingimingi, bracken, kiokio, <i>Hypolepis ambigua</i> , and blackberry. The canopy height is quite variable from 5 to 25 metres.	Hillslope	c. 4.6 ha
3.	Geothermal kānuka-dominant shrubland (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka forms a canopy 0.5-1.5 m high around areas of geothermally-influenced bare ground, fumaroles, and boiling mud. Scattered mingimingi, monoao and local mānuka are	Flat, Hillslope, craters	c. 7.7 ha

¹ In 2014a, the site Western Te Kopia amalgamated sites Te Kopia Northwest, Te Kopia West Mud Pools”, and Te Kopia Red Stream” from Wildland Consultants 2012. In the current report the site Te Kopia amalgamates sites ‘Te Kopia’, ‘Western Te Kopia’ and Mangamingi Station from Wildland Consultants 2014a.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	present. Note that better quality aerial photographs means that this area is able to be mapped.		
4.	(Kāmahi)/geothermal kānuka-(monoao) scrub (04.01.08) Local kāmahi, mānuka and other broadleaved indigenous species (e.g. <i>Coprosma lucida</i> and rewarewa) are emergent over a dense geothermal kānuka canopy (0.5-3 m height) with monoao locally common, and scattered minigminigi, prickly mingimingi, <i>Gleichenia microphylla</i>, and tūrutu. Local patches of mānuka, <i>Dicranopteris linearis</i>, and the moss <i>Campylopus</i> are present. Patches of kāmahi/mingimingi-geothermal kānuka scrub and kāmahi-rewarewa scrub are present within this vegetation type but are too small to map separately.	Foot of scarp, hillslope	c.25.3 ha
5.	Geothermal kānuka-mingimingi scrub (04.02) Geothermal kānuka-mingimingi scrub (04.02.01) Geothermal kānuka, or mingimingi, or a mixture of both form the cover in these areas. Geothermal kānuka is dominant on warmer soils, whilst cooler soils support higher proportions of mingimingi and prickly mingimingi. The canopy is up to c.2.5 m high with occasional emergent kōhūhū, kāmahi, mānuka, and dead wilding pines. Local <i>Histiopteris incisa</i> is present in the understorey along with large patches of the moss <i>Campylopus</i>. Occasional areas of blackberry, broom and bracken occur on margins. Where mingimingi is dominant, mānuka often occurs in association with occasional kāmahi, and locally common radiata pine. The subcanopy comprises the above species as well as prickly mingimingi, monoao, <i>Dicranopteris linearis</i>, and bracken. The groundcover is dominated by tūrutu, and a moss and liverwort mat on which there is infrequent <i>Schizaea dichotoma</i> and <i>Schizaea fistulosa</i>.	Hillslope	c.18.5 ha
6.	Mānuka scrub (04.04) Mānuka scrub (04.04.01) Mānuka scrub with occasional geothermal kānuka present in the canopy with scattered <i>Korthalsella salicornioides</i>.	Wetland, hillslope	c.0.5 ha
7.	Mānuka-mingimingi scrub (04.04.02) Mangamingi Station part A small area of mānuka and mingimingi scrub above an area of geothermal activity. Other species present include kōhūhū, whekī, horoeka, and tāwiniwini. Exotic grasses are common. One rimu seedling was seen. Sheep tracks are throughout. <i>Pyrrosia eleagnifolia</i> is epiphytic in this vegetation type. Banks are locally covered with non-vascular species and occasional <i>Asplenium flaccidum</i>.	Hillslopes	<0.1 ha
8.	Mixed indigenous species scrub (04.08) Rewarewa-kāmahi/geothermal kānuka-mingimingi scrub (04.08.03) Rewarewa and kāmahi form a patchy canopy over geothermal kānuka and mingimingi with scattered māpou and whekī. Local patches of <i>Histiopteris incisa</i>, <i>Dicranopteris linearis</i>, and tūrutu are present. Steam vents are present throughout.	Hillslopes	c.2.0 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
9.	Exotic species dominant scrub (04.10) Mixed indigenous and exotic trees and shrubs/blackberry scrub (04.10.08) (Grey willow)-(ornamental cherry)-(kōhūhū)-(mānuka)/blackberry-mingimingi-prickly mingimingi scrub Emergent grey willow (to 10 metres), ornamental cherry, scattered kōhūhū, and mānuka are present over a widely variable understorey and ground cover with dense areas of blackberry and mingimingi, whekī, prickly mingimingi, and broom. A few overhanging poplars and Douglas fir are present. A small patch of <i>Dicranopteris linearis</i> is present, while a few plants of the introduced male fern were observed. Prickly mingimingi is more abundant on the immediate stream margins with occasional <i>Histiopteris incisa</i>, tūrutu, <i>Carex virgata</i>, <i>Gleichenia microphylla</i>, kiokio, and <i>Deparia petersenii</i> subsp. <i>Congrua</i> also on stream margins.	Gully	c.0.2 ha
10.	Geothermal kānuka-dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) This vegetation type occurs around the most active geothermal features, and comprises a sparse low canopy of geothermal kānuka (0.3-1 m high) with occasional mingimingi and monoao, and scattered radiata pine and emergent rewarewa saplings are present. The groundcover is dominated by <i>Campylopus</i> and <i>Dicranoloma</i> (mosses), with lichens, liverworts, and <i>Lycopodiella cernua</i> also present. Unvegetated areas occur locally throughout this vegetation type. Mānuka-kāmahi/prickly mingimingi scrub is locally common around the margins, covering areas that were too small to map. <i>Dicranopteris linearis</i> is abundant throughout this habitat type, while a small population of <i>Nephrolepis flexuosa</i> is present at the north end of geothermal activity.	Foot of scarp; hillslope	<0.1 ha
11.	Geothermal kānuka shrubland (05.01) Geothermal kānuka/geothermally-influenced bare ground shrubland (05.01.07) A small geothermal manifestation in a gully north of Te Kopia Mud Pools. Much of the area is unstable bare ground with an extensive network of springs present. This area is surrounded by a macrocarpa plantation including recently fallen macrocarpa trees, with abundant blackberry and pōhuehue. Areas of <i>Campylopus</i> mossfield, scattered plants of paspalum, broad-leaved fleabane, tūrutu and occasional <i>Lycopodiella cernua</i>. Tūrutu and bush lawyer are common on the margins. A stream flowing through the southern corner is surrounded by kāmahi, mamaku, whauwhaupaku, karamū, makomako, whekī, kōhūhū, and macrocarpa forest. Three plants of <i>Nephrolepis flexuosa</i> were present in this area in 2010, but none were found in 2023. The cover of geothermal kānuka also appears less abundant in this area in 2023, probably as a result of decreased vigour from shading from macrocarpa trees.	Gully	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
12.	Mingimingi-dominant shrubland (05.02) Mingimingi-<i>Histiopteris incisa</i> shrubland (05.02.01) Mingimingi and <i>Histiopteris incisa</i> form an incomplete canopy over bare ground with local patches of <i>Lycopodiella cernua</i>. Several patches of <i>Dicranopteris linearis</i> are present. Boiling hot springs are present within this type.	Hillslope	c. 1.0 ha
13.	Mānuka shrubland (05.04) Mānuka/mixed indigenous wetland species shrubland (05.04.06) A small wetland. Mānuka 1 to 3 metres tall forms a shrubland canopy over abundant <i>Cyperus ustulatus</i> and <i>Machaerina rubiginosa</i>.	Wetland	<0.1 ha
14.	Indigenous fernland (07.01) <i>Dicranopteris linearis</i> fernland (07.01.01) Some of the larger areas of this vegetation type are now able to be mapped in this updated report due to improved aerial photography. <i>Dicranopteris linearis</i> is dominant with a few geothermal kānuka, kāmahī, and mingimingi also present.	Hillslope	<0.1 ha
15.	<i>Histiopteris incisa</i> fernland (07.01.03) <i>Histiopteris incisa</i> fernland surrounds a bubbling mudpool/spring within farmland in the southern part of the site. Soil temperatures of up to 40 °C were recorded at c. 10 cm depth. The fernland is fringed by pasture dominated by cocksfoot, browntop, Yorkshire fog, and paspalum. Domestic stock have access.	Hillslope	<0.1 ha
16.	Mixed indigenous fernland (07.01.07) <i>Paesia scaberula</i>-kiokio-<i>Hypolepis ambigua</i>-geothermal kānuka-sweet vernal-browntop/<i>Gonocarpus micranthus</i> fernland <i>Paesia scaberula</i> fernland, with common patches of <i>Lycopodiella cernua</i> and <i>Hypolepis ambigua</i>, and scattered mingimingi, tūrutu, kiokio, <i>Blechnum parrisiae</i> and geothermal kānuka. Some of the geothermal kānuka appears to have been killed by overspray of herbicide. There are local patches of pasture dominated by sweet vernal, browntop, white clover, and sheep's sorrel. Several small areas of <i>Gonocarpus micranthus</i> are present. Three juvenile plants of <i>Dicranopteris linearis</i> were recorded at one location in this vegetation type in 2010 but were not seen in 2023.	Hillslope	c. 0.2 ha
17.	Whekī fernland (07.01.18) Whekī treefern to 4 metres tall dominate this area. Beneath the canopy the vegetation is quite varied with patches of <i>Hypolepis ambigua</i>, <i>Histiopteris incisa</i>, <i>Hiya distans</i>, <i>Machaerina rubiginosa</i>, <i>Carex geminata</i>, bracken, blackberry and harakeke. There are also small patches of <i>Machaerina teretifolia</i>, and local geothermal kānuka.	Wetland	c. 1.9 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
18.	Exotic grassland (08.01) Indian doab grassland (08.01.07) This area is boarded on two sides by blackberry. Indian doab is dominant with scattered blackberry and local paspalum. Soil temperature in an area of bare ground on the edge of this type was 96 °C at 10 centimetres depth.	Flat	<0.1 ha
19.	Indigenous sedgeland (09.01) Bracken-Machaerina rubiginosa-mixed fern sedgeland (09.01.05) A wetland where whekī, harakeke, toetoe, and mānuka are emergent over a dense cover of bracken, <i>Machaerina rubiginosa</i>, and <i>Hiya distans</i>. Locally common species include <i>Gleichenia microphylla</i>, <i>Machaerina tenax</i>, <i>Hypolepis ambigua</i>, <i>Histiopteris incisa</i>, swamp kiokio, and kiokio. Occasional patches of <i>Carex geminata</i> and <i>Cyperus ustulatus</i>, and scattered emergent whekī-ponga are also present.	Wetland	c.2.0 ha
20.	Exotic rushland (10.01) Soft rush-paspalum rushland (10.01.01) Soft rush and paspalum rushland with creeping bent, water purslane, sweet vernal, and narrow-leaved plantain occurs around the margins of small hot springs and small areas of bubbling mud.	Hillslope	<0.1 ha
21.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Te Kopia part Thermally altered clay, mud, and sinter. Patches of raw-soilfield located within farmland support scattered patches of browntop. Mangamingi Station part Bare geothermally influenced clays and silicified rocks and several pools of geothermally influenced water. Mostly bare ground, with local scattered areas of mossfield and exotic grasses. Non-vascular plant species present include the mosses <i>Campylopus clavatus</i> and <i>Wijkia extenuata</i>, and the liverwort <i>Monoclea fosteri</i>; however, a detailed non-vascular plant survey was not undertaken. Scattered plants of the following species are also present: geothermal kānuka, <i>Lycopodiella cernua</i>, <i>Paesia scaberula</i>, <i>Histiopteris incisa</i>, mingimingi, prickly mingimingi, <i>Blechnum fluviatile</i>, and Spanish heath.	Foot of the Paeroa fault scarp; hillslope, gully	c.4.7 ha
22.	Harekeke flaxland (21.01) Harakeke flaxland (21.01.03) The central part of the wetland in the northern part of Te Kopia contains an area dominated by harekeke to c.3 metres tall, with occasional patches of <i>Hypolepis ambigua</i> and <i>Machaerina rubiginosa</i>. Occasional emergent whekī is present.	Wetland	c.0.3 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
23.	Water (22.01) Geothermal water (22.01.01) Hot springs, hot pools, and mud pools. Mudpools and springs within farmland are often surrounded by pasture dominated by exotic species including browntop, Yorkshire fog, and paspalum with scattered soft rush and <i>Histiopteris incisa</i> .	Foot of scarp; hillslopes	c.0.8
24.	Mudpools (22.01.02)	Crater, flat	<0.1 ha

Indigenous Flora:

Geothermal kānuka (Threatened-Nationally Endangered) dominates a large percentage of the geothermal vegetation present.

Dicranopteris linearis (Threatened-Nationally Endangered), known from only a small number of locations in New Zealand, is common throughout the site. *Schizaea dichotoma* (At Risk-Naturally Uncommon) is known from this site. A small population of *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) is present and two 'At Risk' orchids - *Calochilus paludosus* (At Risk-Naturally Uncommon) and *C. robertsonii* (At Risk-Naturally Uncommon) - are also well represented here. *Schizaea fistulosa* has been recorded here in the past (Clarkson 1984; Burns and Leathwick 1995). The population of *N. flexuosa* appears to have increased in the northern part of the Te Kopia site since 2014, although some other smaller populations (e.g. sites on the western side of Te Kopia Road), did not appear to be present in 2023. The small population of *D. linearis* on Mangamingi Station that was observed in 2014, appears to have gone, but this species appears stable in the Te Kopia Scenic Reserve part of the site, which is one of the largest populations of this species in Aotearoa New Zealand.

A survey of *Korthalsella salicornioides* (dwarf mistletoe; Threatened-Nationally Critical) in 2000 estimated the population at this site to comprise 100-200 plants (Anon 2000). There appeared to be at least this many plants at the site during both the 2014 and 2023 surveys.

Other species typical of geothermal habitats are also present including mānuka, mingimingi, prickly mingimingi, tāwiniwini, *Deparia petersenii* subsp. *congrua*, *Gleichenia microphylla*, *Lycopodiella cernua*, tūrutu, bracken, *Hiya distans*, *Histiopteris incisa*, *Paesia scaberula*, *Blechnum penna-marina* subsp. *alpina*, *Blechnum parrisiae*, *Hypolepis ambigua*, and *Gonocarpus micranthus*.

Fauna:

Common indigenous and introduced bird species typical of the habitat are present and include pūtangitangi/paradise shelduck, pūkeko, kāhu/swamp harrier, kōtare/sacred kingfisher, pīpīwharau/roa/shining cuckoo, koekoeā/long-tailed cuckoo (Threatened-Nationally Vulnerable), pīwakawaka/fantail, miromiro/North Island tomtit, tūi, kererū, toutouwai/North Island robin (At Risk-Declining), korimako/bellbird, warou/welcome swallow, and riroriro/grey warbler. Introduced species recorded include common pheasant, wild turkey, Eastern rosella, skylark, Eurasian blackbird, song thrush, European goldfinch, European greenfinch, and Australian magpie.

Possum sign was recorded in part of the site. Parts of the site are grazed by cattle and sheep.

A few rainbow skinks (plague skinks), an introduced species, were observed in geothermal vegetation on the western side of Te Kopia Road in January 2023.

**Geothermal
Ecosystems:**

Heated ground (dry), fumaroles, geothermal wetlands, hydrothermally altered ground (now cool), geothermal streamsides.

Current Condition:

Te Kopia Part

The geothermal vegetation is virtually unchanged since 1948 (Burns 1996b) and the area is relatively free from adventive species, although pines were invading the mingimingi scrub until recently. The Department of Conservation has undertaken control of wilding pines at this site in recent years, and this has significantly improved the condition of the site. It is the most intact remaining example of natural vegetation zonation that includes geothermal vegetation (extending over c.579 m in altitude), ranging from tall kāmahi-dominated forest through to geothermal kānuka shrubland and geothermal wetland (see also Clarkson 1984). Very small patches that are present outside the reserve amongst farmland are generally in much poorer condition with abundant exotic species and are impacted by grazing by farm stock.

Western Te Kopia Part

Most of the geothermal features within this part of the site are in moderate condition, with the vegetation containing a high proportion of exotic plant species. However, a threatened fern species is present.

Mangamingi Station Part

The site has until recently, been grazed by sheep. Part of the site has recently been planted in radiata pines. Prior to planting, part of the site including some geothermal kanuka, was sprayed. The geothermal vegetation here is likely to be further impacted by shading in the future.

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Te Kopia Part

Pine control has been ongoing in the reserve over recent years. The invasion of pines (previously c.6-25% cover, but now only c.1-5% cover) will be a continuing problem within the geothermal areas, and there is potential for ongoing weed invasion along the walking tracks. Blackberry (c.1% cover internally, c.5% cover on margins), Spanish heath (c.1% cover), grey willow (<1% cover), ornamental cherry (<1%), buddleia (<1%), gorse (<1% cover), Himalaya fairy grass (<1%), and pampas (<1%) are present.

Western Te Kopia Part

Blackberry is common at the margins of the geothermal stream and on cooler soils (5-25% cover). Other pest plant species present include common alder (<1% cover) and cotoneaster (<1% cover). Although Tasmanian blackwood and brush wattle are present in part of the site, these species are not having a significant impact on geothermal features at the site.

Mangamingi Station Part

Several Spanish heath plants are present. The site is surrounded by pine plantation.

*Human impacts:***Te Kopia Part**

There are few walking tracks and human impact is low. A new walking track has been constructed near the northern end of the reserve.

Western Te Kopia Part

Macrocarpa and Tasmanian blackwood have been planted close to parts of this site. A track has been cut through blackberry to the southern of the two mudpools within the site.

Mangamingi Station Part

The site is surrounded by plantation, and some of the geothermal kānuka has been killed by overspray. There has also been some planting of pines right to the edge of geothermal habitat. A 10-20m buffer around the site would help protect the ecological values. Until recently the site has been impacted by sheep grazing.

*Grazing:***Te Kopia Part**

The reserve is fenced, and fences appeared to be in good condition in all areas inspected in 2023. Parts of this site are located in farmland and are unfenced. These areas are grazed, and geothermal features are being damaged by stock trampling.

Western Te Kopia Part

The site has been fenced to exclude domestic stock.

Mangamingi Station part

The site planted in pine plantation so is no longer grazed.

*Adjoining land use:***Te Kopia Part**

Indigenous forest and scrub, farmland.

Western Te Kopia Part

Macrocarpa plantation, Tasmanian blackwood plantation, mixed indigenous and exotic species scrub, farmland.

Mangamingi Station Part

Plantation forest (newly established).

Site Change:*Recent change:***Te Kopia Part**

Most changes to vegetation type boundaries are as a result of better quality aerial photographs available for the current study, rather than real change. A few additional areas, located in farmland, were added to this site in 2014 and in 2023. These areas are not new geothermal manifestations but have been found because of the better quality aerial photographs. Considerable wilding pine control has been undertaken in Te Kopia since 2014. A boardwalk and viewing platform has been established at the north of the site.

Western Te Kopia Part

The farmer advised that the southern of the two mud pools has become more active in recent years. In 2023, one of the previously active mud pools appeared to be no longer active. An area of grassland has become extremely geothermally active since the previous site visit in 2014.

Mangamingi Station Part

Some geothermal vegetation, including geothermal kanuka, appears to have been damaged by overspray. The surrounding land was farmed in 2010, but in 2023 was surrounded by pine plantation.

*Historical:*¹

Te Kopia Part

Previous geological investigations of the field included the drilling of two temporary wells (drilled 1965-67, plugged 1973) (Burns 1997b).

Burns (1996b) carried out an in-depth assessment of vegetation changes at Te Kopia using historical photos from 1948, 1963, 1975, and 1991. He found that areas of bare sinter or mud occur in the same relative locations in all photographs, but change in extent. There was a marked increase in bare areas between 1948 and 1963 on steep slopes (probably as a result of earthquake or an extreme storm event), but bare areas decreased from 1963 to 1975 and essentially remained unchanged in character. Areas with vegetation dominated by geothermal kānuka did not change in obvious extent, structure, or composition since 1948 suggesting that this vegetation type is stable for long periods. Emergent wilding pines are not present in 1948, but can be seen in the 1968 photos onwards. These have been controlled in recent years.

Western Te Kopia Part

Site not assessed, no historical photos found. As most of the vegetation is in a gully and the site is small, changes are unlikely to be visible on historical black and white photographs. Blackberry and other pest plant species are likely to have changed the character of the site, and reduced the extent of indigenous dominant vegetation in association with geothermal features.

Mangamingi Station Part

Possible historic extent is difficult to determine because of the small size of the site. Geothermal features on site suggest that the most significant change has been the conversion of land to farming. There are no obvious areas near this site that could previously have been geothermal areas, but at which geothermal activity has ceased. The site is too small to locate on historical aerial photographs.

Management Requirements:

Te Kopia Part

Ongoing control of wilding pines should be undertaken and the geothermal area kept as weed free as possible. Fences should be checked regularly and maintained. Fencing of the geothermal features within private farmland should be considered. The spread of blackberry in areas of treefall should be monitored, especially near the north of the site. Control should be considered if natural regeneration does not occur.

Western Te Kopia Part

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

Fences should be maintained to ensure continuing exclusion of stock. The spread of pest plant species should be monitored at regular intervals (e.g. five-yearly). Cotoneaster and common alder should be removed from the site.

Mangamingi Station Part

Consideration should be given to creating a buffer between the geothermal habitat and plantation forest while the trees are still small. If the surrounding area is to be grazed by stock it should be fenced to exclude stock.

Significance Level:

I: International (Criteria 1, 3, 5, 6, 7, 9, 10, 11).

L: Local (Criteria 3, 5,)

Significance Justification:

I: This site is of international significance because it forms the best quality example of a relatively intact area of geothermal vegetation which is part of a high quality ecological sequence. The site is within Te Kopia Scenic Reserve which comprises an ecological sequence extending from geothermal vegetation through to tall forest, including a small geothermal wetland area. The Te Kopia Scenic Reserve has an elevation range of 400 to 979 m. This site is also an excellent, high quality example of geothermal vegetation with few weeds and little human-related disturbance. One of the largest populations of *Dicranopteris linearis* (At Risk-Naturally Uncommon; de Lange *et al.* 2013) in Aotearoa New Zealand occurs here. This site also contains one of the largest areas dominated by geothermal kānuka (Threatened-Nationally Endangered), as well as good populations of three 'At Risk-Naturally Uncommon' species: *Nephrolepis flexuosa*, *Calochilus paludosus*, *C. robertsonii*, and the Threatened-Nationally Critical mistletoe, *Korthalsella salicornioides*.

L: Western Te Kopia and Mangamingi Station are locally significant because they contain a nationally uncommon habitat type (geothermal).

Notes:

Te Kopia Scenic Reserve was ranked as the protected natural area of highest conservation significance in the Atiamuri Ecological District (Spring-Rice 1996). Given (1996) assessed the botanical value of many geothermal sites in the Waikato Region, and in this survey this site was classed as Category A - the highest category.

The area of geothermal habitat alongside the stream was referred to as 'Road Spring' in Hochstein (2007b).

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. The geophysical assessment is presented as three separate sites - Te Kopia Northwest, Te Kopia West Mudpools, and Te Kopia Red Stream.

References:

Anon 2000; Burns 1996b & 1997b; Burns and Leathwick 1995; Clarkson 1984; Hochstein 2005 & 2007b; Spring-Rice 1996; Wildland Consultants 2000, 2004c, 2012, 2014a.



A geothermal pool, geothermal kānuka scrub and geothermally influenced bare ground. Note the scale of the geothermal area with the geothermal vegetation on the steep slopes in the background. 17 January 2023. NZMT E1880263 N5743798.



Several small isolated features, and geothermal streams are located in farmland to the west of the Te Kopia Scenic Reserve site. 20 January 2023. NZTM E1879855 N5742591.



Geothermal vegetation on Mangamingi Station includes *Paesia scaberula* fernland, geothermal kānuka shrubland, mingimingi shrubland, *Campylopus* sp. and other non-vascular species mossfield, exotic grassland, and small areas of geothermally-influenced bare ground. Note the sprayed and killed geothermal kānuka in the foreground. 18 January 2023. NZTM E1880783 N5742140.



A mud pool surrounded by planted Tasmanian blackwood in a fenced off area surrounded by farmland in the western part of the Te Kopia site. 20 January 2023. NZTM E1880925 N5745142

VASCULAR PLANT SPECIES RECORDED AT SURFACE GEOTHERMAL SITES IN THE TE KOPIA GEOTHERMAL SYSTEM

Scientific Name	Common Name	Te Kopia	Murphy's Spring
INDIGENOUS SPECIES			
Gymnosperms			
<i>Dacrycarpus dacrydioides</i>	Kahikatea	✓	
<i>Dacrydium cupressinum</i>	Rimu	✓	
<i>Pectinopitys ferruginea</i>	Miro	✓	
<i>Phyllocladus trichomanoides</i>	Tānekaha	✓	
<i>Podocarpus totara</i> var. <i>totara</i>	Tōtara	✓	
Monocot. trees and shrubs			
<i>Cordyline australis</i>	Ti kōuka, cabbage tree	✓	✓
<i>Cordyline banksii</i>	Ti ngahere, forest cabbage tree	✓	
Dicot. trees and shrubs			
<i>Aristotelia serrata</i>	Makomako, wineberry	✓	
<i>Beilschmiedia tawa</i>	Tawa	✓	
<i>Brachyglottis repanda</i>	Rangiora	✓	
<i>Carpodetus serratus</i>	Putaputawētā	✓	
<i>Coprosma grandifolia</i>	Kanono, raurēkau, raurākau, manono	✓	
<i>Coprosma ×cunninghamii</i>		✓	
<i>Coprosma lucida</i>	Karamū, kāramuramu, glossy karamū	✓	
<i>Coprosma propinqua</i> var. <i>propinqua</i>	Mingimingi	✓	✓
<i>Coprosma robusta</i>	Karamū, kāramuramu	✓	✓
<i>Coriaria arborea</i> var. <i>arborea</i>	Tutu	✓	
<i>Dracophyllum strictum</i>	Tōtorowhiti	✓	
<i>Dracophyllum subulatum</i>	Monoao	✓	
<i>Elaeocarpus dentatus</i>	Hīnau, whīnau	✓	
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taupuku	✓	
<i>Gaultheria oppositifolia</i>	Niniwa	✓	
<i>Geniostoma ligustrifolium</i> var. <i>ligustrifolium</i>	Hangehange	✓	
<i>Griselinia littoralis</i>	Kāpuka	✓	
<i>Hedycarya arborea</i>	Porokaiwhiri; pigeonwood	✓	
<i>Knightia excelsa</i>	Rewarewa	✓	
<i>Korthalsella salicornioides</i>	Dwarf mistletoe	✓	
<i>Kunzea robusta</i>	Kānuka	✓	
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	
<i>Leptecophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi	✓	
<i>Leptospermum scoparium</i>	Mānuka	✓	✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	
<i>Leucopogon fraseri</i>	Pātōtara	✓	
<i>Litsea calicaris</i>	Mangeao	✓	
<i>Meliccytus ramiflorus</i> subsp. <i>ramiflorus</i>	Māhoe	✓	
<i>Myrsine australis</i>	Māpou, matipou, māpau	✓	
<i>Myrsine salicina</i>	Toro	✓	
<i>Olearia rani</i> var. <i>colorata</i>	Heketara	✓	
<i>Pennantia corymbosa</i>	Kaikōmako	✓	
<i>Pittosporum eugenioides</i>	Tarata; lemonwood	✓	
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓	✓
<i>Pomaderris amoena</i>	Tauhinu	✓	
<i>Pseudopanax arboreus</i>	Whauwhaupaku, puahou, five finger	✓	
<i>Pseudopanax crassifolius</i>	Horoeka, lancewood	✓	
<i>Pterophylla racemosa</i>	Kāmahi	✓	
<i>Schefflera digitata</i>	Patē	✓	
<i>Veronica stricta</i> var. <i>stricta</i>	Koromiko, kōkōmuka	✓	✓
Monocot. lianes			
<i>Ripogonum scandens</i>	Supplejack, kareao	✓	
Dicot. lianes			
<i>Clematis forsteri</i>	Poananga, puawānanga	✓	
<i>Clematis paniculata</i>	Puawānanga	✓	
<i>Metrosideros diffusa</i>	Rātā	✓	
<i>Muehlenbeckia australis</i>	Puka	✓	

Scientific Name	Common Name	Te Kopia	Murphy's Spring
<i>Parsonia capsularis</i>	Akakiore	✓	
<i>Rubus cissoides</i> agg.	Tātarāmoa, tātarakeke, bush lawyer	✓	
<i>Rubus schmidelioides</i> var. <i>schmidelioides</i>	Tātarāmoa, bush lawyer	✓	
Lycopods and psilopsids			
<i>Lycopodium fastigiatum</i>	Mātukutuku, alpine clubmoss	✓	
<i>Lycopodium volubile</i>	Waewaekoukou, climbing clubmoss	✓	
<i>Lycopodiella cernua</i>	Mātukutuku	✓	
<i>Phlegmariurus varius</i>		✓	
<i>Psilotum nudum</i>	Fork fern	✓ (Humphries & Ecroyd 1990)	
<i>Tmesipteris elongata</i>		✓	
<i>Tmesipteris tannensis</i>		✓	
Ferns			
<i>Asplenium bulbiferum</i>	Mouku, mouki, mauku, hen and chicken fern	✓	
<i>Asplenium flaccidum</i> subsp. <i>flaccidum</i>	Makawe, ngā makawe o raukatauri, drooping spleenwort	✓	
<i>Asplenium gracillimum</i>		✓	
<i>Asplenium hookerianum</i>		✓	
<i>Asplenium oblongifolium</i>	Huruhuru whenua, shining spleenwort	✓	
<i>Asplenium polyodon</i>	Petako, paratao, sickle spleenwort	✓	
<i>Blechnum chambersii</i>	Rereti, nini, lance fern	✓	
<i>Blechnum filiforme</i>	Pānako, thread fern	✓	
<i>Blechnum fluviatile</i>	Kiwikiwi, kiwakiwa, creek fern	✓	
<i>Blechnum minus</i>	Swamp kiokio	✓	
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio	✓	✓
<i>Blechnum parrisiae</i>	Pukupuku	✓	
<i>Blechnum penna-marina</i> subsp. <i>alpina</i>	Little hard fern	✓	
<i>Blechnum procerum</i>	Small kiokio	✓	
<i>Blechnum deltoides</i>	Korokio	✓	
<i>Botrychium bifforme</i>	Fine-leaved parsley fern	✓	
<i>Christella</i> aff. <i>dentata</i> (b) (AK 126902 "thermal")			✓
<i>Cyathea cunninghamii</i>	Pūnui, gully tree fern	✓	
<i>Cyathea dealbata</i>	Ponga, silver fern	✓	
<i>Cyathea medullaris</i>	Mamaku, black tree fern	✓	
<i>Cyathea smithii</i>	Kātote, soft tree fern	✓	
<i>Deparia petersenii</i> subsp. <i>congrua</i>		✓	
<i>Dicksonia fibrosa</i>	Whekī-ponga, kurīpākā	✓	✓
<i>Dicksonia squarrosa</i>	Whekī	✓	✓
<i>Dicranopteris linearis</i>		✓	
<i>Diplazium australe</i>		✓	
<i>Gleichenia microphylla</i>	Waewaekākā, carrier tangle fern	✓	
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	
<i>Hiya distans</i>		✓	
<i>Hymenophyllum demissum</i>	Irirangi, pipiri, drooping filmy fern	✓	
<i>Hymenophyllum dilatatum</i>	Matua mauku, filmy fern	✓	
<i>Hymenophyllum multifidum</i>	Mauku, much-divided filmy fern	✓	
<i>Hymenophyllum nephrophyllum</i>	Kidney fern, konehu raurenga, kopakopa	✓	
<i>Hymenophyllum sanguinolentum</i>	Piripiri, filmy fern	✓	
<i>Hypolepis ambigua</i>		✓	
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pāharahara, hound's tongue fern	✓	
<i>Lastreopsis hispida</i>	Tuakura	✓	
<i>Leptopteris hymenophylloides</i>	Heruheru, single crepe fern	✓	
<i>Loxogramme dictyopteris</i>	Lace fern	✓	
<i>Nephrolepis flexuosa</i>	Indigenous ladder fern	✓	
<i>Notogrammitis heterophylla</i>		✓	
<i>Paesia scaberula</i>	Mātātā, hard fern	✓	✓
<i>Parapolystichum glabellum</i>	Smooth shield fern	✓	

Scientific Name	Common Name	Te Kopia	Murphy's Spring
<i>Pellaea rotundifolia</i>	Tarawera, button fern	✓	
<i>Pakau pennigera</i>	Piupiu, pākaurōharōha, feather fern, gully fern	✓	
<i>Polystichum wawranum</i>		✓	
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	✓
<i>Pteris tremula</i>	Turawera, shaking brake	✓	
<i>Rumohra adiantiformis</i>	Karuwhai	✓	
<i>Schizaea bifida</i>		✓ (Clarkson 1984, Humphries & Ecroyd 1990)	
<i>Schizaea dichotoma</i>		✓	
<i>Trichomanes venosum</i>		✓	
Orchids			
<i>Acianthus sinclairii</i>		✓ (Humphries & Ecroyd 1990)	
<i>Calochilus robertsonii</i>		✓ (Clarkson 1984)	
<i>Corunastylis nuda</i>		✓ (Clarkson 1984)	
<i>Dendrobium cunninghamii</i>		✓	
<i>Drymoanthus adversus</i>		✓	
<i>Drymoanthus flavus</i>		✓ (Humphries & Ecroyd 1990)	
<i>Earina autumnalis</i>	Raupeka	✓	
<i>Earina mucronata</i>	Peka-a-waka	✓	
<i>Microtis unifolia</i> agg.		✓	
<i>Prasophyllum colensoi</i>		✓ (Clarkson 1984)	
<i>Pterostylis banksii</i>	Tutukiwi	✓	
<i>Thelymitra longifolia</i>		✓	
Grasses			
<i>Austroderia fulvida</i>	Toetoe	✓	
<i>Austroderia toetoe</i>	Toetoe	✓	
<i>Microlaena avenacea</i>	Bush rice grass	✓	
<i>Microlaena stipoides</i>	Pātītī, meadow rice grass	✓	
<i>Pentapogon avenoides</i>		✓	
<i>Pentapogon crinitus</i>	Plume grass	✓	
<i>Rytidosperma gracile</i>		✓	
Sedges			
<i>Carex breviculmis</i>		✓	
<i>Carex forsteri</i>		✓	
<i>Carex geminata</i> agg.	Rautahi	✓	
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio	✓	
<i>Carex solandri</i>		✓	
<i>Carex uncinata</i>	Kamu matau a Maui, kamu	✓	
<i>Carex virgata</i>	Pūrei	✓	✓
<i>Carex zotovii</i>	Matau	✓	
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata	✓	✓
<i>Eleocharis acuta</i>	Spike sedge	✓	
<i>Eleocharis sphacelata</i>	Giant spike sedge, ngāwhā, kuta.kutakuta, paopao	✓	
<i>Gahnia pauciflora</i>	Takahikahi	✓	
<i>Gahnia setifolia</i>	Māpere	✓	
<i>Lepidosperma australe</i>		✓	
<i>Machaerina juncea</i>		✓	
<i>Machaerina rubiginosa</i>		✓	
<i>Machaerina sinclairii</i>	Toetoe tūhara, pēpepe	✓	
<i>Machaerina tenax</i>		✓	
<i>Machaerina teretifolia</i>		✓	
<i>Morelotia affinis</i>		✓	
<i>Schoenus tendo</i>	Wiwi	✓	
Rushes			
<i>Juncus edgariae</i>	Wi, wiwi	✓	
<i>Luzula picta</i> var. <i>picta</i>		✓	
Monocot. herbs (other than orchids, grasses, sedges, and rushes)			
<i>Astelia fragrans</i>	Kakaha	✓	
<i>Astelia microsperma</i>		✓	
<i>Astelia solandri</i>	Kōwharawhara	✓	
<i>Dianella nigra</i>	Tūrutu	✓	✓
<i>Phormium tenax</i>	Harakeke, flax	✓	
<i>Typha orientalis</i>	Raupō	✓	

Scientific Name	Common Name	Te Kopia	Murphy's Spring
Composite herbs			
<i>Euchiton audax</i>		✓	
<i>Lagenophora pumila</i>	Papataniwhaniwha	✓	
<i>Pseudognaphalium luteoalbum</i> agg.	Pukatea	✓	
<i>Senecio bipinnatisectus</i>	Australian fireweed	✓	
<i>Senecio minimus</i>		✓	
Dicot. herbs (other than composites)			
<i>Acaena anserinifolia</i>	Piripiri, hutiwai	✓	
<i>Drosera auriculata</i>	Sundew, wahu	✓	
<i>Epilobium alsinoides</i>		✓	
<i>Gonocarpus micranthus</i>	Piripiri	✓	
<i>Haloragis erecta</i> subsp. <i>erecta</i>	Toatoa	✓	
<i>Hydrocotyle heteromeria</i>		✓	
<i>Hydrocotyle moschata</i> var. <i>moschata</i>		✓	
<i>Hypericum pusillum</i>		✓	
<i>Nertera depressa</i>		✓	
<i>Ranunculus reflexus</i>	Maruru	✓	
<i>Stellaria parviflora</i>	Kohukohu	✓	
<i>Urtica sykesii</i>		✓	
NATURALISED AND EXOTIC SPECIES			
Gymnosperms			
<i>Cupressus macrocarpa</i>	Macrocarpa	✓	
<i>Pinus radiata</i>	Radiata pine	✓	
Dicot. trees and shrubs			
<i>Acacia melanoxylon</i>	Tasmanian blackwood	✓	
<i>Buddleja davidii</i>	Buddleia	✓	
<i>Cytisus scoparius</i>	Broom	✓	
<i>Erica lusitanica</i>	Spanish heath	✓	
<i>Paraserianthes lophantha</i>	Brush wattle	✓	
<i>Prunus</i> sp.	Ornamental cherry	✓	
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓
<i>Salix cinerea</i>	Grey willow	✓	
<i>Ulex europaeus</i>	Gorse	✓	
Grasses			
<i>Agrostis capillaris</i>	Browntop	✓	
<i>Agrostis stolonifera</i>	Creeping bent	✓	
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓	
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass	✓	
<i>Cortaderia selloana</i>	Pampas	✓	
<i>Cynodon dactylon</i>	Indian doab	✓	
<i>Dactylis glomerata</i>	Cocksfoot	✓	
<i>Holcus lanatus</i>	Yorkshire fog	✓	
<i>Lolium arundinaceum</i> subsp. <i>arundinaceum</i>	Tall fescue	✓	
<i>Lolium perenne</i>	Rye grass	✓	
<i>Miscanthus nepalensis</i>	Himalaya fairy grass	✓	
<i>Paspalum dilatatum</i>	Paspalum	✓	
Composite herbs			
<i>Achillea millefolium</i>	Yarrow	✓	
<i>Cirsium vulgare</i>	Scotch thistle	✓	
<i>Crepis capillaris</i>	Hawksbeard	✓	
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane	✓	
<i>Gamochaeta coarctata</i>	Purple cudweed	✓	
<i>Hypochaeris radicata</i>	Catsear	✓	
<i>Jacobaea vulgaris</i>	Ragwort	✓	
Dicot. herbs (other than composites)			
<i>Lotus pedunculatus</i>	Lotus	✓	✓
<i>Lotus suaveolens</i>	Hairy birdsfoot trefoil	✓	
<i>Ludwigia palustris</i>	Water purslane	✓	
<i>Orobancha minor</i>	Broomrape	✓	✓
<i>Plantago lanceolata</i>	Narrow-leaved plantain	✓	
<i>Plantago major</i>	Broad-leaved plantain	✓	
<i>Rumex acetosella</i>	Sheep's sorrel	✓	
<i>Rumex obtusifolius</i>	Broad-leaved dock	✓	
<i>Solanum nigrum</i>	Black nightshade	✓	✓
<i>Trifolium pratense</i>	Red clover	✓	
<i>Trifolium repens</i>	White clover	✓	

23. TOKAANU-WAIHI-HIPAU
GEO THERMAL SYSTEM



HIPAUA

Ecological District: Tongariro
Geothermal System: Tokaanu-Waihi-Hipaua
Bioclimatic Zone: Submontane
Extent of Geothermal Habitat: c.12.7 ha
Extent of Geothermal Vegetation: c.12.7 ha
Date of Most Recent Field Survey: No survey has been undertaken

GPS Reference: NZTM E1836790 N5684476
Altitude: 500-710 m
Local Authority: Taupō

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) A dense cover of geothermal kānuka with local patches of <i>Campylopus</i> moss amongst scattered steaming fissures.	Hillslope	c.2.2 ha
2.	Geothermal kānuka-mingimingi scrub (04.02.01) Geothermal kānuka and mingimingi form a dense cover with occasional fumaroles. Karamū and whauwhaupaku occur locally, particularly at the margins of this type where the geothermal kānuka-mingimingi scrub merges with whauwhaupaku-karamū-kāmahi/tutu scrub (outside of site) (Source: Given 1995).	Hillslope, shallow gullies	c.9.8 ha
3.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Heated bare soil (inferred from aerial photographs).	Hillslope	c.0.7 ha

Indigenous Flora: Geothermal kānuka (Threatened-Nationally Endangered) and *Campylopus* sp., which are both restricted to geothermal areas (Given, 1995), are present. Other Threatened or At Risk geothermal plant species may be present.

Fauna: Unknown. Common indigenous and introduced bird species typical of the habitat are likely to be present.

Geothermal Ecosystems: Heated ground (dry), fumaroles.

Current Condition (1995 Assessment): A relatively unmodified site well buffered by indigenous vegetation. It contains a good example of a mosaic of geothermal vegetation zones corresponding to soil temperatures (Given 1995).

Threats/Modification/Vulnerability:

Invasive pest plants: Unknown. There appears to be some pampas visible on photographs (taken from a helicopter), provided by Waikato Regional Council (July 2002).

Human impacts: Human impacts are currently very low, and the site is virtually unaltered by human interference (Given 1995).

Grazing: Livestock have no access to this area.

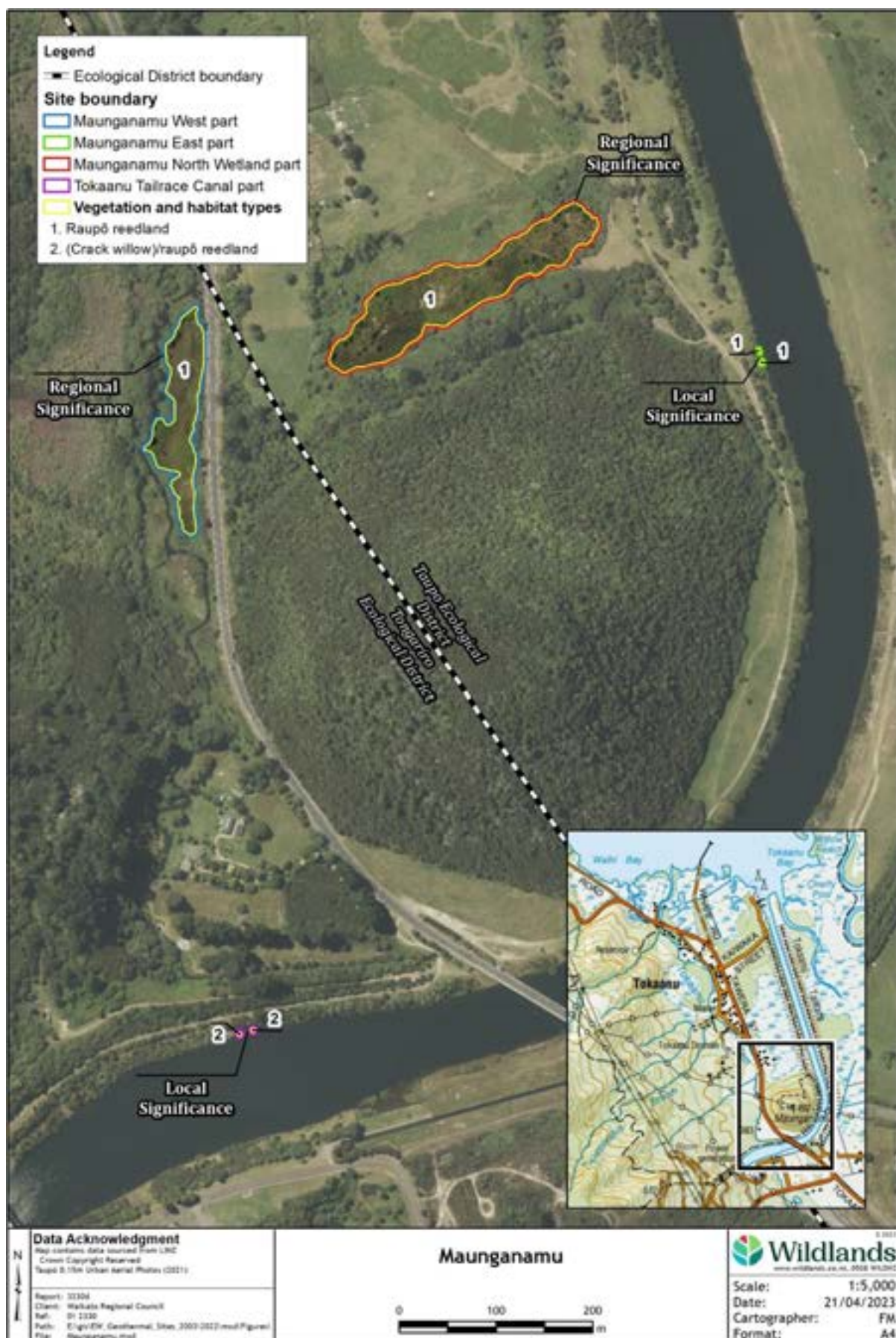
Adjoining land use: Surrounded by indigenous vegetation on unprotected private land.

Site Change:

<i>Recent change</i>	Any change in site boundaries is based on improved aerial photographs.
<i>Historical:</i> ¹	Photographs from 1941 ² were compared with 2007 aerial photographs. The site has probably changed little since 1941, although boundaries between vegetation types, particularly the boundary between geothermal scrub and non-geothermal scrub, are difficult to determine.
Management Requirements:	This site has not been surveyed, so obtaining information on the ecological values and management requirements is a high priority for this site. The current low levels of human impact should be maintained and the site should be monitored regularly to ensure that it remains in good condition. If pampas are present, as indicated by aerial photographs, then it should be controlled.
Significance Level:	National (Criteria 3, 5, 7, 9, 10).
Significance/ Justification:	This site is likely to be of national significance because it is a relatively large area of a nationally uncommon habitat type (geothermal habitat). It also comprises important habitat for a Threatened species (geothermal kānuka), near the southern end of its geographical range. The vegetation types present are representative of the ecological character of the Waikato Region. It is likely to have significant ecological values, however these are unknown as it has not been possible to undertake a field assessment of the site. The vegetation is highly intact, displaying good zonation and high indigenous component (Given 1995), and it is well buffered. The site is part of an extensive natural area and ecological sequence which includes a wide range of habitat types (geothermal, forest, wetland, subalpine) extending from the shores of Lake Taupō to the summit of Kakaramaea, Tihia, and Pihanga and including Lake Rotopounamu and Lake Rotoaira.
Priority for Field Survey:	This site is a high priority for field survey. Information on the condition and management requirements of this site is now relatively old.
Notes:	Access to this site was not granted, and the descriptions and assessments have been compiled from existing literature, digital aerial photographs (2021), and a visual inspection from SH 41 using binoculars during the 1999-2000 survey. The 2021 aerial photographs used for this report are of considerably higher quality than those used in previous reports on geothermal vegetation in the Region (see Wildland Consultants 2004c & 2012, 2014a). If site access is granted in the future, site information and boundaries should be reassessed, and all features should be inspected in detail. Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category A - the highest category.
References:	Department of Conservation 1998; Given 1995 & 1996; Wildland Consultants 2004c, 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photo: SN 178 Run 207 Photos 27, 1941.



MAUNGANAMU¹

Ecological District: Taupō; Tongariro **GPS Reference:** NZTM E1839981 N5682478
 NZTM E1840588 N5682576
Geothermal System: Tokaanu-Waihi- **Altitude:** 365 m
 Hipaua
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.2.1 ha
Extent of Geothermal Vegetation: c.2.1 ha
Date of Most Recent Field Survey: 7 February 2007

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Reedland (11.01) Raupō reedland (11.01.01) Maunganamu West Part Occasional crack willow occurs over raupō reedland in association with <i>Machaerina rubiginosa</i> , lake clubrush, <i>Eleocharis acuta</i> , pōhue, lotus, and creeping bent. Blackberry and Japanese honeysuckle are common on the margins. Soil temperatures at 10 cm depth were around 22.5 C and 25.4 °C in 2007. At 1 m depth temperatures were recorded up to 49.1 C. Maunganamu East Part Raupō reedland with abundant creeping bent and occasional pōhue. Geothermal seepages are present in the open canal water. Maunganamu North Wetland Part The area was viewed from the distance and appeared to be a raupō reedland with emergent crack willow common. This area is included as geothermal based on elevated soil temperatures at the edge of the wetland in 2007, and evidence of Hochstein (2007a) and Bromley and Mongillo (1991).	Wetland, canal margins	c.2.1 ha
2.	(Crack willow)/raupō reedland (11.01.03) Tailrace Canal Part Occasional crack willow occurs over raupō reedland with patches of <i>Machaerina rubiginosa</i> , swamp kiokio, <i>Juncus edgariae</i> , and creeping bent. Other species present include Yorkshire fog, harakeke, <i>Carex virgata</i> , and tall fescue.	Canal margins	<0.1 ha

Indigenous Flora: No 'Threatened' or 'At Risk' species are known from this site.

Fauna: Common indigenous and introduced species typical of the habitats are present. The wetland vegetation is likely to provide habitat for mātātā/North Island fernbird (At Risk-Declining) and pūweto/spotless crane (At Risk-Declining), in conjunction with the adjacent large area of wetland habitat.

¹ The site Maunganamu is an amalgamation of four sites from Wildland Consultants 2014a: Manganamu West, Maunganamu East, Manganamu North Wetland, and Maunganamu Tailrace Canal. South was referred to as Mountain Road in Wildland Consultants (2014a).

**Ecological
Ecosystems:**

Geothermal wetlands

**Current Condition
(2007 Assessment):**

Pest plants are present on some wetland margins, with occasional crack willow within wetlands. Fences were poorly maintained near the northern wetland site in 2007, however because the site was surrounded by blackberry, stock access is probably minimal. This northern wetland was in a moderate condition with common emergent crack willow.

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Blackberry (1-5% cover), Japanese honeysuckle (1-5% cover), and crack willow (1-5% cover). The cover of crack willow was higher in the northern wetland (5-25%), although all pest information is now dated.

Human impacts:

The two eastern areas are located by an artificial canal that is utilised for hydro-electricity. The northern site, at least in 2007, was farmed along its margins. The western wetland has a road within 10 m of the site. A culvert is also present.

Grazing:

In 2007 only the northern wetland had stock access. A range of pest animals will be present. Some pest animal control is undertaken by the hot pools.
<https://www.trap.nz/project/783326/info>: Accessed 20 June 2023.

Adjoining land use:

Tokaanu Stream, Tokaanu Tailrace Canal, indigenous and exotic scrub and forest, state highway, and farmland adjacent to the northern wetland.

Site Change:

Recent change:

Not assessed. Any change not likely to be significant.

*Historical:*¹

The wetland located near the State highway at the Manganamu West part of the site is too small to see any evidence of change since 1941².

In 1941³ there was bare ground in the vicinity of the Maunganamu East and Tokaanu Tailrace Canal parts of the site. This may be indicative of the presence of a greater extent of geothermal vegetation and habitat in the area at that time. Construction of the Tokaanu Tailrace Canal (constructed in conjunction with the Tokaanu Power Station, commissioned in 1973) appears to have resulted in a reduction in the extent of geothermal vegetation and habitats at this site.

Wetland on northern side of Maunganamu: In the 1958 photograph⁴ there appears to be bare ground in the vicinity of the site, of which only a small portion of this is likely to be geothermal.

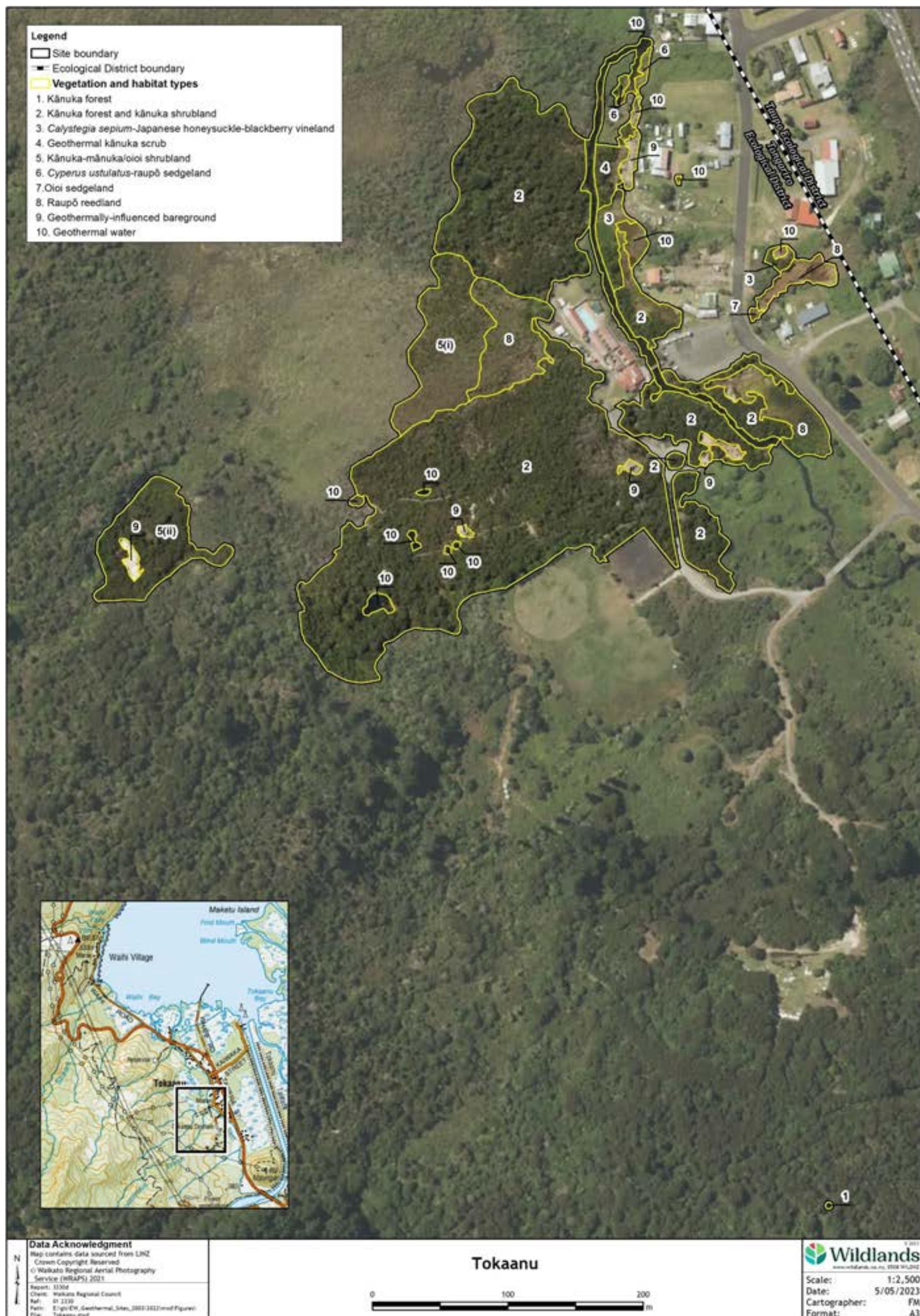
¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 178 Run 207 Photos 29-31, 1941.

³ Historical photos: SN 178 Run 207 Photos 29-31, 1941; SN 1099 Run A Photo 2, 1958.

⁴ Historical photo: SN 1099 Run A Photo 2, 1958.

Management Requirements:	Control of pest plant species (particularly crack willow) will maintain the ecological values of the site. Willow control should be undertaken in the northern wetland, and the site should be fenced to exclude domestic stock. It should be noted that the information on this site is likely to be out of date (2007).
Significance Level:	R: Regional (Criteria 1, 3, 4, 5, 6, 10). L: Local (Criteria 5, 6).
Significance Justification:	R: Maunganamu West and Maunganamu North Wetland parts of the site are of regional significance because it is partly protected and managed by the Department of Conservation and it forms part of an extensive ecological sequence that extends from the shores of Lake Taupō to the summit of Kakaramea, Tihia, and Pihanga, and which includes Lake Rotopounamu and Lake Rotoaira. This ecological sequence includes extensive areas of geothermal habitat. L: Manganamu East, and Tokaanu Tailrace Canal parts of the site are locally significant as it is a very small area of a nationally uncommon habitat type (geothermal) and an under-represented habitat type (wetland).
Notes:	Thermal springs and minor mud pools within this stretch were mapped by Healy (1942). Small groups of hot springs were reported by Healy (1942) in a stretch of swampy ground over the north region of Mt Maunganamu. One hot spring (77 °C) discharged c.100 m to the east of the main road and was sampled by Healy who apparently did not visit other manifestations in the same area. The same or an adjacent spring (Nr.52) was sampled and analysed by Mahon and Klyen (1968); its temperature was 66 °C. It is likely that thermal springs in the swampy area were detected by their infrared (IR) signature in 1991; other recorded IR signals (Bromley and Mongillo 1991) are associated with thermal ground in paddocks to the east of the Oasis Motel. A short summary of the thermal manifestations in the North Maunganamu sector is given by Hochstein (2005). A neighbouring landowner to the Maunganamu North Wetland has reported geothermal steam coming from this site. It is currently a raupō reedland wetland with common crack willow. As we did not have permission to access this area at the time of field survey in 2007, we have only examined this area from the road and neighbouring property. Further surveys are likely to result in the discovery of more examples of geothermal habitat alongside and within the Tailrace Canal, particularly when water levels in the canal are low. A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.
References:	Bromley and Mongillo 1991; Healy 1942; Hochstein and Prebble 2006; Hochstein 2005, 2007a Wildland Consultants 2004c, 2007a, 2012, 2014a.



TOKAANU¹

Ecological District: Taupō; Tongariro **GPS Reference:** NZTM E1839472 N5683151
Geothermal System: Tokaanu-Waihi-Hipaua **Altitude:** 380 m
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.7.8 ha
Extent of Geothermal Vegetation: c.7.5 ha
Date of Most Recent Field Survey: 23 August 2004 (parts visited in February 2007)

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Kānuka-dominant forest (01.01) Kānuka forest (01.01.01) Located near a urupā at the western end of the site. Kānuka forest to c.7 metres tall overhangs two mud pools. There is occasional whauwhaupaku and māpou present in the canopy. Scattered tūrutu, mingimingi, and blackberry are present around the mud pools, which measure c.5 × 5 metres and c.4 × 4 metres.	Mud pool	<0.1 ha
2.	Kānuka forest and kānuka shrubland (01.01.02) (i) Kānuka forest forms the vegetation cover over c.80% of this vegetation type. Kānuka forms a canopy up to c.7 metres high, with an understorey of kānuka, mingimingi, and oioi, with scattered tūrutu, hound's tongue fern, <i>Cyperus ustulatus</i> , and mānuka. Mud pools and hot water pools are common beneath the kānuka canopy. Kānuka shrubland forms the vegetation cover over the remaining c.20% of this area and generally occurs around the site margins. Kānuka shrubs are common with local <i>Cyperus ustulatus</i> and narrow-leaved carpet grass. Mosses (including <i>Wijkia extenuata</i> and <i>Ptychomnion aciculare</i>) often form a dense groundcover. Mānuka and mingimingi are abundant in both vegetation types. Around cooking sites and disturbed areas, weeds, e.g. Japanese honeysuckle, yucca, blackberry, broom, and various ornamental trees such as rhododendron, are present. Other species common within the area include kōhūhū, whauwhaupaku, tūrutu, karamū, whekī, swamp kiokio, and <i>Paesia scaberula</i> . (ii) Kānuka forest to 4 metres tall. Mud pools and hot springs are common throughout with several patches of geothermally-influenced bare ground. Soil temperatures of up to 90.5 °C were recorded at 50 cm depth in this vegetation type. Ivy, blackberry, hound's tongue fern, tūrutu, Japanese honeysuckle, and mingimingi are common in places. Atakororeke Stream, a geothermal stream, flows through this vegetation type. The approximate location of this stream is shown on the site map. The surface temperature of water in the stream was 23.0 °C, but temperatures increased to 58.1 °C at 10 cm depth in substrate. <i>Cyperus ustulatus</i> and kiokio are common along stream margins beneath a kānuka canopy. Blackberry becomes thick around stream margins c.100 m upstream of	Flat	c.5.5 ha

¹ This Tokaanu site is an amalgamation of two sites from Wildland Consultants 2014a: Tokaanu Thermal Park, and Tokaanu Urupā Mudpools.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	where the stream flows into the Tokaanu River. Geothermal kānuka is common near stream margins, particularly towards the northern portion of this site.		
3.	Exotic vineland (03.01) <i>Calystegia sepium</i>-Japanese honeysuckle-blackberry vineland (03.01.01) Dense vineland comprising pōhue and Japanese honeysuckle growing over blackberry. Patches of tall fescue are common. Mud pools and hot springs are scattered throughout this vegetation type.	River margins; mud pool; hot spring	c.0.1 ha
4.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka with a canopy height of 1-2 m. Pōhue, Japanese honeysuckle, and blackberry are common on margins.	Flat	c.0.1 ha
5.	Kānuka-dominant shrubland (05.06) Kānuka-mānuka/oioi shrubland (05.06.02) (i) Emergent kānuka is common in association with scattered mānuka over a dense cover of oioi. Small patches of geothermally-influenced bare ground are also present in places (too small to map separately). (ii) Kānuka dominates the canopy in association with mānuka (height of 3 m) and occasional mingimingi, over an understorey of oioi and sinter. This area is surrounded by dense blackberry scrub.	Hillslope	c.0.1 ha
6.	Indigenous sedgeland (09.01) <i>Cyperus ustulatus</i>-raupō sedgeland (09.01.01) Dense <i>Cyperus ustulatus</i> and raupō to 2.5 m. Japanese honeysuckle and blackberry are common on the margins. Patches of sinter and geothermally influenced bare ground are common (too small to map separately).	Wetland	<0.1 ha
7.	Oioi sedgeland (09.01.02) Oioi is dominant, with local <i>Eleocharis acuta</i> , <i>Schoenus maschalinus</i> , and adventive grasses, including creeping bent and Yorkshire fog.	Wetland	<0.1 ha
8.	Reedland (11.01) Raupō reedland (11.01.01) Dense raupō with scattered <i>Carex virgata</i> and lake clubrush, and a few saplings of grey willow and crack willow. <i>Cyperus ustulatus</i> is locally dominant and blackberry is common along the road margin.	Flat	c.0.6 ha
9.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Boiling water, sinter terraces, hot pools, and boiling mud. Scattered exotic grasses (e.g. narrow-leaved carpet grass, annual poa) and herbs (e.g. wild portulaca) are present. (i) A sinter terrace with oioi common on margins.	Flat; gently sloping; hillslope	c.0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	(ii) Geothermally influenced bare ground (thermally altered soils) with common raupō and geothermal kānuka and <i>Cyperus ustulatus</i> on margins. Hot springs and mud pools are common. Temperatures of up to 96.7 °C were recorded.		
10.	Water (22.01) Geothermal water (22.01.01) Hot stream and hot springs.	Stream; hot springs; open water	c.0.3 ha

Indigenous Flora:

A moderate sized population of *Korthalsella salicornioides* (Threatened-Nationally Critical), a semi-parasitic mistletoe, occurs at this site (Beadel and Bill 2000). *Schizaea dichotoma* (At Risk-Naturally Uncommon) is also present (Beadel and Bill 2000). This is the southern limit of distribution for *S. dichotoma*. (Note *Schizaea dichotoma* was not found during the 2004 or 2007 surveys).

A moderate-sized population of geothermal kānuka (Threatened-Nationally Endangered) is present.

Given (1995) recorded *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) from this site, but it is now considered extinct at this site. *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) was recorded from this site in 1987, but has not been recorded in subsequent surveys and is also presumed extinct at this site.

Fauna:

Mātātā/North Island fernbird (At Risk-Declining) are present at this site. Other birds present include tūī, korimako/bellbird, and riroriro/grey warbler.

Cicadas were audible during the field survey in 2007.

Geothermal Ecosystems:

Geothermal streamsides, geothermal wetlands, heated ground (dry), hydrothermally altered ground (now cool), fumaroles.

Current Condition:

This site was last visited in 2007 so this information is likely to be out of date. Historical photographs held at the tourism complex show that much of the present vegetation cover has developed over the last few decades. The dynamics of this site are not well understood and it is likely that the current vegetation will continue to evolve and change as the thermal activity changes. Continuing draw-off of heat or hot water from the site is likely to have ongoing impacts. However, the vegetation is of relatively good quality, and is contiguous with an extensive wetland to the west. Pest plants are common in the surrounding vegetation and geothermal margins. The site is highly dissected by formed walking tracks.

Threats/Modification/Vulnerability:

Invasive pest plants:

Based on the assessment from 2007, this site is vulnerable to pest plant invasion along track margins. The main weed species present at this site are Japanese honeysuckle (1-5% cover), ivy (<1-5 % cover), exotic grasses (1-5% cover), grey willow (1-5%), and bamboo (<1% cover). Several ornamental species have been planted around a geyser and bathing area. The spread of these species should be regularly monitored and control

implemented as required. Blackberry was present by the urupā mud pools in 2007.

Human impacts: Human impacts relate to the draw-off of heat or hot water which is likely to have ongoing impacts and high use from walkers; however the tracks appear to be generally adhered to. Indigenous species have been planted in parts of this reserve.

Grazing: Domestic livestock are not a threat to this area.

Adjoining land use: Indigenous vegetation, blackberry scrub, residential, farmland, recreation facilities (swimming baths, buildings), vehicle and walking tracks.

Site Change:

Recent change: Additional information located in 2007 resulted in additional areas being added to the site, however this did not represent a real change in the extent of geothermal vegetation or habitats. The site has not been reassessed in the field and any further changes are due to mapping with higher quality aerial photographs.

*Historical:*¹ Comparison of historic aerial photographs² with 2007 aerial photographs was undertaken. The Healy Bore to the south of the site, and its associated geothermal vegetation, was not evident on aerial photographs in 1941, as this was drilled in the 1950s (see geophysical assessment in Appendix 4). The boundary of geothermal surface manifestations at Tokaanu are difficult to determine on historical photos, as much of the site boundary is masked by wetlands. However, it is evident that some geothermal vegetation has been cleared for conversion to pasture and the establishment of a network of walking tracks. There also appears to be significantly more bare ground around the main tourist part of the geothermal site in 1941 than there is today, indicating that the character of this site has changed since the 1940s, and may be less active than in the recent past.

The mud pools in the eastern end of the site by the urupā are shown on a map in a 1942 paper (see Figure 2 in Healy 1942) where they are listed as ‘two larger mud pots’.

Management Requirements: The site should be kept weed free, and vegetation protected from human recreation use, e.g. trampling of vegetation.

Significance Level: National (Criteria 1, 3, 5, 6, 7, 9, 10).

Significance Justification: Most of the site is ranked as being of national significance. The site contains populations of Threatened species. The site is protected under the Reserves Act (1977) and comprises a relatively large example of geothermal vegetation which includes a wide diversity of habitat types. The site is part of an extensive natural area and ecological sequence which includes a wide range of habitat types (geothermal, forest, wetland, subalpine) extending from the

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photo: SN 178 Run 207 Photos 29-31, 1941.

shores of Lake Taupō to the summit of Kakaramaea, Tihia, and Pihanga and including Lake Rotopounamu and Lake Rotoaira.

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and ranked this site as Category B – the second highest category.

It is difficult to safely undertake a detailed inspection to determine exact boundaries of the site because of the geothermal activity. However, the geothermal area mapped in this report is similar to the area shown in infrared anomalies in Bromley and Mongillo 1991, and Hochstein 2007b, Figure 3.2, Page 73).

Two pools within this site are listed in Waikato Regional Council (undated) as Taumatapuhipuhi spring (an unfenced pool of *c.*75°C, which periodically erupts hot water) and Takarea No. 5 (a fenced pool of *c.*75°C).

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2007.

This site is a high priority for field survey. Information on this site is dated (2004 to 2007 field surveys).

References:

Anon. no date; Beadel and Bill 2000; Department of Conservation 1997; Given 1995 & 1996; Healy 1942; Hochstein 2007a & b; Waikato Regional Council (undated); Wildland Consultants 2004c, 2007a & 2012.



TOKAANU LAKE SHORE WETLAND

Ecological District:	Taupō, Tongariro	GPS Reference:	NZTM E1839489 N5684535
Geothermal System:	Tokaanu-Waihi-Hipaua	Altitude:	c.365 m
Bioclimatic Zone:	Submontane	Local Authority:	Taupō
Extent of Geothermal Habitat:	c.47.5 ha		
Extent of Geothermal Vegetation:	c.43.7 ha		
Date of Most Recent Field Survey:	13 February 2007		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Reedland (11.01) Raupō reedland (11.01.01) An extensive area of raupō reedland. A small population of arrow grass was viewed from the road on 13 February 2007. Crack willow and grey willow are present in this wetland, particularly on the margins of Lake Taupō and recently reclaimed wetland. Steam could be seen rising from the wetland at some locations, but access to most of these locations is hazardous.	Lake margin wetland	c.43.7 ha
2.	Water (22.01) Geothermal water (22.01.01) Geothermally-influenced water within the raupō reedland. Steam was viewed rising from this water on 13 February 2011.	Lake margin wetland	c.3.8 ha

Indigenous Flora: No 'Threatened' or 'At Risk' species were noted during the 2007 survey; however, a full field survey was not carried out at that time due to the hazards of accessing most of this site.

Fauna: One 'Threatened' and two 'At Risk' bird species were recorded in this wetland during the 2007 survey: wewea/New Zealand dabchick (Threatened-Nationally Increasing), pūweto/spotless crane (At Risk-Declining), and māātā/North Island fernbird (At Risk-Declining). Matuku hūrepo/Australasian bittern (Threatened-Nationally Critical) are also present in the area (William Shaw, Wildland Consultants, pers. comm. 2009).

Bird species almost certainly present (based on observations in the vicinity on author knowledge of the site, and observations lodged on the New Zealand Bird Atlas programme (Grid Square AZ75: <https://ebird.org/atlasnz/block/blkAZ75>) include kakānau/black swan, pūtangitangi/paradise shelduck, kuruwhengi/Australian shoveler, pāpango/New Zealand scaup, māpunga/black shag (At Risk-Relict), kawau paka/little shag (At Risk-Relict), kawau tuī/little black shag (At Risk-Naturally Uncommon), kotuku ngutupapa/royal spoonbill (At Risk-Naturally Uncommon), pūkeko, kāhu/swamp harrier, kārearea/New Zealand 'bush' falcon (Threatened-Nationally Increasing), poaka/pied stilt, spur-winged plover, karoro/black-backed gull, red-billed gull (At Risk-Declining), black-billed gull (At Risk-Declining), taranui/Caspian tern (Threatened-Nationally Vulnerable), kōtare/sacred kingfisher, pīpīwharau/roa/shining cuckoo, New Zealand pipit (At risk-Declining), warou/welcome swallow, tuī, pīwakawaka/North Island fantail, and tauhou/silvereye. Introduced species include domestic goose, Canada goose, mallard, pheasant, California quail, Eastern rosella, rock

pigeon, Eurasian blackbird, song thrush, dunnoek, yellowhammer, European greenfinch, European goldfinch, house sparrow, and Australian magpie.

Geothermal

Ecosystems:

Current Condition:

Geothermal wetland, geothermal streamsides.

This wetland is in excellent ecological condition. Pest plants are relatively rare in most of this site, with willow species (crack willow and grey willow) noted, particularly on site margins. Some land has been reclaimed for road construction, pasture development, and canal construction.

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Grey willow and crack willow were recorded in the wetland. These species should be controlled.

Human impacts:

Drains are present in parts of the wetland although they do not appear to have been maintained recently. Parts of the wetland have been converted to pasture and residential housing, and roads have been constructed to access the lake.

Grazing:

No grazing is known to occur within this site.

Adjoining land use:

Farming, roads, Lake Taupō, wetland, residential.

Site Change:

Recent change:

Not assessed. No significant change is known to have taken place in this wetland in the last twenty years. Changes to mapped areas in this update is mostly based on higher quality aerial imagery used for the most recent assessment.

*Historical:*¹

Comparison of 1941 aerial photographs of this site² with 2007 aerial photographs was undertaken. While little evidence of change was noted, Tokaanu Tailrace Canal has been constructed through the eastern part of the wetland, which is likely to have changed the character of parts of the wetland. Land has been reclaimed on each side of the canal. An area that was in pasture in 1941, to the east of the road that leads to the boat ramp and jetty (Wharf Road), has now reverted to wetland. Willows have become established alongside this road since 1941. No willows are obvious in 1941 aerials, but are common on the lake margins in the 2007 aerial photographs.

**Management
Requirements:**

Control of willows and any other pest plants should be undertaken in this wetland.

Significance Level:

International (Criteria 1, 3, 4, 5, 6, 7, 9, 10).

**Significance
Justification:**

The site is of international significance because it is one of the largest and best quality example of geothermal wetland in Aotearoa New Zealand. It is very different in character to the other large wetland site at Waiotapu. It is one of the best examples of a wetland-geothermal sequence in Taupō

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 178 Run 207 Photos 29-31, 1941.

Ecological District and is part of a large freshwater wetland that is in excellent ecological condition. It also provides habitat for Threatened and At Risk indigenous bird species.

Notes:

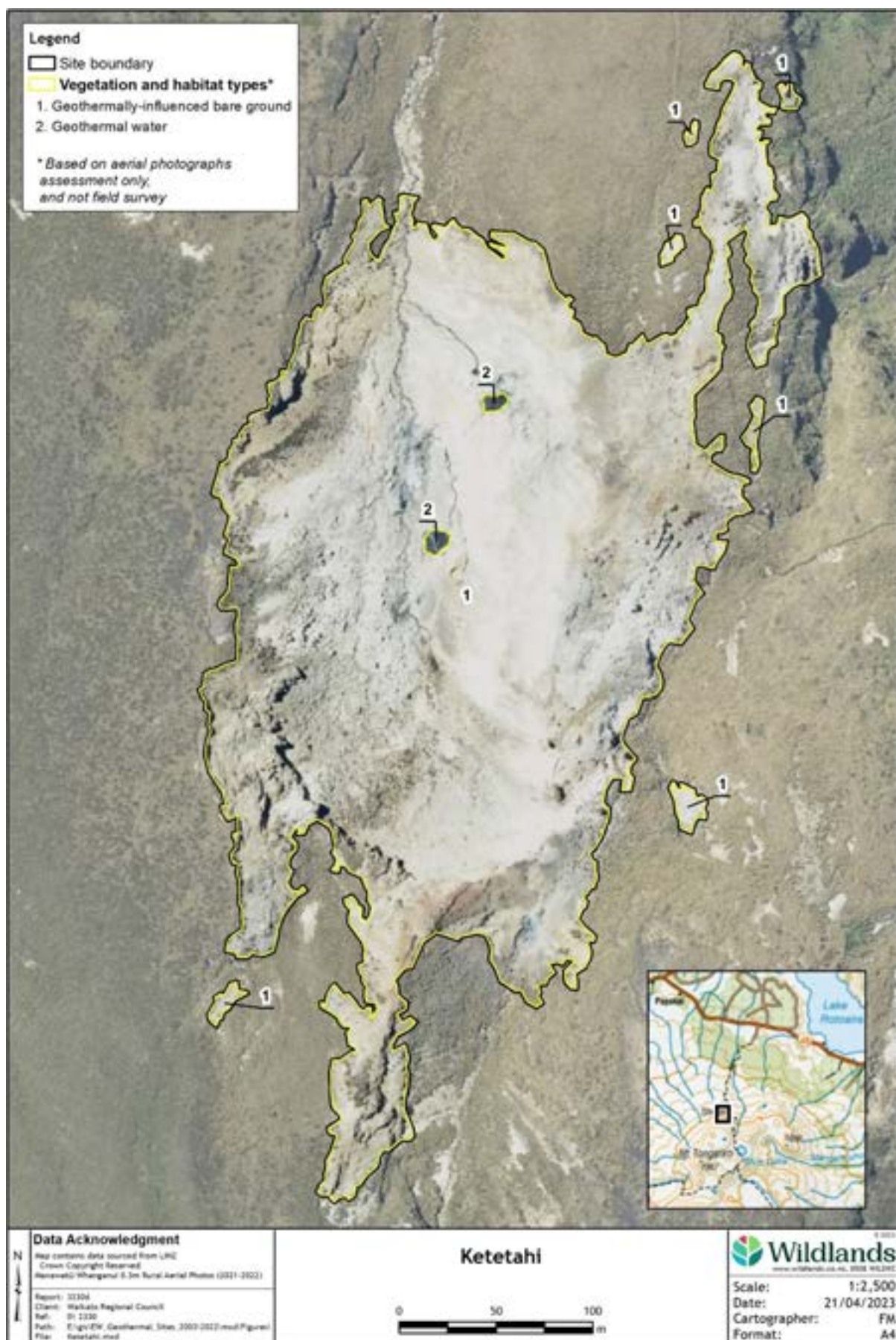
In 2007 the temperature of the substrate at the lake edge was measured in many locations, with temperatures ranging from 17-19 °C. However, extensive areas of geothermal habitat, including surface geothermal manifestations, are present further away from the lake.

Part of the area of raupō reedland was viewed from the road and entered by kayak on 13 February 2007. This is an extensive area of wetland vegetation and geothermal habitat is likely to be scattered throughout the site. The site was also viewed from State Highway 41 on 16 February 2007. Steam was seen rising from open water at several locations within this site. Based on these observations, it is therefore considered that extensive areas of geothermal water and geothermal wetland are present.

References:

Bromley and Mongillo 1991; Hochstein 2007a&b; Wildland Consultants 2007a, 2012, 2014a.

24. TONGARIRO GEOTHERMAL SYSTEM



KETETAHI

Ecological District: Tongariro
Geothermal System: Tongariro
Bioclimatic Zone: Subalpine
Extent of Geothermal Habitat: c.8.5 ha
Extent of Geothermal Vegetation: c.8.5 ha
Date of Most Recent Field Survey: No field survey undertaken.

GPS Reference: NZTM E1828935 N5667965
Altitude: 1,355-1,560m
Local Authority: Taupō

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Silica crusts and fumaroles.	Hillslope, Gullies, Craters.	c.8.5 ha
2.	Water (22.01) Geothermal water (22.01.01) Crater and geothermal streams.	Crater, gully.	<0.1 ha

Indigenous Flora: Unknown.

Fauna: Unknown.

Geothermal Ecosystems: Heated ground (dry), fumaroles, geothermal streamsides, acid rain systems, and hydrothermally altered ground (now cool).

Current Condition: Unknown. Likely to be excellent.

Threats/Modification/ Vulnerability:

Invasive pest plants: No significant pest plants known.

Human impacts: Up until about 25 years ago, a walking track passed through this site and it was a popular bathing spot. Public access is now restricted, the walking track has been relocated, and the site is now rarely visited by people.

Grazing: Not grazed. Site located within Tongariro National Park. A range of pest animals including hares and deer are likely to be present.

Adjoining land use: Tongariro National Park.

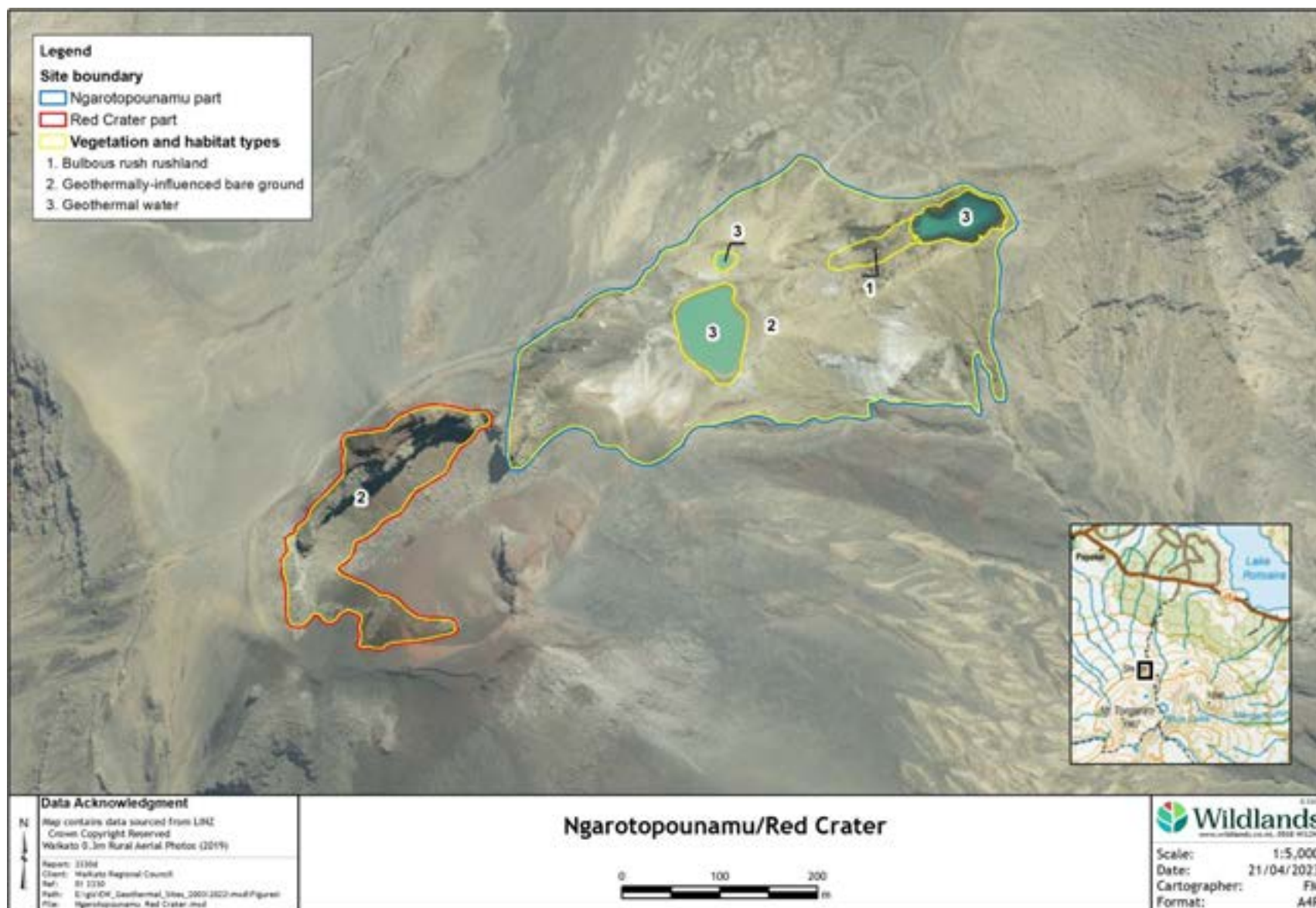
Site Change:

Recent change: Unknown. Probably no significant change as the site is rarely visited. Natural changes to surface geothermal manifestations are likely.

<i>Historical:</i> ¹	Apart from fluctuations in surface geothermal activity, little change to this site is likely. Site change is not easily identified from historical photos ² .
Management Requirements:	Not assessed.
Significance Level:	International (Criteria 5, 9, 10)
Significance Justification:	Based on historic information, Ketetahi Hot Springs is an excellent example of a nationally uncommon habitat type (geothermal). The site is part of an extensive natural area and ecological sequence which includes a wide range of habitat types (geothermal, forest, wetland, subalpine) extending from the shores of Lake Taupō to the summit of Kakaramaea, Tihia, and Pihanga and including Lake Rotopounamu and Lake Rotoaira. Although not legally protected, the site is fully surrounded by a UNESCO World Heritage Site and Tongariro National Park. The springs are of considerable importance to Ngāti Tūwharetoa.
Notes:	The 2023 update is based on an assessment of 2017 WRAPS. Mapping is based on aerial photograph and descriptions in Given (1995 & 1996). There are likely to be additional thermal sites nearby. This site was described by Given 1995 as being highly unusual in having no vegetation on the hot ground area, except for algal crusts on siliceous sites near fumaroles. Given (1995) states that it is an unusual site not replicated elsewhere in the region, and highly unusual even in a botanical sense on account of its lack of any flowering plants, mosses, or lichens. Given (1996) gave this site a botanical ranking of ‘A’ - the highest possible ranking. This site is a high priority for field survey. This site has never been surveyed by the authors and information on this site is dated (>25 years old).
References:	Given 1995 & 1996, Wildland Consultants 2007a, 2012.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical; photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957.



NGAROTOPOUNAMU/RED CRATER¹

Ecological District:	Tongariro	GPS Reference:	NZTM E1829200 N5664800
Geothermal System:	Tongariro	Altitude:	1,635-1,860m
Bioclimatic Zone:	Subalpine-Alpine	Local Authority:	Taupō
Extent of Geothermal Habitat:	c.12.1 ha		
Extent of Geothermal Vegetation:	c.11.1 ha		
Date of Most Recent Field Survey:	31 January 2018		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic rushland (10.01) Bulbous rush rushland (10.01.02) The gully above the lower and most northern Ngarotopounamu/ Emerald Lake has a small geothermal stream and heated ground with abundant boulders, scoria and bare ground. Surrounding the small stream, an area of abundant bulbous rush extends about 40 metres above the lower lake with abundant <i>Campylopus pallidus</i>. In drier areas, occasional blue tussock, <i>Rytidosperma setifolium</i>, and <i>Gaultheria colensoi</i> are present.	Crater, gully floor	c.0.2 ha
2.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) A. Red Crater: Bare heated scoria and soils. Fumarole present. A very low cover of plant species is present in the crater, most probably outside of areas of geothermal influence. Unidentified non-vascular plants could be seen on the walls of crater, but it was not safe to get close to them to assess the species present. Species present (all with a very low cover) in Red Crater include blue tussock, hells bells, <i>Luzula banksiana</i> var. <i>migrata</i>, <i>Euphrasia cuneata</i>, <i>Rytidosperma setifolium</i>, and the moss <i>Campylopus pallidus</i>. Hells bells was turf-like on the crater floor, where present. A small pond was present at the base of the crater, and this appeared to be ephemeral. B. Bare ground surrounding Ngarotopounamu/Emerald Lakes and slopes below Red Crater: The slopes below Red Crater are a boulderfield, while around the lakes themselves it is mostly bare ground, or scoria with many scattered large boulders. While most areas with geothermal activity are bare, there are scattered plants present. Two non-vascular plant species were abundant, <i>Campylopus pallidus</i> and <i>Trichostomiopsis australasiae</i>, with <i>Rytidosperma setifolium</i>, <i>Chaerophyllum colensoi</i> var. <i>colensoi</i>, hells bells, <i>Gaultheria colensoi</i>, and an unidentified moss also present. There are extensive areas of heated ground.	Crater, crater walls, face	c.10.9 ha

¹ The site was referred to as Emerald Lake/Red Crater in Wildland Consultants 2018. The Māori name for Emerald Lakes is Ngarotopounamu.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
3.	Water (22.01) Geothermal water (22.01.01) Three geothermally influenced lakelets occur in this site. Bulbous rush is present on lakelet margins, and relatively deep into the northernmost lake (it was not recorded from the other Ngarotopounamu (Emerald Lake)). It was estimated that the bulbous rush reached close to the lake's maximum depth. It has a dense cover underwater, particularly near the lake edge. For about half of the lake edge it extends two metres or further into the lake. For most of the rest of the lake edge it only extends about 30 cm into the lake, however in some places bulbous rush extends 3-6 metres into the lake from its edge. During the survey it was estimated that bulbous rush covered c.1% of the lake surface but occupied 30-40% of the water column. While the lake water temperature is cold, there is a strong geothermal influence surrounding the lakes (Wildland Consultants 2018b). The lakes are up to 4.5 metres deep and have a pH of 3-5; their colour is caused by minerals, mainly fumarolic sulphur, entering the water forming polysulphide ions (Williams 2001). The immediate lake edge has scattered <i>Rytidosperma setifolium</i>, <i>Chaerophyllum colensoi</i> var. <i>colensoi</i>, hells bells, and <i>Tortella knightii</i>. Upper Ngarotopounamu/Emerald Lake also has the only known record of the liverwort <i>Eoistachis stephanii</i> in the North Island and a species of algae is present in the lakes (possibly <i>Zygogonium ericetorum</i>) (van der Lubbe 2016).	Crater	c.1.0 ha

Indigenous Flora: No 'Threatened' or 'At Risk' plant species are present.

Fauna: Pīhoihoi/New Zealand pipit (At Risk-Declining) were recorded during the 2018 surveys. A kārearea (New Zealand 'bush' falcon; Threatened-Nationally Increasing) was recorded near the site on 22 April 2018. No fish species are known to be present in Ngarotopounamu (Emerald Lakes), and only a few invertebrates (*chironomids* and *caddis flies*) are present (Nick Singers in van der Lubbe 2016).

Geothermal Ecosystems: Acid rain systems, fumaroles, geothermal streamsides, heated ground (dry), hydrothermally heated ground, hydrothermally altered ground (now cool), geothermal wetlands.

Current Condition: Mostly in an excellent condition. Ngarotopounamu (Emerald Lake) contain a pest plant of concern, bulbous rush. The site is impacted by trampling, particularly around the lakes.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Bulbous rush is having significant impacts on the natural character of the lower Ngarotopounamu (Emerald Lake), and may be displacing indigenous species within the lake and in the gully immediately above the lake. Bulbous rush invaded the lower Ngarotopounamu (Emerald Lake) in approximately 1989 (van der Lubbe 2016).

<i>Human impacts:</i>	The site is near the Tongariro Alpine Crossing. A tramping track dissects the site.
<i>Grazing:</i>	Not grazed.
<i>Adjoining land use:</i>	Tongariro National Park, walking track, and tramping track.
Site Change:	
<i>Recent change:</i>	There has been an increase in trampling around the site, and invasion of bulbous rush in the lake. The extent of mapped vegetation has not changed greatly in the last 20 years.
<i>Historical:</i> ¹	Site change is not easily identified from 1957 photographs ² as the site was under snow. No change has been recorded in the literature at this site in the last 50 years.
Management Requirements:	A management plan to control bulbous rush was prepared by Wildland Consultants in 2018 (Wildland Consultants 2018b), following a full survey of the lake. The Department of Conservation subsequently undertook an eradication programme, but the effectiveness of this has not been determined.
Significance Level:	International (Criteria 1, 3, 5, 6, 7, 9, 10)
Significance Justification:	Red Crater and Ngarotopounamu (Emerald Lakes) are part of an internationally significant site because they are located within the part of Tongariro National Park that is listed as a UNESCO World Heritage Site. The site is part of an extensive natural area and ecological sequence which includes a wide range of habitat types (geothermal, forest, wetland, subalpine) extending from the shores of Lake Taupō to the summit of Kakaramea, Tihia, and Pihanga and including Lake Rotopounamu and Lake Rotoaira.
Notes:	The 2023 update is based on an assessment of 2017 WRAPS and Wildland Consultants (2018b).
References:	Wildland Consultants 2007a, 2012, 2018a & 2018b.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photographs: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957.



One of the Ngarotopounamu/Emerald Lakes. 31 January 2018. NZTM E1829618 N5664971.



Geothermal springs above one of the Ngarotopounamu/Emerald Lakes. NZTM E1829615 N5665010. 31 January 2018.



Overview of the three Ngarotopounamu/ Emerald Lakes. 31 January 2018. NZTM E1829364 5664828.



Red Crater. NZTM E1829244 N5664789. 31 January 2018.



ROTOPAUNGA

Ecological District: Tongariro **GPS Reference:** NZTME1829890 N5666480
Geothermal System: Tongariro **Altitude:** 1,710-1,810m
Bioclimatic Zone: Subalpine-Alpine **Local Authority:** Taupō
Extent of Geothermal Habitat: c.3.2 ha
Extent of Geothermal Vegetation: c.3.2 ha
Date of Most Recent Field Survey: 22 April 2018

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Specific type: (<i>Rytidosperma setifolium</i>)-(<i>Racomitrium lanuginosum</i>)-(<i>Celmisia spectabilis</i> subsp. <i>spectabilis</i>)-rocks/geothermal gravel and loam. An area of white surface alteration, indicative of past geothermal activity. The site meets the definition of “hydrothermally heated ground now cool”. Most of the ground is bare, but plants are establishing in local areas. Abundant rocks and gravel are present. Species present include <i>Rytidosperma setifolium</i> , <i>Racomitrium lanuginosum</i> , <i>Celmisia spectabilis</i> subsp. <i>spectabilis</i>) and a few <i>Veronica</i> (<i>Hebe</i>) <i>tetragona</i> subsp. <i>tetragona</i> , <i>Gentianella bellidifolia</i> , <i>Chaerophyllum colensoi</i> var. <i>colensoi</i> , hells bells, <i>Luzula banksiana</i> var. <i>migrata</i> , and blue tussock. Simons (2014) reported steaming ground in the vicinity of this site, but no steaming ground was recorded in the 2018 survey.	Hillslope, saddle.	c.3.2 ha

Indigenous Flora: No ‘Threatened’ or ‘At Risk’ plant species are present.

Fauna: A kārearea (New Zealand ‘bush’ falcon; Threatened-Nationally Increasing) was recorded near the site on 22 April 2018. New Zealand pipit (At Risk-Declining) were recorded nearby during the 2018 surveys.

Geothermal Ecosystems: Heated ground (dry), hydrothermally altered ground (now cool).

Current Condition: No pest plants were recorded and the site appears to be in a natural condition. The site may be subject to some trampling damage if people choose to walk up to Rotopaunga from the Tongariro Alpine Crossing.

Threats/Modification/ Vulnerability:

Invasive pest plants: None recorded

Human impacts: The site is near the Tongariro Alpine Crossing, but is rarely visited and human impacts are negligible with only minor trampling on the ridge.

Grazing: Not grazed. Browsing by hares and other pest mammals likely to occur on occasion.

Adjoining land use: Tongariro National Park.

Site Change:

Recent change: Unknown.

*Historical:*¹ Not assessed.

Management Requirements: None noted.

Significance Level: International (Criteria 1, 5, 9, 10)

Significance Justification: This site is part of an internationally significant site because it is located within the part of Tongariro National Park that is listed as a UNESCO World Heritage Site. The site is part of an extensive natural area and ecological sequence which includes a wide range of habitat types (geothermal, forest, wetland, subalpine) extending from the shores of Lake Taupō to the summit of Kakaramea, Tihia, and Pihanga and including Lake Rotopounamu and Lake Rotoaira.

Notes: The 2023 update is based on an assessment of 2017 WRAPS.

References: Wildland Consultants 2018a.



View of the Rotopaunga site from the Tongariro Crossing. 23 April 2018.



Rotopaunga site. 23 April 2018.
NZTM E1829890 N5666480.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



TE MAARI CRATERS

Ecological District: Tongariro Geothermal System: Tongariro Bioclimatic Zone: Subalpine Extent of Geothermal Habitat: c.28.5 ha Extent of Geothermal Vegetation: c.27.1 ha Date of Most Recent Field Survey: 25 January 2018 and 22 April 2018	GPS Reference: NZTM E1831000 N5668300 Altitude: 1,310-1,600m Local Authority: Taupō

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Indigenous fernland (07.01) <i>Lycopodiella cernua</i> fernland (07.01.15) All populations of <i>Lycopodiella cernua</i> that were observed in 2011 were destroyed during the 2012 eruptions. In 2018, a population was found on valley sides above the upper parts of Te Karo Stream, in the easternmost part of the geothermal vegetation mapped at the site (this population could have survived the eruptions). Scattered plants of <i>Lycopodiella cernua</i> are present over c.30-40 metres of hillslope amongst large boulders on geothermally heated ground. Other plants present include blue tussock, <i>Rytidosperma setifolium</i> , <i>Luzula banksiana</i> var. <i>migrata</i> , <i>Wahlenbergia pygmaea</i> subsp. <i>pygmaea</i> and occasional catsear.	Face	c.0.1 ha
2.	Stonefield (18.01) (<i>Rytidosperma setifolium</i>)-(blue tussock)/stonefield/loam and mud (18.01.01) There is mostly bare ground surrounding Sulphur Lagoon, with shingle and mud, and scattered tussocks of <i>Rytidosperma setifolium</i> , blue tussock, <i>Chaerophyllum colensoi</i> var. <i>colensoi</i> , <i>Gaultheria macrostigma</i> , and <i>Leucopogon fraseri</i> . <i>Hierochloa redolens</i> clumps are present on the northern side of Sulphur Lagoon.	Crater	c.0.7 ha
3.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) Most of the site has almost no vegetation, and the tephra deposits from the 2012 eruptions are the dominant cover. Areas of soils with a higher temperature, often with a white soil surface, have no vascular plant species present. A few ferns species – including <i>Paesia scaberula</i> and <i>Histiopteris incisa</i> – have established on tephra since the eruption, near NZTM E1830761 N5667878. Further from recent activity, but still under the influence of steam, scattered plants of <i>Rytidosperma setifolium</i> , blue tussock, <i>Celmisia spectabilis</i> subsp. <i>spectabilis</i> , <i>Gaultheria colensoi</i> , and <i>Luzula banksiana</i> var. <i>migrata</i> , and the moss <i>Racomitrium lanuginosum</i> are present. Fumaroles are abundant; examples include NZTM E1830871 N5667826 and NZTM E1838055 N5667825. In small drainage gullies formed in the tephra from the 2012 eruption, a few local occurrences of the mosses <i>Tortella knightii</i> , <i>Campylopus pallidus</i> , and <i>Campylopus introflexus</i> are present.	Crater rim, crater face	c.26.2 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
4.	Water (22.01) Geothermal water (22.01.01) Geothermal water is present in the base of a crater. This part of the site is labelled 'Sulphur Lagoon' on topographic maps. Water depth and extent varies over time. The mapped area is based on aerial photographs and the 2018 site visit. A few <i>Rytidosperma setifolium</i> were present, partly submerged by water during the site visit.	Crater	c.1.4 ha

Indigenous Flora: The site has an interesting complex of alpine and subalpine plants in association with geothermal influence. *Lycopodiella cernua* surrounds small north-facing vents. In inland areas in the central North Island, this species only occurs in geothermal sites, and at approximately 1500 metres a.s.l., this is the highest altitude known for this species in Aotearoa New Zealand.

Fauna: Pīhoihoi/New Zealand pipit (At Risk-Declining) were recorded during the 2011 and 2018 surveys. Kārearea/New Zealand 'bush' falcon (Threatened-Nationally Increasing) were recorded near the site by one of the authors in 2008, and flying over the site on 22 April 2015. Eurasian skylarks, blowflies and hoverflies were also present.

Geothermal Ecosystems: Acid rain systems, fumaroles, geothermal streamsides, heated ground (dry), hydrothermally altered ground (now cool), geothermal wetlands.

Current Condition: The site is in an excellent ecological condition. Occasional trampling by people, although the site has been rarely visited by the public since the 2012 eruptions.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: None known

Human impacts: This site is c.1.5 km to the east of an internationally recognised walking track (Tongariro Alpine Crossing). It is in a remote experience zone, and is only occasionally visited by tramping parties.

Grazing: Not grazed. Hares are present near the site and may visit occasionally.

Adjoining land use: National Park

Site Change:

Recent change: The Te Maari craters erupted twice in 2012 (August and November). Changes in the vegetation composition of this site are likely to have occurred as a result of these eruptions, but the extent of vegetation change at the site is unknown. The site boundaries have been redrawn based on the 2017 aerial photographs and this has resulted in an increase in size of the site, comprising what appears to be bare ground and steaming ground.

<i>Historical:</i> ¹	Site change between 1957 and 2011 is not easily assessed from inspecting aerial photographs from those years ² .
Management Requirements:	None identified. Monitoring changes in vegetation following the 2012 eruptions is of scientific interest, and regular monitoring (e.g. three to five yearly) is recommended.
Significance Level:	International (Criteria 1, 3, 5, 7, 9, 10)
Significance Justification:	Te Maari Craters is an internationally significant site because it is located within the part of Tongariro National Park that is listed as a World Heritage Site. The vegetation is naturally of relatively low diversity, but it is habitat of exceptional quality, with no recorded pest plant species and few human-induced impacts.
Notes:	The geothermal area at Te Maari Craters had changed markedly since the previous survey of this site in 2011. Two hydrothermal eruptions occurred in the Upper Te Maari Crater area in 2012, and the area of geothermal habitat has increased markedly in recent years. The 2023 updates is based on an assessment of 2017 WRAPS.
References:	Wildland Consultants 2007a, 2012 & 2018a.



Te Maari Craters. 13 June 2011.
Prior to the eruption of 2012.

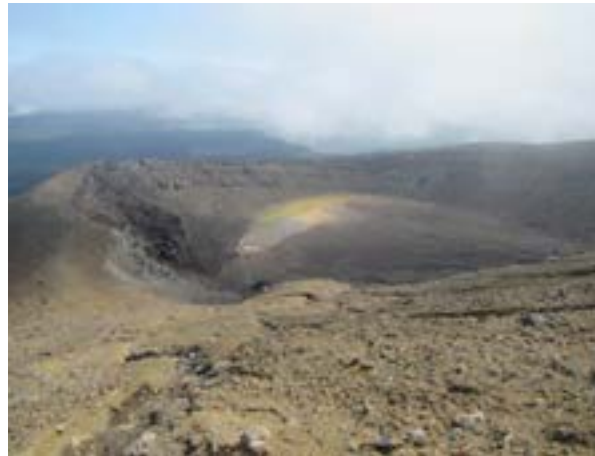


Te Maari Craters, the crater of the 2012 eruptions. 25 January 2018.
NZTM E1830975 N5667759.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.
² Historical photos: SN 1035 Run 2569 Photos 3-6, 1957; SN 1035 Run 2570 Photos 2-4, 1957.



Gully with geothermally influenced bare ground to the west of Te Maari Craters.
25 January 2018. NZTM E1830808
N5667816.

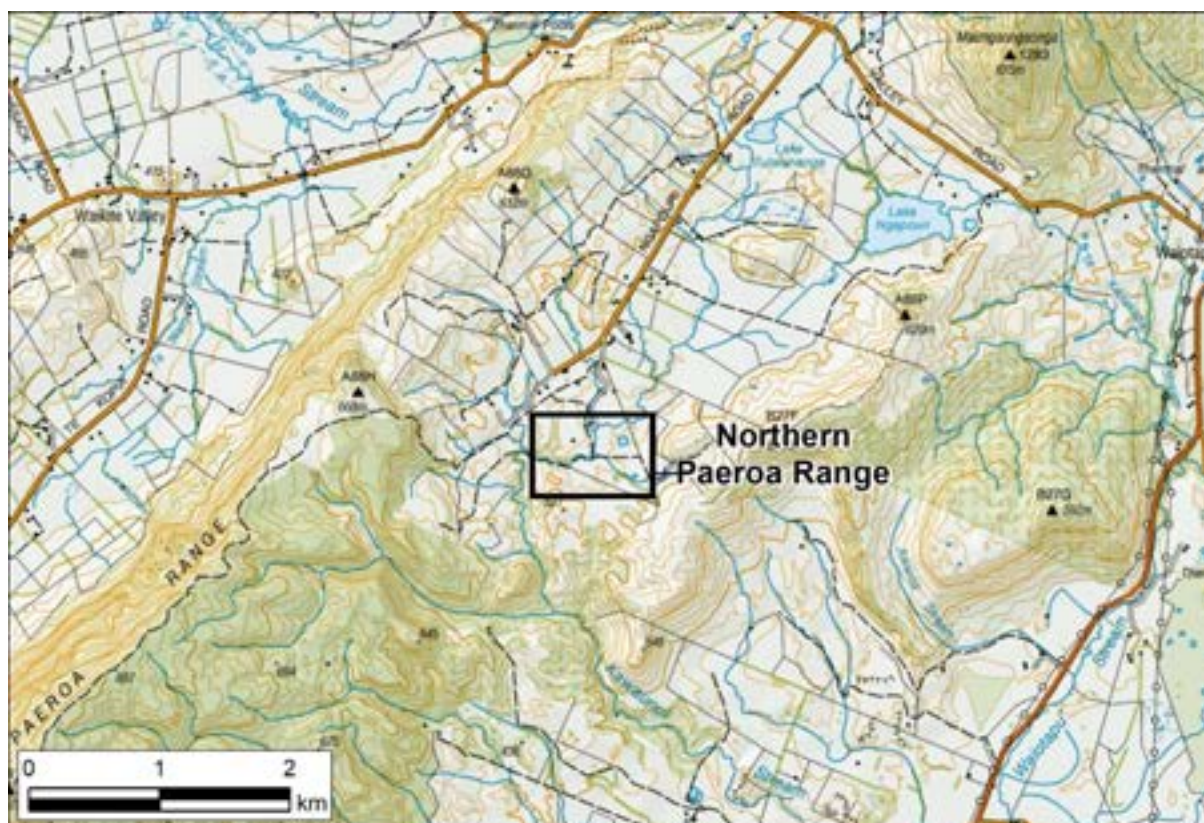


View towards the northern (lower) large Te Maari Crater with Sulphur Lagoon.
25 January 2018. NZTM E1830838
N5667829.



A small population of *Lycopodiella cernua* remains in geothermal habitat at Te Maari Craters. 25 January 2018. NZTM E1831505
N5667875.

25. WAIKITE-WAIOTAPU-WAIMANGU
GEOTHERMAL SYSTEM



Data Acknowledgment Map coordinate data sourced from LINZ Crown Copyright Reserved © Hokitika Regional aerial photography Service (HRAPS) 2021 Report: 22/04 Client: WRC Ref: 21-2108 Path: E:\GIS\DM_Geothermal_Sites_2002-2022\road\figures File: Northern Paeroa Range.mxd	Northern Paeroa Range	Wildlands www.wildlands.co.nz, 0800 915242 Scale: 1:5,000 Date: 26/06/2023 Cartographer: FM Format: A4

NORTHERN PAEROA RANGE

Ecological District:	Atiamuri	GPS Reference:	NZTM E1889118, N5749700
Geothermal System:	Waikite-Waiotapu-Waimangu	Altitude:	480 m
Geothermal System:	Waikite		
Bioclimatic Zone:	Submontane	Local Authority:	Rotorua
Extent of Geothermal Habitat:	c.0.4 ha		
Extent of Geothermal Vegetation:	c.0.4 ha		
Date of Most Recent Field Survey:	11 November 2022		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka scrub (04.01) Geothermal kānuka scrub (04.01.01) In Area B, the vegetation is dominated by geothermal kānuka and mingimingi. Scattered emergent silver birch, wilding pines and grey willow are present. In Area D, the vegetation is a mixture of geothermal kānuka and mingimingi. Occasional emergent radiata pine and grey willow are present. Area G comprises scattered eucalyptus to 20 metres tall which are emergent over scrub (1-3 metres high) dominated by geothermal kānuka and mānuka. Local areas of Yorkshire fog are present on the margin, along with geothermally influenced bare ground. Small numbers of grey willow, radiata pine, and broom are present throughout.	Gently sloping	c.0.1 ha
2.	Indigenous fernland (07.01) Bracken fernland (07.01.19) Dead bracken is dominant with occasional blackberry and mānuka. The bracken fronds were dead in Area G during the 2022 field inspection, likely seasonal dieback.	Gently sloping	<0.1 ha
3.	Indigenous sedgeland (09.01) Mixed <i>Carex</i> species-Yorkshire fog sedgeland (09.01.04) (Radiata pine)-(grey willow)/<i>Carex geminata</i>-Yorkshire fog sedgeland Occasional radiata pine and grey willow are emergent over sedgeland dominated by <i>Carex geminata</i> with local patches of Yorkshire fog. In drier areas there are local patches of mingimingi and mānuka. The wetland has expanded markedly in this area since 2010.	Wetland	<0.1 ha
4.	Bare ground (20.01) Geothermally-influenced bare ground (20.01.01) There are seven areas of geothermally influenced bare ground located within gullies in a northwestern tributary of the Kawaunui Stream. Area A: Geothermally influenced bare ground. The surrounding radiata pines have recently been harvested and pine debris cover	Gully (Area D is gully and wetland) Gully	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	areas that were previous active geothermal features. The area did not appear to be active during the previous survey of the site in June 2010 survey or the current (November 2022) survey. Scattered mānuka are present on margins.		
	Area B: This site was the most active of the geothermal areas visited in November 2022. Geothermally influenced bare ground with several geothermal kānuka plants, and occasional browntop. A concrete pipe is present in the hottest area of geothermal activity. The areas of bare ground are surrounded by maritime pine forest with a mānuka subcanopy to c.3 metres, and occasional mingimingi, grey willow, and blackberry.	Gully	<0.1 ha
	Area C: Geothermally influenced bare ground. The site is surrounded by harvested pine plantation and mānuka-mingimingi and blackberry scrub with occasional broom, and bracken, and several small patches of Yorkshire fog grassland and grey willow forest along the stream margin.	Gully	<0.1 ha
	Area D: This area is predominantly exposed geothermal clays surrounded by plantation forest. Occasional mānuka (to three metres height), water fern, and mingimingi are present on the margins.	Gully, wetland	<0.1 ha
	Area E: A small area of geothermally influenced bare ground surrounded by pine plantation, with mānuka and mingimingi, and occasional water fern and bracken in the understorey, with occasional Yorkshire fog, sweet vernal, mānuka seedlings, and geothermal kānuka. Difficult to view in 2022.	Gully	<0.1 ha
	Area F: Bare soil surrounded by pine and eucalyptus plantation. A small wetland is present in the gully with a cover of <i>Carex geminata</i> (too small to map).	Gully	<0.1 ha
	Area G: Mostly bare ground. Occasional geothermal kānuka, and patches of Yorkshire fog and <i>Gonocarpus micranthus</i> are present.	Flat	<0.1 ha

Indigenous Flora: There is occasional scattered geothermal kānuka (Threatened-Nationally Endangered). Other species typical of geothermal habitats present include mānuka, bracken, mingimingi, *Carex geminata*, and water fern.

Fauna: Common bird species are present. Indigenous species recorded include riroriro/grey warbler, tauhou/silvereye, pīwakawaka/fantail, and spur-winged plover. Introduced species recorded include Australian magpie (2010 observation), mallard, European goldfinch, European greenfinch, and common myna. Rabbits are present.

Geothermal Ecosystems: Heated ground (dry), hydrothermally altered ground (now cool), fumaroles, and geothermal wetland.

Current Condition: In a moderate condition. A concrete pipe is present in Area B. The site has been fenced to exclude stock subsequent to the 2011 survey. Pest plants are common on site margins.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Whilst most areas of geothermally-altered soils are largely devoid of vegetation, blackberry and grey willow are locally common on margins.

	Species cover within geothermal habitat are radiata pine (5%), grey willow (1%), <i>Eucalyptus</i> sp. (1%), broom (1%), blackberry (1%).
<i>Human impacts:</i>	An old concrete pipe is present in Area B.
<i>Grazing:</i>	The site is fenced, and no sign of stock was seen during the 2023 survey (c.f. cattle sign was observed during the 2011 survey).
<i>Adjoining land use:</i>	Fenced riparian vegetation, exotic plantation forest, and farming.
Site Change:	
<i>Recent change:</i>	There was little change in the vegetation between the 2011 and 2022 surveys. However, it has been fenced and cattle are excluded. However, there was a marked increase in spread of pest plants in the vegetation surrounding the site.
<i>Historical:</i> ¹	Site not assessed, no historical photos found. The surrounding land use was previously pastoral and is currently plantation forestry. As most sites are in gullies and relatively small it is unlikely that changes will be visible on black and white aerial photographs.
Management Requirements:	Fences should be maintained to ensure stock cannot access site. Consider management of pest plants (e.g., willows and any wilding trees). Care should be undertaken when felling the pine trees that surround some of the site to not damage geothermal features or indigenous geothermal vegetation.
Significance Level:	Local (Criteria 3, 4, 5, 6)
Significance Justification:	Northern Paeroa Range is locally significant because it comprises several small examples of a nationally uncommon habitat type (geothermal) and very small geothermal wetland areas. The site also provides habitat for a very small population of a threatened species (geothermal kānuka).
Notes:	A geophysical assessment of the surface geothermal manifestations at this site, undertaken in 2010, is presented in Appendix 4.
References:	Wildland Consultants 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



Northern Paeroa Range: Area B: Geothermally-influenced bare ground surrounded by bracken fernland and geothermal kānuka scrub. NZTM E1889222 N5749808. 11 November 2022.



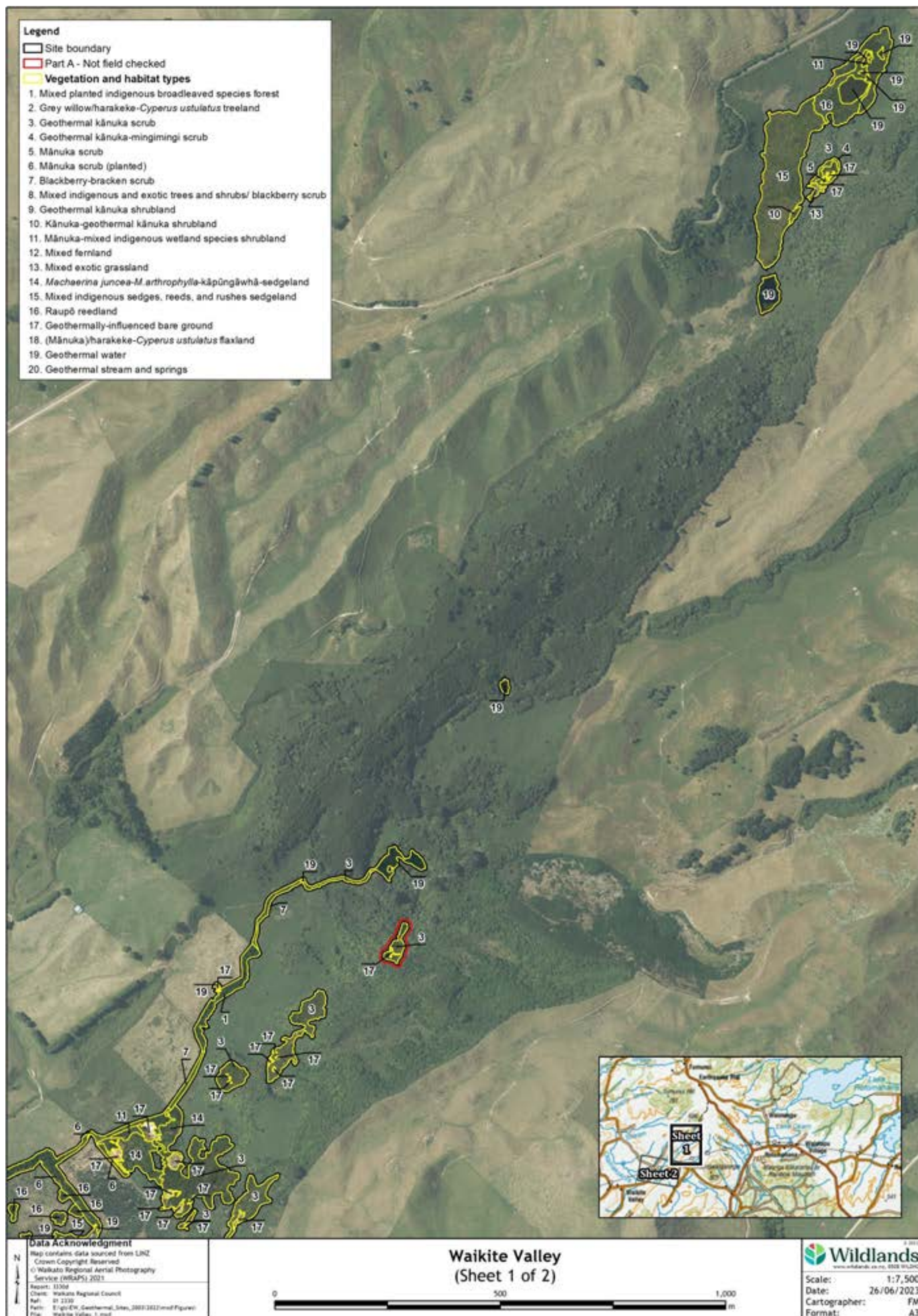
Northern Paeroa Range Area C. A panoramic view showing wetland vegetation that has re-established since the 2010 field inspection. NZTM E1889104 N5749707. 11 November 2022.

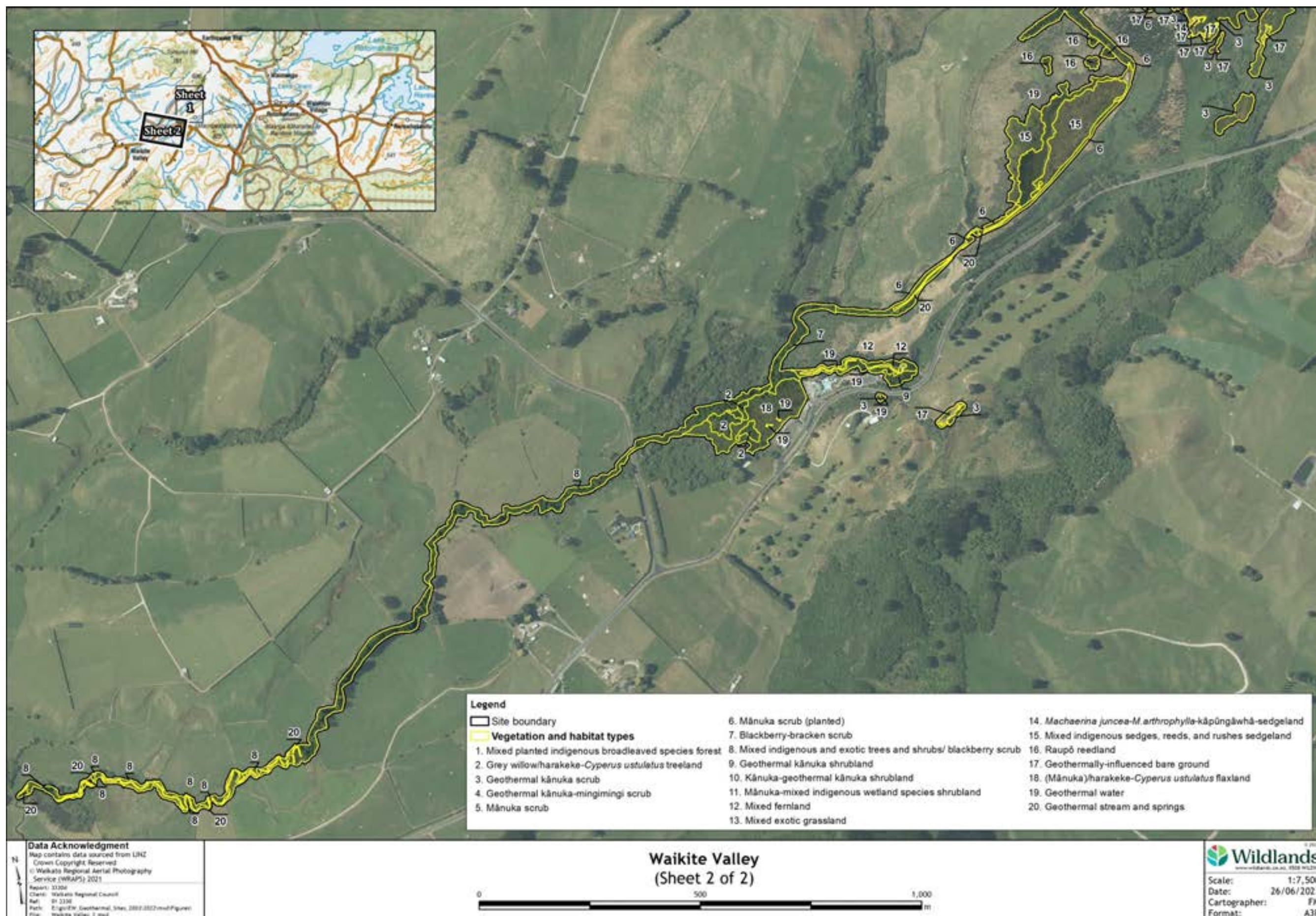


Northern Paeroa Range Area C. There has been an increase in cover of grey willow in this area since 2010. NZTM E1889190 N5749754. 11 November 2022.



Northern Paeroa Range Area G. This area of geothermally influenced bare ground is surrounded by bracken fernland and geothermal kānuka-mānuka scrub. NZTM E1889135 N5749306. 11 November 2022.





WAIKITE VALLEY

Ecological District:	Ataimuri	GPS Reference:	NZTM E1889034, N5752934
Geothermal System:	Waikite-Waiotapu-Waimangu	Altitude:	c.350-475 m
Geothermal System:	Waikite		
Bioclimatic Zone:	Submontane	Local Authority:	Rotorua
Extent of Geothermal Habitat:	c.25.1 ha		
Extent of Geothermal Vegetation:	c.22.4 ha		
Date of Most Recent Field Survey:	2, 10 and 25 November 2022		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Mixed indigenous broadleaved species forest (01.04) Mixed planted indigenous broadleaved species forest (01.04.02) Rautāwhiri-mānuka forest and scrub. Planted rautāwhiri c.3-7 metres high with local mānuka form the forest and scrub canopy. Rank grassland, dominated by Yorkshire fog, occurs locally on the margins of a stream. <i>Christella</i> aff. <i>dentata</i> (“thermal”) is abundant on the banks of the stream with locally common <i>Paesia scaberula</i>, and occasional <i>Cyperus ustulatus</i>, <i>Carex secta</i>, and <i>C. virgata</i>.	Stream margin	c.0.4 ha
2.	Exotic treeland (02.02) Grey willow/harakeke-Cyperus ustulatus treeland (02.02.01) Grey willow forms a discontinuous canopy over harakeke, and <i>Cyperus ustulatus</i>. Swamp kiokio, <i>Carex secta</i>, and <i>C. virgata</i> are also present. (This area was viewed from the margins as it was not safe to enter).	Wetland	c.0.5 ha
3.	Geothermal kānuka-dominant shrubland (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka forms a canopy approximately 0.5-1.5 metres high around geothermally influenced bare ground, fumaroles, and boiling mud. Scattered mingimingi and local mānuka are present, along with occasional Spanish heath and broom along the margins. The areas near the golf course have a sparse groundcover that includes mats of moss (<i>Campylopus</i> sp. and <i>Sphagnum cristatum</i>) with local patches of <i>Nephrolepis flexuosa</i> and wild portulaca. A few patches of <i>Cheilanthes sieberi</i> are present in one part of this type. Pasture surrounds some areas which are grazed by domestic stock. The area marked as A on the map has not been field assessed. It was identified from assessment of aerial photographs during the current survey.	Flat, gentle slopes, scarp	c.4.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
4.	Mingimingi dominant scrub (04.02) Geothermal kānuka-mingimingi scrub (04.02.01) Mingimingi to two metres tall dominant with local areas of geothermal kānuka, and local bare areas with mosses and lichens such as <i>Campylopus</i> sp. and <i>Cladonia</i> species. A few <i>Lycopodiella cernua</i> are present. Scattered broom, kāramu, and rewarewa occur on the margins.	Hillslope	<0.1 ha
5.	Mānuka-dominant scrub (04.04) Mānuka scrub (04.04.01) Mānuka is dominant, to two metres tall, with geothermal kānuka on margins.	Gully floor	<0.1 ha
6.	Mānuka scrub (planted) (04.04.07) Planted mānuka scrub (from two to four metres tall), mainly on riparian margins.	Riparian margins.	c.1.8 ha
7.	Exotic species-dominant scrub (04.10) Blackberry-bracken scrub (04.10.05) Dense scrub dominated by blackberry and bracken is present along the margins of the main stream. Kiokio and <i>Hypolepis ambigua</i> are common with occasional <i>Cyperus ustulatus</i> and karamū, local patches of kōhūhū and occasional emergent barberry. Scattered plants of <i>Christella</i> aff. <i>dentata</i> (“thermal”) and occasional <i>Cyclosorus interruptus</i> are also present.	Stream margins	c.0.8 ha
8.	Exotic-dominant scrub (04.10) Mixed indigenous and exotic trees and shrubs/ blackberry scrub (04.10.08) West of the Corbett Road Bridge, the margins of Otamakokore Stream are dominated by blackberry, with bracken and cocksfoot common. Patches of <i>Carex geminata</i>, <i>Paesia scaberula</i>, kiokio, <i>Muehlenbeckia australis</i>, <i>Deparia petersenii</i>, and swamp millet are locally common. Clumps of mature <i>Christella</i> aff. <i>dentata</i> (“thermal”) are scattered along the stream margins with local patches of <i>Nephrolepis flexuosa</i>. Other species occurring along the stream margin include <i>Hypolepis distans</i>, <i>H. ambigua</i>, water fern, ivy, feijoa, Lawson’s cypress, Lombardy poplar, and pampas, with local barberry, kōhūhū, karamū, and tī kōuka. The site margins are fenced and a small section has been planted in indigenous species, predominantly tī kōuka, kōhūhū, and harakeke. Small areas of Yorkshire fog-cocksfoot grassland are present within this type but are too small to map separately.	Stream margins	c.3.5 ha
9.	Geothermal kānuka shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Geothermal kānuka/geothermally-influenced bare ground shrubland. Scattered to common geothermal kānuka emergent over bare ground, pools, and cliff faces. There is local mānuka, blackberry,	Flat, gently rolling, terrace	c.0.2 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	and wetland with arrow grass, <i>Machaerina rubiginosa</i> , <i>Machaerina juncea</i> , and <i>Carex virgata</i> .		
10.	Kānuka-dominant shrubland (05.04) Kānuka-geothermal kānuka shrubland (05.04.03) Kānuka-geothermal kānuka/bracken-blackberry shrubland Kānuka to 3 metres tall with scattered patches of geothermal kānuka over an understorey of bracken and blackberry on the edge of the large northern wetland.	Terrace, riparian margins	<0.1 ha
11.	Mānuka-dominant shrubland (05.04) Mānuka-mixed indigenous wetland species shrubland (05.04.06) Mānuka/<i>Machaerina rubiginosa</i>-harakeke shrubland Scattered mānuka to 3 metres tall over a wetland dominated by harakeke and <i>Machaerina rubiginosa</i> with local oioi, <i>Machaerina juncea</i> and <i>Carex virgata</i>.	Wetland	c.0.8 ha
12.	Indigenous fernland (07.01) Mixed fernland (07.01.07) Several fern species, including <i>Nephrolepis flexuosa</i>, <i>Dicranopteris linearis</i>, <i>Deparia petersenii</i>, and water fern surround the Te Manaroa Hot Spring and the margins of the stream that flows from the spring. Scattered <i>Christella</i> aff. <i>dentata</i> ("thermal") are present downstream of the spring. Local patches of <i>Lycopodiella cernua</i>, bracken, kiokio, and <i>Hypolepis ambigua</i> are also present in this area, with occasional kōhūhū, karamū, whauwhaupaku, and kāmahi on higher, cooler areas. Blackberry and bracken become more abundant along stream margins downstream of the Waikite Pools. In places along the stream margins, <i>Cyperus alternifolius</i> subsp. <i>flabelliformis</i> and ivy have spread into indigenous geothermal vegetation.	Stream gully	c.0.5 ha
13.	Exotic grassland (08.01) Mixed exotic grassland (08.01.15) Narrow-leaved carpet grass-Indian doab grassland. Grassland dominated by narrow-leaved carpet grass, and Indian doab with local Mercer grass. Small areas of geothermally influenced bare ground and <i>Campylopus</i> mossfield are present.	Flat areas and gentle slopes at the foot of scarp	<0.1 ha
14.	Indigenous sedgeland (09.01) <i>Machaerina juncea</i>-<i>M. arthrophylla</i>-kāpūngāwhā-sedgeland (09.01.09) Scattered emergent mānuka are present over sedgeland dominated by <i>Machaerina juncea</i>, <i>M. arthrophylla</i> and kāpūngāwhā. <i>Cyclosorus interruptus</i> is scattered along the stream margin. Arrow grass grassland occurs on seepages on terraces within this type, fringed by narrow-leaved carpet grass on dry edges. Blackberry is common on drier, raised areas within this type.	Wetland	c.1.0 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
15.	Mixed indigenous sedges, reeds, and rushes sedgeland (09.01.13) The northern area is a wetland with abundant <i>Carex virgata</i>, <i>Carex secta</i>, kāpūngāwhā, and raupō with a height of 1.0 to 2.5 metres. Local emergent mānuka, harakeke, and <i>Coprosma propinqua</i> are present. Around the ponds and lakes, raupō reedland is present, although too small to map separately. On margins there is abundant blackberry and exotic grasses such as Yorkshire fog. There are a few areas of shrubland too small to be mapped with abundant mānuka, kānuka, and whekī-ponga. Local patches of <i>Hypolepis ambigua</i> and bracken are present along drier margins. One small patch of royal fern was found during the current survey. There are scattered plants of Japanese hill cherry establishing throughout the wetland. In 2014 this wetland was almost entirely covered by grey willow forest. The grey willow has been controlled, and some woody debris is locally abundant. Neither <i>Cyclosorus interruptus</i> or <i>Thelypteris confluent</i> was found in this area in 2022, and the habitat where they were previously located looked less suitable. Where this type occurs in the southern wetland the vegetation comprises a mosaic of <i>Carex secta</i> and <i>Carex virgata</i> sedgeland, raupō reedland, rank exotic grasses such as Yorkshire fog, local open water and mānuka shrubland. The geothermal wetland has increased in extent since the Department of Conservation has undertaken works in this area.	Wetland	c.5.5 ha
16.	Raupō-dominant reedland (11.01) Raupō reedland (11.01.01) Occasional emergent mānuka are present over raupō with harakeke locally common. <i>Carex secta</i>, <i>Cyperus ustulatus</i>, kāpūngāwhā, and <i>Machaerina rubiginosa</i> are common within this type. Blackberry and bracken are common around the margins. <i>Nephrolepis flexuosa</i> and <i>Christella</i> aff. <i>dentata</i> (“thermal”) occur locally where hot water flows into the reedland.	Flat/wetland	c.1.0 ha
17.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Thermally altered clay and fumaroles. Occasional geothermal kānuka, <i>Cyperus ustulatus</i>, <i>Lycopodiella cernua</i>, and mosses are present locally. Narrow-leaved carpet grass and Yorkshire fog are common locally on the cooler margins. In Area B, occasional <i>Cheilanthes sieberi</i> and wild portulaca are present on the non-vegetated raw-soilfield, and <i>Nephrolepis flexuosa</i> is present beneath Spanish heath on the upper margins. Some sinter is present on lower hillslopes at the southeastern part of the site.	Hillslopes, gentle slope, flat	c.0.6 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
18.	Flaxland (21.01) (Mānuka)/harakeke-Cyperus ustulatus flaxland (21.01.01) Scattered mānuka is present over harakeke and <i>Cyperus ustulatus</i> , with local patches of raupō, <i>Machaerina juncea</i> , and kāpūngāwhā. Swamp kiokio, <i>Carex secta</i> , and <i>C. virgata</i> are also present. Grey willow is common on the southern margin of this type. Blackberry, bracken, <i>Hypolepis ambigua</i> , creeping buttercup, and exotic grasses occur on dryer, cooler soils. Seepages of hot water are scattered throughout. <i>Christella</i> aff. <i>dentata</i> (“thermal”) occurs near several of these seepages. <i>Cyperus alternifolius</i> subsp. <i>flabelliformis</i> is locally common on the southern margin of this area.	Wetland	c.1.7 ha
19.	Water (22.01) Geothermal water (22.01.01) Hot springs, geothermally influenced ponds, and streams.	Flat, gully	c.2.3 ha
20.	Geothermal stream and springs (22.01.03) Geothermal stream, springs.	Gully	c.0.4 ha

Indigenous Flora:

There are three ‘Threatened’ and four ‘At Risk’ indigenous plant species present within this site: *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered), *Dicranopteris linearis* (Threatened-Nationally Endangered), geothermal kānuka (Threatened-Nationally Endangered), *Cyclosorus interruptus* (At Risk-Declining), *Hypolepis dicksonioides* (At Risk-Naturally Uncommon), *Nephrolepis flexuosa* (At Risk-Naturally Uncommon), and *Thelypteris confluentis* (At Risk-Naturally Uncommon).

A large population of *Christella* aff. *dentata* (“thermal”) is present at this site. Bycroft and Beadel (2007) estimated that there were c.400 plants at this site in 2007. One hundred and sixty-two clumps of *Christella* aff. *dentata* (“thermal”) were noted at this site in 2014 but this does not represent the entire extent of the population at the site as undertaking a detailed inventory of the population was outside of the scope of the current project. The population of this species appeared stable in 2022.

Scattered populations of *Nephrolepis flexuosa* are present alongside stream margins, Waikite scarp, within geothermal kānuka shrubland, and beside geothermal wetlands at the site. Bycroft and Beadel (2007) estimated that there were c.100 clumps of *N. flexuosa* at the Waikite site. In 2022, *N. flexuosa* remains particularly abundant around the Te Manaroa hot spring and on stream margins near E1889533, N5753311. The stream margin population of *N. flexuosa* initially increased significantly after a fence was erected along the stream margins to exclude domestic stock, and has remained relatively stable since. This population may be threatened with ongoing spread of blackberry near the central wetland, if not managed.

Also present are small populations of *Dicranopteris linearis* and *Hypolepis dicksonioides*. Bycroft and Beadel (2007) recorded ten plants of *H. dicksonioides* from this site in 2007 and nine were recorded in 2014. All plants recorded were located downstream of the Corbett Road Bridge. Bycroft and Beadel (2007) also estimated that there were about 20 clumps of *D. linearis* spread between Te Manaroa Hot Spring and Waikite Scarp.

Several populations of *Cyclosorus interruptus* are present. *Thelypteris confluens* has been recorded from the site in the past, but has not been recorded during more recent surveys (e.g. 2014 and 2022). Generally these populations cover small areas but are often relatively healthy within those areas, e.g. over 800 fronds of *Thelypteris confluens* occurred in over two distinct areas of c.10 m² (Bycroft and Beadel 2007). Some of the *Cyclosorus interruptus* plants are threatened by stock. Bycroft and Beadel (2007) identified two distinct populations of *C. interruptus* at this site: sixteen clumps were recorded in Waikite Wildlife Management Reserve, while another eight clumps were recorded on Waikite Landcorp Farm. The Waikite Management Reserve population was not found in November 2022. The plants on the farm were threatened by grazing, but recently stock have been excluded from most of this area, protecting most of these plants from grazing.

Geothermal kānuka which is endemic and restricted to geothermal areas, is locally common, particularly on Waikite scarp.

One *Psilotum nudum* plant was observed in an area of geothermal kānuka shrubland in the northeast of the site (Waikite Wildlife Management Reserve) in 2014; *P. nudum* had previously only been recorded from this site historically (Ecroyd and Coham 1976). A small population of *P. nudum* and *Cheilanthes sieberi* was present by the Waikite Valley Road in 2022. *Lycopodiella cernua*, *Machaerina juncea*, *M. arthropphylla*, arrow grass, wīwī, *Campylopus* sp. and *Blechnum parrisiae* also occur here.

Fauna:

Wewea/New Zealand dabchick (Threatened-Nationally Increasing) and māātātā/North Island fernbird (At Risk-Declining) were recorded from the site in 2022. Based on the 2014 survey, the population of North Island fernbird appeared healthy in the wetland and scrub upstream of the Corbett Road Bridge. Further indigenous and exotic species recorded at the site in 2022 include: kōtare/kingfisher, riroriro/grey warbler, pūtangitangi/paradise shelduck, tūī, korimako/bellbird, pīwakawaka/North Island fantail, warou/welcome swallow, kāhu/swamp harrier, European greenfinch, European goldfinch, yellowhammer, common pheasant, Eastern rosella, Australian magpie, Canada goose, and mallard. Two kōtuku ngutupapa/ royal spoonbills were seen flying from the western section of the stream and a lone poaka/pied stilt was observed in a paddock south of Otamakokore Stream.

Other bird species previously recorded at the site include pūweto/spotless crane (At Risk-Declining), pārerā/grey duck (Threatened-Nationally Vulnerable), tauhou/silvereye, miromiro/North Island tomtit, pōpokatea/whitehead, spur-winged plover, and Eurasian blackbird.

Pig sign (scat and rooting), rabbit sign (scat), hares (observed), deer sign (scat), possum sign (scat), and goat sign (scat) were observed within the site. Frogs were heard along the stream edge.

Geothermal Ecosystems:

Geothermal wetland, geothermal streamsides, heated ground (dry), hydrothermally altered ground (now cool).

Current Condition:

The geothermal vegetation ranges in condition from very high to moderately poor. The areas where the condition is poor is predominantly due to a high density of adventive species. The geothermal vegetation is discontinuous and is often surrounded by vegetation dominated by adventive species. Although

many key geothermal areas are fenced, the margins are heavily infested with blackberry. Some populations of thermal ferns are accessible to stock.

Part of the fenced paddock adjacent to the rediverted geothermal stream is reverting to predominantly indigenous-dominated vegetation. Whilst invasive pest plant species are present in this area they are currently at low density and cover. The vegetation composition of this area is likely to continue to change over the next five to ten years. The location of the stream rediversion is thought to reflect the original location of the stream prior to human modification.

The entire length of the main geothermal stream that passes through the site has been fenced to exclude stock, and blackberry is locally invading geothermal habitat around some drains, and competing for habitat with At Risk ferns. Some restoration planting with indigenous species has been undertaken. As a result of fencing of the stream margins, many areas of At Risk ferns previously threatened by stock grazing and trampling on stream margins are now recovering and are in good health.

Threats/Modification/ Vulnerability:

Invasive pest plants:

Invasive exotic plants are common within the site. Estimates of the percentage cover of invasive pest plants given here are an average cover for the entire site. Locally, covers may therefore be much larger than what is presented here. Blackberry is common to locally abundant throughout (c.20% cover) and grey willow is locally dominant (c.2% cover). Other invasive pest plant species present include broom (<1% cover), barberry (c.1% cover), Chinese privet (<1-5% cover), common alder (c.1% cover), *Cyperus alternifolius* subsp. *flabelliformis* (1-5% cover, is increasing in cover), elephant's ear (<1% cover), ivy (c.2% cover), Japanese honeysuckle (<1% cover), *Cotoneaster franchetii* (<1% cover), Lombardy poplar (2% cover), Mexican daisy (<1% cover) pampas (<1% cover), Spanish heath (c.1% cover), Japanese hill cherry (<1% cover), and tradescantia (<1% cover).

The *Cyperus alternifolius* subsp. *flabelliformis* population near the Te Manaroa spring has spread noticeably since 2014, and reaches 90% cover on some stream banks within the site. It has established on the other side of the river since the 2014 survey. Ivy has also spread noticeably within this area since 2007.

A small population of royal fern was found in the northern wetland in November 2022, and management action has since been undertaken by the Department of Conservation. The Department of Conservation is also actively managing the Japanese hill cherry at this site.

Human impacts:

Human impacts associated with the public thermal baths are the responsibility of the Rotorua District Council who has specific management policies for its biological features (Rotorua District Council 1994). Geothermal water is used in the swimming and bathing pools at the site.

A path is present from the public thermal baths to Te Manaroa Spring. A small amount of rubbish was present around this path.

A portion of the thermal stream has been rediverted and some restoration planting has occurred on the margins (see above). Vegetation composition change is likely to occur in this area over time.

Grazing:

The entire length of the main geothermal section of Otamakokore Stream within this site has been fenced to exclude domestic stock. Most of this fencing has taken place since 2007. The central wetland north and north-east of the pool complex is also fenced.

Stock are excluded from most parts of Waikite Scarp.

The wetland near the pool complex and Te Manaroa Hot Springs are not grazed by stock.

Some small parts of geothermal habitat remain unfenced and have stock access, although this is considerably smaller than in 2014.

Adjoining land use:

Farmland, scrub and forest habitats, public thermal baths, and golf course.

Site Change:

Recent change:

Indigenous species are starting to re-establish and become dominant in the wetland and adjacent damp paddock in the centre of the site as a result of stream diversion, management to raise water tables (to negate impacts of drains), restoration planting, and fencing to exclude stock. The main wetland is now dominated by harakeke and sedges rather than raupō, and indigenous and exotic rushes and indigenous sedges have colonised and established within the adjacent paddock. The restoration works within this part of the site have been funded by the Wairākei Environmental Mitigation Charitable Trust. The entire length of the main stream that passes through the site has been fenced to exclude stock, and some restoration planting with indigenous species has been undertaken. The vegetative character of these areas is likely to change over the next five to ten years as vegetation is released from grazing pressure.

Considerable willow control has occurred in the northern wetland (Waikite Wildlife Management Reserve) by the Department of Conservation and the wetland is no longer dominated by willow forest, but is a mosaic of sedges, reeds and rushes.

*Historical:*¹

It appears that the extent of geothermal vegetation and habitats has reduced since 1961². Geothermal vegetation/habitats have been removed to construct the commercial pool complex and in places have been replaced with farmland. Semi-heated geothermal bare ground on Waikite Scarp has been invaded by blackberry and broom scrub. It is difficult to make out the boundaries between geothermally-influenced scrub and other scrub habitats on Waikite Scarp in 1961 photographs. The wetlands on the Landcorp Farm, north of Waikite Valley Road, and the pool complex were grazed, with an extensive drain network similar to those observed in the field surveys undertaken. The wetland above the Corbett Road bridge and the vegetation

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photo: SN 1394 Run 3170 Photos 18-20, 1961.

around Te Manaroa Hot Spring appear similar in extent to the current day. Below the Corbett Road bridge there has probably been little change to the extent of the geothermal vegetation between 1961 and the present day. It is likely that the stream margins have been fenced at some locations, however the buffer of scrub around the stream was wider in other locations in 1961 than it is today. Only the upstream section of Otamakokore Stream was viewed on the 1961 aerial photographs.

**Management
Requirements:**

Blackberry is well established along stream margins in some places and will be difficult to control without damaging the indigenous vegetation. Regular surveillance and control of pest plant species (particularly blackberry) within fenced stream margins would be beneficial to ensure unwanted exotic species do not get established in these areas. Remaining unfenced geothermal vegetation and habitats should be fenced to exclude domestic stock.

Pest plants have become a major management issue downstream of Te Manaroa Spring. Ivy is smothering populations of *Nephrolepis flexuosa*, and banks above the stream have become locally dominated by *Cyperus alternifolius* subsp. *flabelliformis*. Both of these species require urgent control before they spread further within this site and potentially into other nearby geothermal sites. An ecological restoration plan (including an implementation plan) should be prepared for the highest priority areas of geothermal vegetation at the site. High priority areas include vegetation surrounding Te Manaroa Spring downstream to the pool facilities, the wetland on the farm to the north of Te Manaroa Spring, Waikite Wildlife Management Reserve, and *Christella* aff. *dentata* (“thermal”) habitat near, and downstream, of Corbett Road Bridge.

Significance Level:

National (Criteria 1, 3, 4, 5, 6, 7, 9).

**Significance
Justification:**

This site is nationally significant because it contains good quality, high diversity, and representative examples of geothermal habitat types that are nationally uncommon (geothermal and wetland). It includes good quality, large, geothermal wetland habitat which contains most of the species diversity typical of geothermal wetland. The site also contains a large population of a Threatened plant taxon (*Christella* aff. *dentata* (“thermal”)). Two other Threatened and four At Risk plant species are also present. Two Threatened and two At Risk indigenous bird species are also present at the site. Much of the site is a healthy representative example of its type.

Notes:

This site comprises three areas ranked in Given (1996): “Waikite Valley”, “Paeroa Scarp”, and “Otamakokore Stream”; these sites were ranked as Category A, Category B, and Category B respectively.

The Department of Conservation has administered parts of the site since 1987. Some of the most significant geothermal areas and wetlands were not captured in the protected area and were subsequently developed as part of Waikite Pamu/Landcorp farm. Sensitive areas were grazed and wetlands drained during this time period. In 2007, \$90,000 from the Wairākei Environmental Charitable Trust was used to protect, enhance and restore key features at Waikite. This involved fencing, enhancement and manipulation of hydrology, and planting and protection of surface geothermal features. These works showed that, by 2014, significant improvements of populations of *Christella*, *Nephrolepis*, and *Cyclosorus* had occurred at Waikite. In 2014 DOC received Resource Consent to raise the water level in part of the Waikite

wetland. Since 2012 the Department of Conservation also undertook considerable control of willows in the Waikite Wildlife Management Reserve <https://www.doc.govt.nz/our-work/waikite-valley-restoration>: Accessed 18 April 2023; Reeves *et al.* 2018)

Cashmore and Thompson (2021) note that exotic grassland, blackberry vineland, mixed indigenous shrubland over exotic grassland, and raupō reedland have all declined since restoration began. Large increases have been seen in rushland, toetoe grassland, pūrei sedgeland, indigenous scrub (without the exotic grassland), geothermally heated water and streamsides, and indigenous dominated sedgelands. Indigenous dominated vegetation classes have doubled in size since 2014. This change has been due to both increases in water table and pest plant control.

References:

Beadel 1995b; Bycroft and Beadel 2007; Cashmore and Thompson 2021; Ecroyd and Coham 1976; Given 1996; Miller and Ecroyd 1993; Reeves *et al.* 2018, 2021. Rotorua District Council 1994; Wildland Consultants 2004c, 2007b, & 2012.; Wildland Consultants 2000, 2004, 2012, 2014a.



Geothermal wetlands at the base of Waikite Scarp. Oioi, *Machaerina juncea*, arrow grass, and *Machaerina rubiginosa* with emergent mānuka are prominent. NZTM E1889544 N5753513. 2 November 2022.



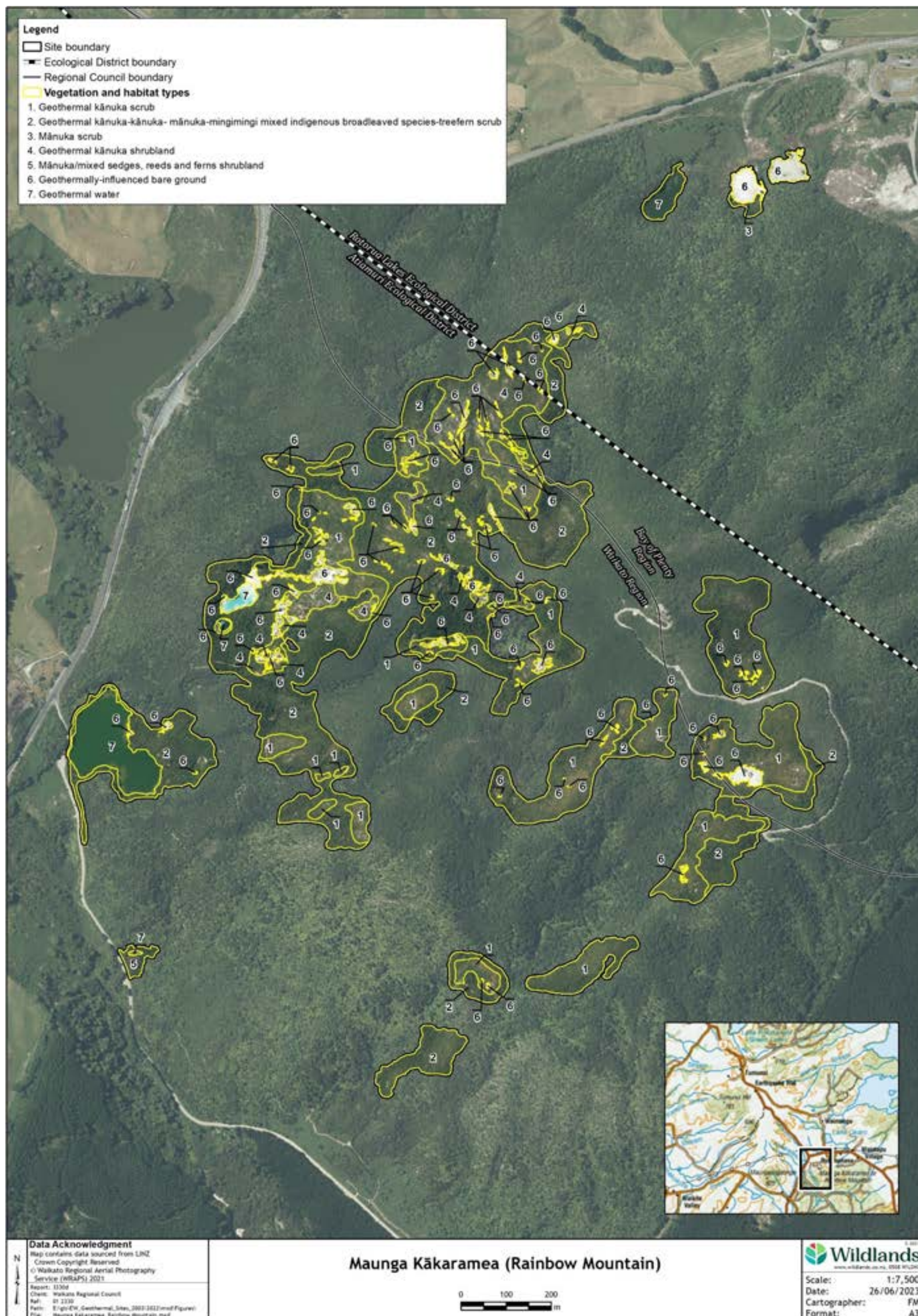
Algaefield on sinter, at base of Waikite Scarp. NZTM E1889589 N5753473. 2 November 2022.



Upper Otamakokore Stream, above Waikite Valley Thermal Pools, Waikite Valley. NZTM E1888882 N5752732. 10 November 2022.



Otamakokore Stream from Corbett Road Bridge. *Christella* aff. *dentata* ("thermal") is abundant alongside stream margins. NZTM E1888279 N5752653. 25 November 2022.



MAUNGA KĀKARAMEA (RAINBOW MOUNTAIN)

Ecological District:	Atiamuri; Rotorua Lakes	GPS Reference:	NZTM E1895633 N5753443
Geothermal System:	Waikite-Waiotapu- Waimangu	Altitude:	c.400-700 m
Geothermal System	Waiotapu		
Bioclimatic Zone:	Submontane	Local Authority:	Rotorua
Extent of Geothermal Habitat:	Entire site: c.68.0 ha; Waikato Region: c.52.3 ha		
Extent of Geothermal Vegetation:	Entire site: c.64.4 ha; Waikato Region: c.49.3 ha		
Date of Most Recent Field Survey:	9 and 10 November 2022		

CODE	VEGETATION TYPE	LANDFORM	EXTENT ¹
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka dominates the canopy (0.3-3 m high) with kāmahī and kānuka scattered throughout, and locally scattered mingimingi, prickly mingimingi, tāwiniwini, toru, rewarewa, and toatoa. The groundcover comprises bracken, <i>Gleichenia microphylla</i> , and tūrutu. The ground cover often has a dense moss and lichen cover, including <i>Dicranoloma</i> , <i>Campylopus</i> , and <i>Cladonia</i> species. The areas mapped as this type are mostly shorter geothermal kānuka with prostrate form, rather than Vegetation Type 2 below which contains geothermal kānuka that is generally taller.	Hillslope, ridges, crater	c.15.7 ha (c.21.9 ha)
2.	Geothermal kānuka-kānuka-mānuka-mingimingi mixed indigenous broadleaved species-treefern scrub (04.01.12) The vegetation in this area comprises a mosaic of geothermal kānuka scrub (described above), mānuka scrub, and mingimingi scrub with small pockets of forest comprising mixtures of geothermal kānuka and indigenous broadleaved species and treeferns. Broadleaved species locally present include kāmahī, rewarewa, hangehange, kōhūhū, whauwhaupaku, karamū, and toru. Several small areas with toatoa and rimu and treeferns such as whekī, whekī ponga, ponga and mamaku are present. Within the scrub habitats scattered tūrutu, tōrorowhiti, <i>Gleichenia microphylla</i> , monoao, prickly mingimingi, bracken, <i>Lepidosperma australe</i> , and tāwiniwini are present. The ground cover often comprises predominantly dense moss and lichen, including <i>Dicranoloma</i> , <i>Campylopus</i> , and <i>Cladonia</i> species. On lower slopes, some blackberry has established. Fumaroles are abundant throughout. Wilding pines, particularly radiata pine, are establishing in places.	Hillslope, cliffs, ridge, and shallow basin	c.29.6 ha (c.32.4 ha)
3.	Mānuka-dominant scrub (04.04) Mānuka scrub (04.04.01) Mānuka forms a canopy over an understorey of mingimingi, bracken, tūrutu, and kiokio, with geothermal kānuka in more geothermally active areas. <i>Sphagnum</i> sp. often forms the ground	Lake margin, hillslope.	None (c.0.2 ha)

¹ Top value is the extent in the Waikato Region, the bottom value is the extent for the entire site including parts in the Bay of Plenty Region.

CODE	VEGETATION TYPE	LANDFORM	EXTENT ¹
	cover where there is a high water table. Water fern and <i>Carex geminata</i> occur locally near areas of hot water in poorly drained areas. Occasional whekī and kāmahi are present.		
4.	Geothermal kānuka-dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Geothermal kānuka shrubland (0.3-0.75 m high) is common in areas with high substrate temperatures, with patches of mossfield interspersed with areas of nonvegetated heated ground and steaming ground. This type mostly occurs on the northern slopes of Maunga Kākarama. Monoao, mingimingi, and the lichen <i>Pulchocladia retipora</i> are locally scattered in these areas. Other vascular species present include tūrutu, toru, <i>Lycopodiella cernua</i> , kānuka, mānuka, and prickly mingimingi. Kāmahi occurs at the margins of the areas of high substrate temperatures, and local populations of <i>Dicranopteris linearis</i> and <i>Nephrolepis flexuosa</i> are present. Wilding pines are establishing within this vegetation type.	Hillslope, Ridge, cliff, crater	c.1.8 ha (c.6.3 ha)
5.	Mānuka-dominant shrubland (05.04) Mānuka/mixed sedges, reeds and ferns shrubland (05.04.04) (Crack willow)/mānuka/ <i>Carex secta</i> - <i>Carex geminata</i> -raupō- <i>Histiopteris incisa</i> shrubland. Mānuka forms a canopy c.2-4 m high with geothermal kānuka and mingimingi scattered throughout. Scattered emergent crack willow are present. Other species present include whekī-ponga, whekī, karamū, broom, and grey willow. The groundcover includes local areas dominated by <i>Carex secta</i> , <i>Carex geminata</i> , raupō, and <i>Histiopteris incisa</i> . Whauwhaupaku, kōhūhū, and kāmahi occur around the margins of this type, and locally throughout.	Wetland	c.0.3 ha (c.0.3 ha)
6.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Geothermally-altered soil, mud, sinter, explosion craters, and fumaroles.	Flat, hill, hillslope, ridge, crater	c.1.9 ha (c.3.4 ha)
7.	Water (22.01) Geothermal water (22.01.01) Geothermally influenced lakes, small pools, springs, and streams.	Crater, depression	c.3.0 ha (c.3.6 ha)

Indigenous Flora:

The following species characteristic of geothermal vegetation occur here: geothermal kānuka (Threatened-Nationally Endangered), *Schizaea dichotoma* (At Risk-Naturally Uncommon), *Dicranopteris linearis* (Threatened-Nationally Endangered), a small population of *Nephrolepis flexuosa* (At Risk-Naturally Uncommon), and *Schizaea fistulosa*. Populations of *D. linearis*, *N. flexuosa* and *S. dichotoma* appear to be relatively stable at this site. Four orchid species - *Calochilus paludosus*, *C. robertsonii*, *Caladenia alata*², and *Caladenia atradenia*³ (all At Risk-Naturally Uncommon) - have been recorded at the site (Rotorua Botanical Society 2006). *C. alata* and *C. atradenia* were not recorded in the 2010 or

² Previously *Petalochilus alatus*.

³ Previously *Stegostyla atradenia*.

2022 survey. *Calochilus paludosus* and *C. robertsonii* were recorded in the 2022 survey. Other species typical of geothermal habitats present include mānuka, monoao, mingimingi, prickly mingimingi, tāwiniwini, tūrutu, *Lycopodiella cernua*, *Morelotia affinis*, *Drosera auriculata*, *D. spathulata*, and bracken. Other species of interest in geothermal areas are toatoa, *Dracophyllum strictum*, *Gaultheria paniculata*, toru, and *Corokia buddleioides*.

Other species of interest present in the wider reserve area are *Ileostylus micranthus*, *Thelymitra carnea*, *T. nervosa*, *T. ixioides*, (At Risk-Naturally Uncommon), *T. pulchella*, *T. pauciflora*, and *Psilotum nudum* (see species list, Rotorua Botanical Society 2006), however these species may not all be present in the areas of geothermal vegetation and habitats.

Fauna:

Common indigenous bird species typical of the habitat are present. Species recorded during the current site visit, and recent visits by the authors include: weweia/New Zealand dabchick (Threatened-Nationally Vulnerable), pūtangitangi/paradise shelduck, kāhu/swamp harrier, kārearea/New Zealand ‘bush’ falcon (Threatened-Nationally Increasing), ruru/morepork, pūkeko, spur-winged plover, karoro/black-backed gull, kōtare/sacred kingfisher, kererū/New Zealand pigeon, koekoeā/long-tailed cuckoo (Threatened-Nationally Vulnerable), pīpīwharau/shining cuckoo, tūi, koromiko/bellbird, pōpokotea/whitehead, toutotuwai/North Island robin (At Risk-Declining), miromiro/North Island tomtit, warou/welcome swallow, tauhou/silvereye, riroriro/grey warbler, and pīwakawaka/North Island fantail.

Introduced species recorded include mallard, pheasant, California quail, eastern rosella, Eurasian blackbird, song thrush, Australasian magpie, common myna, common starling.

Long-tailed pekapeka/bats (Threatened-Nationally Critical) were detected at Maunga Kākaramea in December 2009 (Cosnahan 2010).

Geothermal Ecosystems:

Heated ground (dry), geothermal streamsides, fumaroles, geothermal wetland, hydrothermally altered ground (now cool).

Current Condition:

The geothermal vegetation in this site is surrounded by a relatively large area of indigenous vegetation within Rainbow Mountain Scenic Reserve. There are public access tracks to some of the geothermal areas, and these tracks appear to be well maintained and adhered to. The small part of the site that had stock access in 2022 has been fenced. The biggest ecological concern is the impact of pest animals and plants. The Department of Conservation undertakes a pest plant control programme in geothermal areas in this reserve with a particularly focus on wilding conifers.

Threats/Modification/Vulnerability:

Invasive pest plants:

Wilding pines are the key invasive plant species in areas of geothermal vegetation. Whilst geothermal hot spots appear to be resistant to weed

invasion, wilding conifers¹ are a threat to some areas of geothermal kānuka scrub which occurs on cooler soils, particularly on the eastern side of the site. Considerable pine control has been undertaken by Department of Conservation in recent years, and the current population of pines in geothermal areas is now very low (<1% cover of the area in which geothermal vegetation occurs). Pampas is locally present in some geothermal areas.

Crack willow (<1%) and grey willow (<1%) are present alongside stream margins and wetlands adjacent to the 'old' Waikaremoana Road. Gorse (<1%) and Spanish heath (<1%) are present in geothermal areas alongside Kerosene Creek Road and site margins. Willow-leaved hakea (1-5% cover) has become more common on the north faces of the reserve. Chinese privet (<1%) is also present on the north-facing slopes. Along the road side and southern slopes, plants of broom and blackberry are abundant, and patches of *Cotoneaster franchetii* and *montbretia* are present. *Aristea ecklonii* is present alongside the road to Maunga Kākaramaea summit.

Human impacts: Human impacts are minimal and are mainly associated with recreational use restricted to clearly defined tracks. In the past, orchid collectors have been a major threat to the orchid populations, however there have been no recent reports of collecting.

Grazing: No longer an issue at this site, c.f. horses and sheep were grazing the northern part of the reserve in 2010.

Adjoining land use: Surrounded by indigenous vegetation in Rainbow Mountain Scenic Reserve, roads, and plantation forest.

Site Change:

Recent change: The ongoing control of wilding pines within the site has markedly improved the condition of the geothermal vegetation. Additional areas of geothermal vegetation were found in 2010 and 2022 as a result of better quality aerial photographs. The changes in extent is almost entirely related to better aerial imagery.

*Historical:*² A series of historic photographs³ were compared with 2007 photographs. In most places it is difficult to determine the differences between geothermal and non-geothermal scrub and shrubland however the following observations were made:

- A small lake, which may have been geothermal, is no longer present to the southwest of Lake Rotowhero (approximately E1894870 N5752800). The extent of bare ground in the southern portion of the site was also greater on the 1941 photographs (c.f. 2007); weed invasion and establishment of plantation forests on historically geothermal soils are the likely cause of the decrease in extent of bare ground since 1941.

¹ Conifers previously recorded in the reserve prior to control works being undertaken include bishop pine (*Pinus muricata*), Douglas fir, lodgepole pine, European larch (*Larix decidua*), black pine, maritime pine, radiata pine, and strobus pine (*Pinus strobus*) (Rotorua Botanical Society 2006).

² This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

³ Historical photos: SN 172 Run 1157 Photos 7-12, 1941; SN 172 Run 1158 Photos 7-8, 1941.

- The extent of bare ground visible on the eastern and northern slopes of Maunga Kākaramea has decreased significantly since 1941. This is partly as a result of cooling geothermal soils, and establishment of shrubs and exotic pines.
- More bare ground was evident on the margins of Lake Rotowhero, but not markedly so.
- The extent of geothermal vegetation and habitat in the north of the site, near SH38, appears significantly reduced since 1941, likely as a result of land being converted for industrial and farm use. A geothermal lake and surrounding geothermal vegetation, and geothermally-influenced bare ground have been converted to pasture. The lake at F3 on the site map may have also been more active in 1941, with bare ground on northern and southern margins of the lake.

Taking into account the fact that many areas that were historically bare geothermal sites have been invaded by indigenous shrubs and wilding pines, an estimated loss of geothermal activity at this site is likely to be in the order of 5-20% since 1941.

Management Requirements:

Ongoing management of pest plants should continue. Management of trampling impacts by people in geothermal habitats should be encouraged.

Significance Level:

International (Criteria 1, 3, 4, 5, 6, 7, 9, 10, 11).

Significance Justification:

This site has been assessed in the context of the greater area in which it sits (i.e. part of the best quality parts of the Waiotapu Geothermal System including the wetland from the south of Waiotapu to the top of Maunga Kākaramea). It is of international significance because it is part of the largest and best quality example of geothermal vegetation in New Zealand. The site contains a good quality representative example of an ecological sequence grading from geothermal vegetation to tall forest over an elevation gradient of 380-743 m (see Nicholls 1974; Clarkson 1981b; Beadel 1995a). The site has a high diversity of vegetation types related to thermal activity, subsequent cooling, and succession after periodic burning (Watt 1986). The geothermal vegetation is a very good example of the distinctive vegetation zones which progress over increasingly cool ground into indigenous scrub and forest. The variety of vegetation types is matched by few other reserves in the South Auckland Land District (Clarkson 1981a). A range of Threatened species are present.

Notes:

The Maunga Kākaramea (Rainbow Mountain) site is located partly within the Waikato Region and partly in the Bay of Plenty Region. For the region-wide analysis, only the data from the Waikato Region is assessed, but ecological values of the site are considered as an entire site, including parts of the site within the Bay of Plenty Region and in a continuum to Waiotapu.

Maunga Kākaramea is a dacite volcano and the extent of geothermal activity has apparently declined since European colonisation. Lloyd (1959) based on a comparison of an earlier assessment of Hochstetter¹. Hochstetter (1864) who viewed Maunga Kākaramea from Lake Rotomahana in 1853 stated the

¹ Hochstetter, F. Von, 1864: "Geologie von Neu-Seeland: Beitrage zur Geologie der Provinzen Auckland und Nelson". Reise der Novara, Geo- logi~cher Theil, 1 Band, 1 Abtheilung, Gerold, Vienna. Referenced in Lloyd 1959.

mountain was steaming from foot to summit, so that the mountain was enveloped in steam as if it were a volcano. Lloyd (1959) also describes several observations in the late 1800s indicating greater activity than during observations made in the 1950s. They led Lloyd to conclude that activity on the northern slopes of Maunga Kākaramēa had declined noticeably in the last 60 years.

A geophysical assessment of the surface geothermal manifestations at this site was presented in Wildland Consultants 2014, Appendix 4. This assessment was undertaken in 2010.

References:

Beadel and Bill 2000; Bycroft 2006; Clarkson 1981a & 1982b; Rotorua Botanical Society 2006; Hobbs 2018, Lloyd 1959; Watt 1986; Wildland Consultants 1998, 2004c, & 2012, 2014.



A wide diversity of geothermal vegetation and habitats in the crater of Maunga Kākaramēa ranging from bare ground and geothermal water to forest habitats.
NZTM E1895278 N5753402. 9 November 2022.



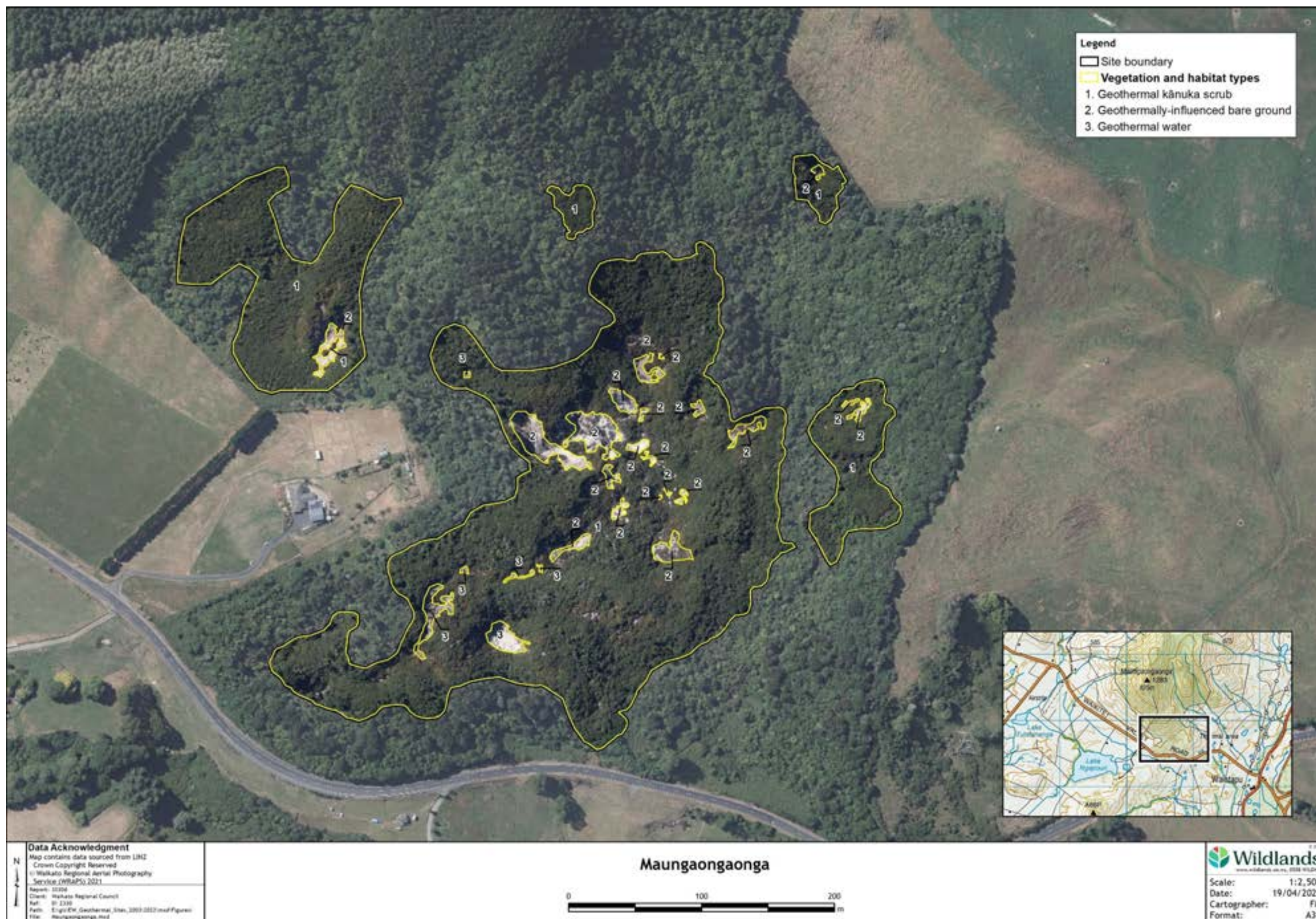
The heated ground on upper slopes have steaming bare ground, *Campylopus* mossfields, and geothermal kānuka scrub and shrubland, surrounded by forest habitats with less or no geothermal influence.
NZTM E1895678 N5753250. 9 November 2022.



Lake Rotowhero on the western side of Maunga Kākaramaea.
NZTM E1894907 N5752996. 9 November 2022.



A geothermal wetland on the south side of Maunga Kākaramaea on the 'old' Waikaremoana Road. NZTM E1895022 N5752557. 10 November 2022.



MAUNGAONGAONGA

Ecological District: Atiamuri **GPS Reference:** NZTM E1892615, N57101642
Geothermal System: Waikite-Waiotapu- **Altitude:** c.460-580 m
 Waimangu
Geothermal System: Waiotapu
Bioclimatic Zone: Submontane **Local Authority:** Rotorua
Extent of Geothermal Habitat: c.9.2 ha
Extent of Geothermal Vegetation: c.9.1 ha
Date of Most Recent Field Survey: 29 November 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) A dense canopy of geothermal kānuka with an average height of 0.3-1.0 metres dominates this area, in association with locally scattered mānuka, mingimingi, and local patches of monoao (up to 50% cover in places). The groundcover is dominated by mosses (<i>Dicranoloma billardierei</i> and <i>Sphagnum cristatum</i>), with local scattered tūrutu and kōwaowao. This vegetation and habitat type exhibits a height gradient, with mānuka and monoao forming a dense canopy up to two metres high, mostly on the margins, away from the geothermal area, in association with prickly mingimingi and locally scattered whauwhaupaku. Kāmahi and toru occur on several rocky outcrops. The groundcover associated with these outcrops comprises scattered tūrutu with local <i>Gleichenia microphylla</i> and occasional kōwaowao. Small patches of <i>Nephrolepis flexuosa</i> , <i>Dicranopteris linearis</i> , <i>Asplenium polyodon</i> , and māpou seedlings are present beneath the geothermal kānuka canopy. Occasional rewarewa, shining karamū, wilding radiata pine, and dense gorse and blackberry occur on the margins, on ground with less geothermal influence. Local areas of geothermal kānuka shrubland (not mapped separately) forms a low discontinuous canopy (c.0.1-1.0 metres high) in association with scattered monoao and mingimingi. The groundcover comprises dense cushions of mosses with <i>Campylopus</i> spp. (including <i>C. clavatus</i>) covering c.30% of the area. <i>Dicranoloma billardierei</i> , <i>Sphagnum cristatum</i> , and lichens (e.g. <i>Cladonia</i> sp. and <i>Cladia</i> sp.) are also present. <i>Lycopodiella cernua</i> is locally present in areas of relatively high geothermal activity. <i>Histiopteris incisa</i> occurs occasionally near steam vents. This vegetation type occurs sporadically amongst the geothermal kānuka scrub. The orange alga <i>Trentepohlia</i> is abundant on geothermal kānuka and monoao branches.	Hillslope and rocky outcrops	c.8.7 ha
2.	Loamfield (20.01) Geothermally influenced bare ground (20.01.01) Geothermal clays, mud pools, geothermally altered soils, and fumaroles. <i>Lycopodiella cernua</i> is locally present on the walls of highly geothermally active craters.	Hillslope	c.0.4 ha
3.	Water (22.01) Geothermal water (22.01.01) Geothermal water, mudpools.	Flat	<0.1 ha

Indigenous Flora:	Geothermal kānuka (Threatened-Nationally Endangered), a species endemic to geothermal areas, is present. A population of <i>Korthalsella salicornioides</i> (Threatened-Nationally Critical), a semi-parasitic mistletoe is known to be present. A few patches of <i>Nephrolepis flexuosa</i> (At Risk-Naturally Uncommon), a species confined to geothermal areas in the North Island in New Zealand, and at least 50 plants of <i>Dicranopteris linearis</i> (Threatened-Nationally Endangered), are known to be present at this site (population numbers based on 2004 field assessment). Note, <i>Korthalsella salicornioides</i>, <i>Nephrolepis flexuosa</i>, and <i>Dicranopteris linearis</i> were not observed in the 2022 survey. Other species of interest present are <i>Schizaea bifida</i> (recorded by Beadel 1995a) and <i>Lycopodiella cernua</i>. <i>S. bifida</i> was not recorded in the 2004, 2014, or 2022 surveys.
Fauna:	Common indigenous and introduced bird species typical of the habitat present include tūī, tauhou/silvereye, pīwakawaka/North Island fantail, pīpīwharau/shining cuckoo, kōtare/sacred kingfisher, Australian magpie, Eurasian blackbird, and European goldfinch. Small mammal faecal pellets were seen on site.
Geothermal Ecosystems:	Heated ground (dry), fumaroles, hydrothermally altered ground (now cool).
Current Condition:	The geothermal vegetation is largely unmodified. It is relatively untracked (by humans), and adventive species are not common.
Threats/Modification/Vulnerability:	
<i>Invasive pest plants:</i>	Weeds are present at low density and extent at this site. The main weed species present are blackberry (1% cover), wilding radiata pine (<1% cover), Spanish heath (<1% cover), and gorse (<1% cover). The distribution of pest plants in Maungaongaonga Scenic Reserve in 1998 was mapped and described in Wildland Consultants (1998).
<i>Human impacts:</i>	This site is vulnerable to damage from human trampling, as can be seen from the vegetation destruction associated with an informal track (Beadel 1995a). Informal tracks are used occasionally by local residents and hunters.
<i>Grazing:</i>	Livestock are not a threat to this area.
<i>Adjoining land use:</i>	Farmland, indigenous forest and scrub.
Site Change:	
<i>Recent change:</i>	Any changes to the area mapped since the 2014 report are based on better quality aerial photographs rather than any real site change.

*Historical:*¹

It is difficult to determine the difference between “geothermal” and “non-geothermal” scrub on the historic black and white photos². However, the vegetation surrounding the geothermal areas has developed from scrub in 1941 to secondary forest. Within the geothermal areas the historic photographs show considerably more bare ground, and it is likely that the “cooler” geothermal soils have been invaded by blackberry in recent years. Overall, based on the above assessment, we consider that no real change can be identified in the extent of geothermal vegetation and habitats at this site, although invasion of pest plants on less active geothermal soils may have taken place.

Management Requirements:

Further use and establishment of informal tracks should be discouraged. Ongoing weed control, particularly of wilding pines which occur occasionally on the margins, is suggested.

Significance Level:

National (Criteria 1, 3, 4, 5, 9, 10, 11).

Significance Justification:

This site is of national significance because it comprises a very high quality example of geothermal vegetation and habitat, which includes nationally uncommon habitat types (fumaroles, hydrothermally altered ground (now cool), and heated ground (dry) (Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013)). The site is part of an indigenous ecological sequence that extends from geothermal vegetation to tall forest (see Nicholls 1974; Clarkson 1981b; Beadel 1995a) and a stepping stone to other geothermal sites nearby. The vegetation is of good quality and is relatively unmodified and provides habitat for Threatened and At Risk plant species. The site is protected as a Scenic Reserve.

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in this survey this site was classed as Category A - the highest category.

References:

Beadel 1995a; Beadel and Bill 2000; Clarkson 1981b; Nicholls 1974; Wildland Consultants 1998, 2004c, 2012, 2014a.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

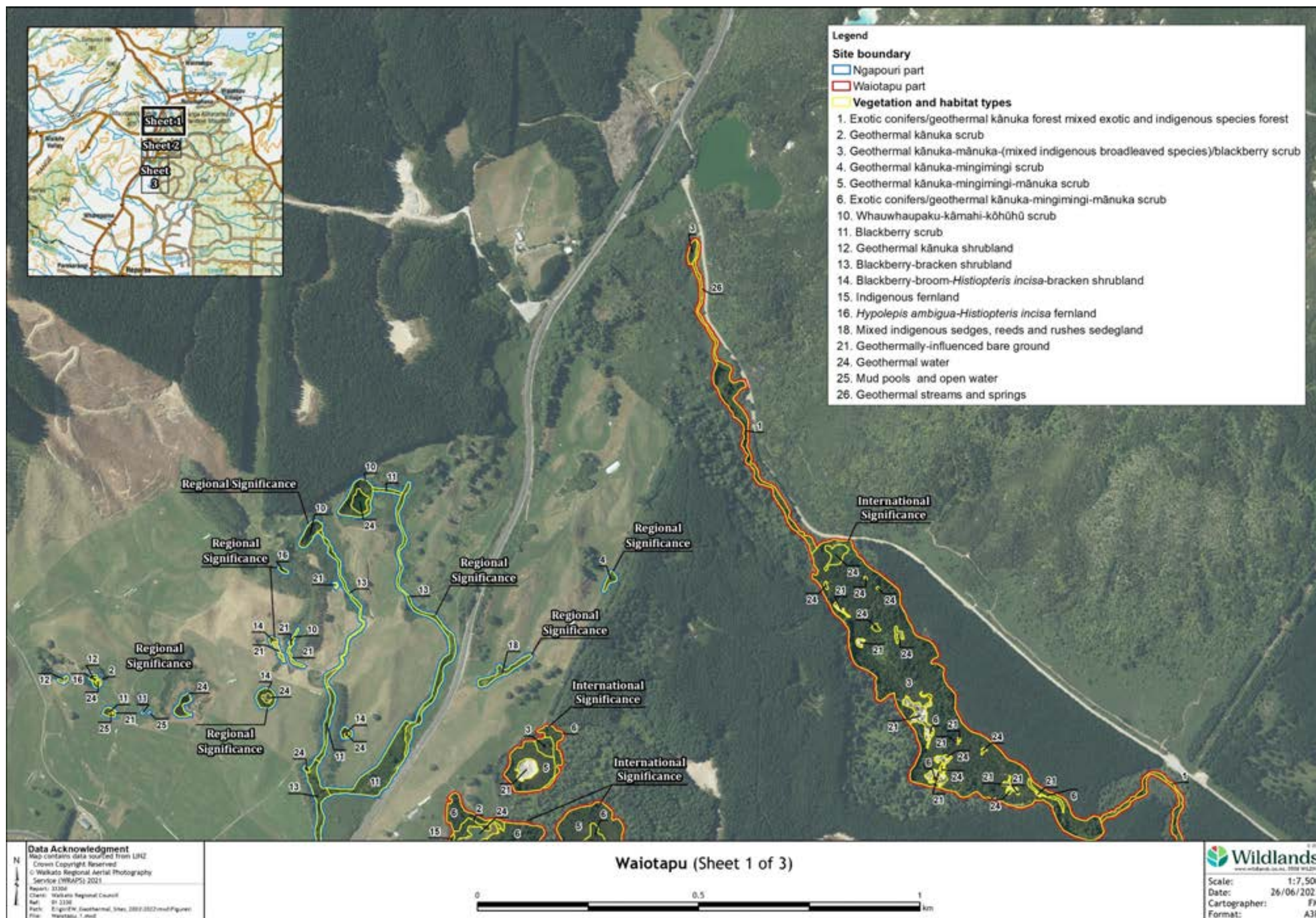
² Historical photo: SN 172 Run 1158 Photos 2-4, 1941.

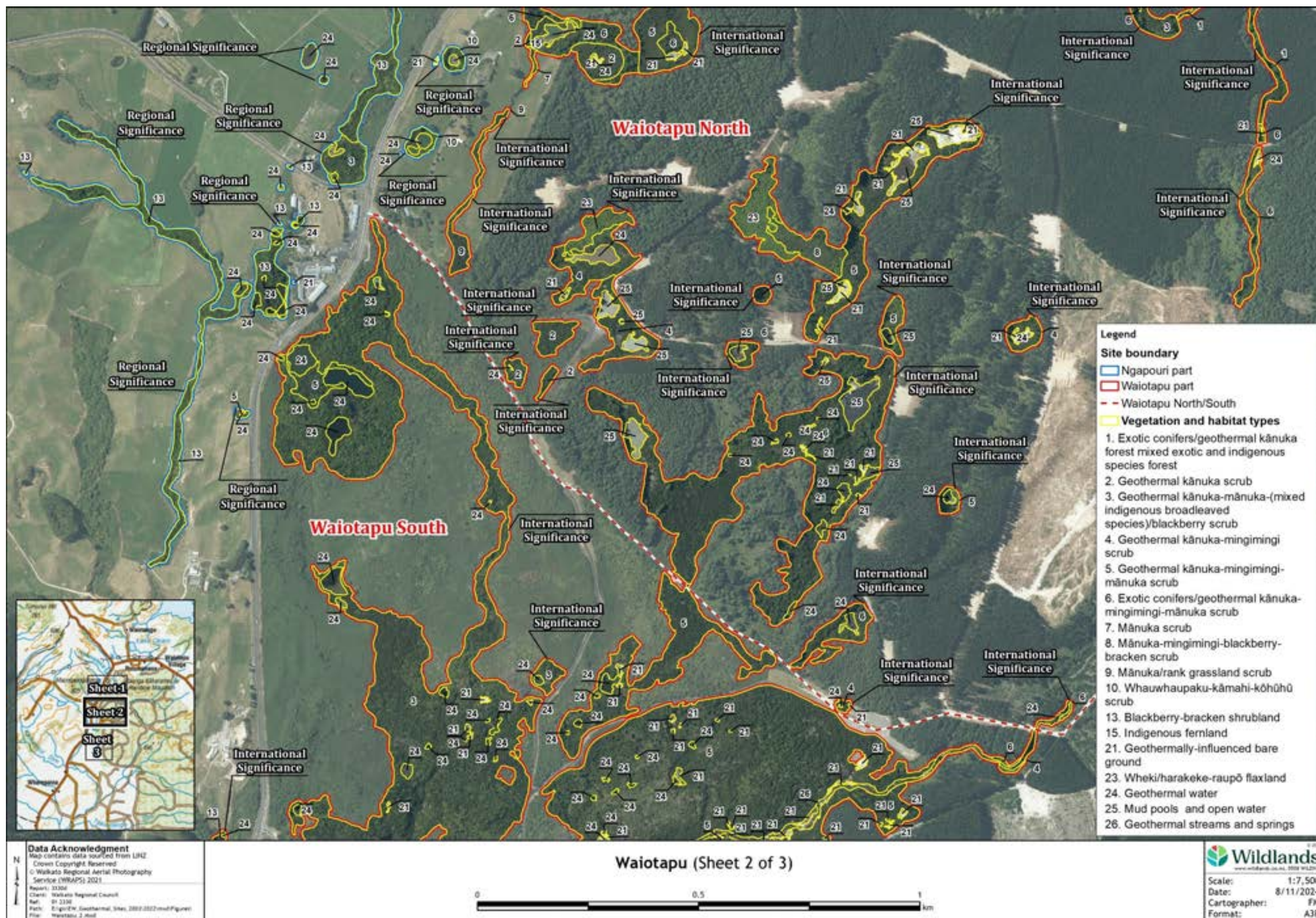


A pool of geothermal water (foreground) and kānuka scrub (midground) in the northwest of the Maungaongaonga site. Viewed to the northeast. Approximately located at NZTM E1892604, N5751714. 29 November 2022.



Small patches of geothermally-influenced bare ground surrounded by geothermal scrub and shrubland at the Maungaongaonga site. Approximately located at NZTM E1892665, N5751637. 29 November 2022.





WAIOTAPU¹

Ecological District: Ataiamuri
Geothermal System: Waikite-Waiotapu-Waimangu
Geothermal System: Waiotapu
Bioclimatic Zone: Submontane
Extent of Geothermal Habitat: c.234.4 ha
Extent of Geothermal Vegetation: c.206.6 ha
Date of Most Recent Field Survey: 28 February and 2, 3 March 2023

GPS Reference: NZTM E1894491 N5748676
Altitude: c.310-450 m
Local Authority: Rotorua

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Mixed exotic and indigenous species forest (01.03) Exotic conifers/geothermal kānuka forest mixed exotic and indigenous species forest (01.03.02) A mixture of exotic conifers form in the canopy, such as radiata pine, maritime pine, Douglas fir, Japanese cedar and strobilus pine. The subcanopy is a mixture of indigenous species, with the most abundant species often being geothermal kānuka, mānuka, mingimingi, and mixed broadleaved species such as karamū and whauwhaupaku. False acacia is locally abundant, particularly along the upper sections of Waiotapu Stream. A mixture of fern species, including bracken, kiokio, <i>Histiopteris incisa</i> , <i>Gleichenia microphylla</i> , <i>Paesia scaberula</i> , <i>Hypolepis ambigua</i> , <i>Hiya distans</i> , and other herbaceous species such as <i>Dianella nigra</i> , often forms the ground cover.	Hillslope, gully, gently sloping	c.1.5 ha
2.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka scrub with occasional emergent kāmahī, local whekī and occasional mingimingi are often located in steep-sided gullies surrounded by dense blackberry. There is local bracken and monoa. Steam was observed rising through the geothermal kānuka but these areas could not be accessed safely.	Gully	c.2.7 ha
3.	Geothermal kānuka-mānuka-(mixed indigenous broadleaved species)/blackberry scrub (04.01.09) Geothermal kānuka and mānuka are dominant. There are scattered areas dominated by mixed broadleaved species such as whauwhaupaku, kāmahī and kōhūhū with locally common mingimingi, and occasional tree ferns (whekī and whekī-ponga). There are local patches of blackberry. Local patches of ferns such as <i>Hypolepis ambigua</i> , <i>Hiya distans</i> and <i>Paesia scaberula</i> are present. Patches of grassland dominated by paspalum and Mercer grass are present around the margins of mud pools. Dead emergent woody species such as kāmahī occur locally. A few male ferns were found along stream margins across the road from the Arataki Honey/Waiotapu Tavern site.	Riparian margins, hillslope	c.44.1 ha

¹ The sites Waiotapu South, Waiotapu North and Ngapuna of Wildland Consultants 2014a have been merged in this assessment.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
4.	Geothermal kānuka-mingimingi scrub (04.02) Geothermal kānuka-mingimingi scrub (04.02.01) Geothermal kānuka and/or mingimingi dominant scrub with local areas of mānuka, broom, prickly mingimingi, <i>Coprosma lucida</i>, blackberry, and whauwhaupaku, with occasional black wattle, kāmahī, and whauwhaupaku. Groundcover components include bracken, <i>Carex secta</i>, tūrutu, <i>Hypolepis ambigua</i>, kiokio, swamp kiokio and <i>Paesia scaberula</i>. Along the margins of heated streams, pines are scattered above a canopy dominated by geothermal kānuka, with local small areas of steaming ground. Tūrutu, <i>Histiopteris incisa</i>, broom, harakeke, and Yorkshire fog are also common within these areas. <i>Lycopodiella cernua</i> and <i>Gleichenia microphylla</i> occur locally. Boiling mud pools are scattered throughout this area. Blackberry and mingimingi dominate less geothermally active areas within this type. Since 2010 this type has expanded in extent following control of wilding pines.	Riparian margins, flat, gently rolling, hillslope	c16.4 ha
5.	Geothermal kānuka-mingimingi-mānuka scrub (04.02.02) Geothermal kānuka (c.0.3-4 m tall) forms a dense cover with mingimingi locally co-dominant. Mānuka, kānuka, and whekī are common throughout and there is occasional emergent kāmahī and wilding pines. Mānuka and whekī are common to dominant in wet areas and along stream margins. The groundcover comprises scattered bracken and <i>Histiopteris incisa</i>. Wilding pines, Japanese cedar, broom, and blackberry are common on the margins. Pine control has been undertaken in parts of this vegetation type. Blackberry and bracken occur locally in the understorey (for example in the Ngapouri area).	Sides of crater, flat, riparian margins, and lake margins	c.59.7 ha
6.	Exotic conifers/geothermal kānuka-mingimingi-mānuka scrub (04.02.03) Wilding radiata pine and maritime pine occur over geothermal kānuka, mingimingi, mānuka, broom, prickly mingimingi, <i>Coprosma lucida</i>, blackberry, and whauwhaupaku, with occasional black wattle, and kāmahī. Groundcover includes bracken, <i>Carex secta</i>, tūrutu, <i>Hypolepis ambigua</i>, kiokio, swamp kiokio and <i>Paesia scaberula</i>. Along the margins of heated streams, wilding pines are scattered above a canopy dominated by geothermal kānuka, with local small areas of steaming ground. Tūrutu, <i>Histiopteris incisa</i>, broom, harakeke, and Yorkshire fog are also common in these areas. Other characteristic geothermal species include <i>Lycopodiella cernua</i> and <i>Gleichenia microphylla</i>. Boiling mud pools are scattered throughout this area. Blackberry and mingimingi dominate less geothermally active areas within this type.	Flat areas, stream margins, wetland, flat and gently rolling hills	c.28.4 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
7.	Mānuka-dominant scrub (04.04) Mānuka scrub (04.04.01) This vegetation type occurs in an extensive wetland in the south of the site. Mānuka forms a canopy c.2-4 m tall over a dense groundcover of <i>Machaerina rubiginosa</i>, kiokio, <i>Carex secta</i>, <i>Hypolepis distans</i>, and exotic grasses such as Yorkshire fog in drier areas. Geothermal kānuka and mingimingi are common around sinter and hot springs within this type, with local arrow grass. Raupō reedland occurs locally, and there are patches of lake clubrush, <i>Carex secta</i>, and <i>Carex virgata</i>. Arrow grass occurs in several locations on sinter. Pig sign was abundant throughout.	Wetland	c.20.1 ha
8.	Mānuka-mingimingi-blackberry-bracken scrub (04.04.05) The dominant canopy species vary in this vegetation type. There are areas of mānuka scrub, mingimingi scrub, local geothermal kānuka shrubs and trees, blackberry scrub, and bracken fernland. There are scattered emergent wilding maritime pines. Broom is common in places, and whekī and whekī-ponga occur in wet areas. Mud pools and hot springs are common, with sinter present near many of the hot springs. Along stream margins, mingimingi, mānuka, <i>Histiopteris incisa</i>, tūrutu, and bracken are common. Blackberry becomes dominant on cooler soils, although steam is common within the blackberry. Vegetation within this type along the stream margins was viewed from a distance.	Flat, rolling hills, gently undulating, stream margins	c.4.2 ha
9.	Mānuka/rank grassland scrub (04.04.08) This type generally occurs in gullies below geothermal features amongst farmland. It is generally a terrestrial habitat and not wetland. Local liquidamber have been planted, along with a few scattered silver birch. Rank grassland species dominate the ground cover including Yorkshire fog soft rush, creeping bent, and creeping buttercup.	Gully	c.0.7
10.	Whauwhaupaku-kāmahi-kōhūhū scrub (04.08.02) Indigenous species dominated scrub is located on steep crater sides, gullies, and riparian margins. The canopy is dominated by either whauwhaupaku or kāmahi, with kōhūhū, geothermal kānuka, and mānuka common, and scattered to locally common whekī, mingimingi, and blackberry. Where this type occurs on the margins of craters, indigenous dominated scrub grades into blackberry and bracken scrub on very steep sides, with <i>Hypolepis ambigua</i> common to locally abundant close to the mud pools that are often present in the crater bases.	Crater, riparian margin, gully	c.0.9 ha
11.	Exotic species dominated scrub (04.10) Blackberry scrub (04.10.01) Located about 30 m north of the bridge in the northeast of the site (c. NZTM E1896462 N5751308). Steam was seen rising from an area of blackberry scrub.	Gully	c.1.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
12.	Geothermal kānuka-dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Geothermal kānuka from 0.3 to c.4 m high with local mingimingi over bare ground. Local patches of <i>Hypolepis ambigua</i>, <i>Histiopteris incisa</i>, wilding pines, and occasional <i>Lycopodiella cernua</i> are present.	Gully, riparian margins	c.0.2 ha
13.	Mixed indigenous and exotic shrubland (05.08) Blackberry-bracken shrubland (05.08.07) Dense blackberry with bracken and locally common broom and mānuka. Occasional emergent whauwhaupaku, karamū, whekī, and kānuka are present throughout. Local patches of <i>Hypolepis ambigua</i>, and scattered <i>Carex secta</i> and <i>Carex virgata</i> are present where the blackberry is less dense. Where this type occurs near geothermal ponds, <i>Machaerina articulata</i> is common with scattered harakeke. Emergent Tasmanian blackwood are locally common in one part of this type. Along stream margins, mingimingi, mānuka, <i>Histiopteris incisa</i>, tūrutu, and bracken are common. Blackberry becomes dominant on cooler soils, although steam is common within the blackberry. Vegetation within this type along the stream margins was viewed from a distance. This type is highly variable - in places there is often dense blackberry and there are local patches of fernland around small wetlands and geothermal pools.	Riparian margin, flat	c.5.9 ha
14.	Exotic shrubland (05.09) Blackberry-broom-<i>Histiopteris incisa</i>-bracken shrubland (05.09.10) Shrubland dominated by blackberry and broom with locally common <i>Histiopteris incisa</i> and bracken is present on the walls of a steep-sided crater surrounding a mud pool.	Crater margin	c.0.2 ha
15.	Indigenous fernland (07.01) Bracken fernland (07.01.19) Bracken fernland with occasional blackberry present	Hillslope	<0.1 ha
16.	<i>Hypolepis ambigua</i>- <i>Histiopteris incisa</i> fernland (07.01.21) Two areas of this type are present within the site. One is located in the base of a steep-sided gully containing a geothermal spring, which flows into a small stream. Scattered emergent mingimingi are present above fernland dominated by <i>Hypolepis ambigua</i> and <i>Histiopteris incisa</i>. The other area is a small area of <i>Hypolepis ambigua</i> and <i>Histiopteris incisa</i> above a steam vent on a steep hillslope which is surrounded by blackberry scrub.	Riparian margin, hillslope	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
17.	Exotic grassland (08.01) Mixed exotic grassland (08.01.15) Occasional mudpools and steaming ground in paddock. Exotic grassland dominated by <i>paspalum</i> and local bare ground.	Flat	<0.1 ha
18.	Indigenous sedgeland (09.01) Mixed indigenous sedges, reeds and rushes sedgeland (09.01.13) Grey willow/raupō-<i>Carex secta</i>-<i>Carex geminata</i> sedgeland A small area identified in the north of the site for the first time in 2023. Scattered trees such as grey willow, silver birch, and paulownia occur over local areas of raupō reedland, <i>Carex virgata</i> and <i>Carex geminata</i> sedgelands.	Wetland	c.0.2 ha
19.	Reedland (11.01) Raupō reedland (11.01.01) Raupō forms a dense reedland between 1 and 3 metres tall.	Wetland	c.0.4 ha
20.	Raupō-harakeke-mixed sedges and rushes reedland (11.01.06) Raupō-harakeke reedland↔<i>Carex secta</i>-<i>Machaerina rubiginosa</i>-<i>M. juncea</i> sedgeland This area comprises a mosaic of raupō-harakeke reedland and <i>Carex secta</i>-<i>Machaerina rubiginosa</i>-<i>M. juncea</i> sedgeland with patches of mānuka shrubland throughout. Raupō and harakeke are locally dominant in association with <i>Austroderia toetoe</i>, koromiko, <i>Coprosma propinqua</i>, karamū, and kiokio. <i>Carex secta</i>, <i>Carex virgata</i>, lake clubrush, <i>Machaerina rubiginosa</i>, and <i>M. juncea</i> dominate the sedgeland, in association with <i>Juncus</i> species and <i>Eleocharis acuta</i>. Geothermal activity is evident in areas throughout this vegetation type with occasional <i>Cyclosorus interruptus</i> present. Blackberry is common in dry areas.	Wetland	c.8.4 ha
21.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) This includes heated ground, sinter pavements, hot water springs and seepages, boiling mud, and steaming ground. Heated soils and sinter occur with patches of narrow-leaved carpet grass, <i>paspalum</i>, and browntop, occasional <i>Lycopodiella cernua</i>, and local woody species such as geothermal kānuka, mānuka, and mingimingi. Steam vents are present (surface temperature up to c.76 °C in 2014). Grassland dominated by narrow-leaved carpet grass is common around areas of this type.	Crater, flat, river terraces, flat, gently undulating, and gently rolling.	c.6.3 ha
22.	Sinter (20.01.04) Sinter, including the largest sinter terrace remaining in Aotearoa New Zealand.	Flat, gently to moderately sloping	c.3.4 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
23.	Flaxland (21.01) Whekī/harakeke-raupō flaxland (21.01.02) Harekeke flaxland with emergent whekī, occasional mānuka and local areas of raupō and sedges such as <i>Carex virgata</i> and <i>Machaerina rubiginosa</i> .	Wetland	c.1.8 ha
24.	Water (22.01) Geothermal water and mudpools (22.01.01) Heated pools/ponds. A small lake is present at the base of a steep-sided gully in the north of the site. Fog obscured the view of the lake but it appears to be geothermal in nature. Patches of <i>Histioglossa incisa</i> are present on the margin.	Open water, flat, crater	c.23.3 ha
25.	Mud pools and open water (22.01.02) Small mud pools and often surrounding open water and mud.	Mud pools, craters	c.2.1 ha
26.	Geothermal streams and springs (22.01.03)	Gully	c.2.5 ha

Indigenous Flora:

A large population of *Cyclosorus interruptus* (At Risk-Declining), is present in the wetland in the south of the reserve. Hobbs (2002) recorded >300 *C. interruptus* plants in Orotu Wetland (in the south part of this site), however the total population is likely to be considerably larger than this, as large parts of the site are not easy to access safely. One *Dicranopteris linearis* frond (Threatened-Nationally Endangered) was observed near 'Twin Rivers' geothermal stream (Paul Cashmore pers. comm. 2007) and a small population has also been recorded north of the tourist area in the past, but has not been seen in recent site surveys.

Geothermal kānuka (Threatened-Nationally Endangered) and *Lycopodiella cernua*, a characteristic feature of geothermal areas, are both abundant within the survey area. A large mānuka wetland is present in the southern end of Waiotapu, and mānuka is scattered in damper areas of geothermal habitat throughout the site.

Fauna:

The southern part of the site supports a small population of weweia/New Zealand dabchick (Threatened-Nationally Increasing), mātātā/North Island fernbird (At Risk-Declining), pūweto/spotless crane (At Risk-Declining), and potentially other threatened wetland species such as matuku-hūrepo/Australasian bittern (Threatened-Nationally Critical). Weweia are present on other ponds in the wider Waiotapu site such as on farmland in the northwestern part of the site. Other indigenous wetland and water birds recorded on site include pūtangitangi/paradise shelduck, kakīānau/black swan, pūkeko, warou/welcome swallow, kuriwhengi/Australasian shoveler, poaka/pied silt and the introduced mallard duck.

The forest, shrubland margins, and open habitats support populations of koekoeā/long-tailed cuckoo (Threatened-Nationally Vulnerable), toutouwai/North Island robin (At Risk-Declining) and kārearea/New Zealand 'bush' falcon (Threatened-Nationally Increasing). Other indigenous species recorded at this site include kāhu/swamp harrier, spur winged plover, kōtare/sacred kingfisher, pīpīwharau/shining cuckoo, kererū/New Zealand pigeon, tūi, korimako/bellbird, miromiro/pied tomtit, pīwakawaka/North Island fantail, touhou/silvereye, and riroriro/grey warbler.

Introduced species present include common pheasant, Californian quail, Eurasian blackbird, European goldfinch, European greenfinch, yellowhammer, chaffinch, house sparrow, Australian magpie, common starling and common myna.

Kahu kowhai/yellow admiral butterflies were abundant in throughout the site in March 2023. The recently self-introduced spider species Broun's marbled orb weaver (*Backobourkia brouni*) was present in the southern part of the Waiotapu site in 2023.

**Geothermal
Ecosystems:**

Heated ground (dry), hydrothermally altered ground (now cool), geothermal streamsides, fumaroles, geothermal wetland.

Current Condition:

The site contains the largest, and one of the most complete, range of geothermal habitats present in the Waikato Region. The parts of the site on farmland to the west and some parts of the site amongst forestry in the north and east are highly modified. Adventive plants are common and some areas in the northern part of the site are grazed. In the central part of the site considerable improvement has occurred since 2010 with the control of many wilding conifers and other weeds such as African feather grass. Wilding conifers and other woody weed species such as false acacia are still an issue in many parts of the site and ongoing management will be required. In the tourist area, the habitats around the key geothermal features are well maintained for public viewing, except for the presence of scattered wilding conifers on the site margins. Pigs have had a major negative impact on understorey vegetation in the wetlands to the south and southwest of the site. Despite the impacts of pigs, and the presence of pines, large areas of the site are in excellent condition, with a wide diversity of features and vegetation types present.

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Pest plants remain a considerable issue in many parts of this site.

Wilding conifers are the pest plant of most concern at the site. There has been a considerable control effort undertaken in some of the better quality parts of the site since 2010. Further work is required amongst forestry areas, particularly in the northern part of the site. Work will be ongoing in the future, as the site has extensive areas surrounded by a seed source of planted conifer species. The most abundant conifer species recorded at the site are maritime pine, radiata pine, strobus pine, Douglas fir, coast redwood, black pine, Japanese cedar, and Lawson's cypress.

Many of the streams amongst farm habitat, and some within forestry have a high cover of weeds. Extensive areas are dominated by blackberry, and gorse and broom. Some woody exotic tree pest plant species are also present in these habitats such as false acacia, silver birch, grey willow, crack willow, cotoneaster, *Cotoneaster franchetii*, poplars, English oak, Tasmanian blackwood, silver wattle, ornamental cherry, and liquidambar. Other species present in these habitats include ivy, and montbretia.

It was noted cover of blackberry and Chinese privet in the southern wetland at Waiotapu has increased since the last survey.

Male fern (probably the species *Dryopteris affinis*) was present alongside the geothermal stream opposite the Waiotapu Tavern. A small population of aluminium plant was present alongside the stream at the very northern part of this site.

Alongside dry site margins, but establishing in parts of the site are a wide variety of weeds including blackberry, gorse, broom, Chinese privet, montbretia, Spanish heath, pampas, and heather.

Other notable weeds recorded include barberry, hawthorn, climbing rose, and jasmine.

It should be noted that African feather grass, which was present north of the mudpools viewing site, at the northern end of the tourist part in 2010, appears to have been eradicated.

Ngapouri part: Large parts of this site are dominated by invasive exotic plants. Invasive pest plant species present include: apple (<1% cover), barberry (<1% cover), blackberry (50% cover), broom (1% cover), cotoneaster (<1% cover), crack willow (1% cover), false acacia (<1% cover), flowering cherry (<1% cover), grey willow (<1% cover), crack willow (1% cover), ivy (<1% cover), montbretia (<1% cover), *Pyracantha* sp. (<1%), pampas (<1% cover), poplar (<1% cover), paulownia (<1% in wetland east of State Highway 5), Spanish heath (<1% cover), Tasmanian blackwood (<1% cover), and wilding pines (radiata pine (2% cover) and maritime pine (<1% cover)).

Waiotapu North part: Invasive exotic plants dominate the margins of these areas. Although extensive wilding pine control has been undertaken since 2004, wilding pines are still common (5-25% cover). Other pest plant species present include false acacia (1-5% cover), apple (<1% cover), blackberry (1-5% cover), broom (5-25% cover), climbing rose (<1% cover), cotoneaster (<1% cover), grey willow (1-5% cover), and Spanish heath (1-5% cover). Blackberry and grey willow are often common on geothermal stream margins.

Waiotapu South part: Wilding pines comprise c.6-25% cover. Several species are present, the most common of which is maritime pine with local radiata pine, black pine, and strobis pine. However, the density of pines in the northern part of the site has been significantly reduced through control over time, and further reductions are evident in 2023. Other invasive exotic plant species present are blackberry (5-25% cover), black wattle (<1% cover), broom (1-5% cover), gorse, and Spanish heath (<1% cover). Chinese privet is common in the western wetland. The distribution of environmental weeds at the site was mapped and described in Wildland Consultants (1998).

Human impacts:

The central portion of this area is managed as a tourism venture, which focuses on the geothermal features (e.g. the Champagne Pool and extensive sinter terraces). The tracks are well maintained and generally adhered to, and the overall impact is probably low. The southern wetland parts of the site are rarely visited with low human impacts, other than tracks to the lake. Alongside highways and farmland, herbicide and fertiliser drift are potential issues. In the past, building refuse has been dumped in a fumarole, although this was not observed in the 2023 survey. The forestry areas have well maintained roads, and Kerosene Creek is a popular bathing area for tourists

and locals, however the larger areas of geothermal vegetation are seldom visited as most cannot be seen from a main road. The dumping of rubbish is an issue in areas where the public have vehicle access. Careful management of plantation harvesting is required around geothermal sites.

Grazing:

Grazing is only an issue in farmed areas in the western parts of the site. No grazing occurs in plantation forest areas (unless fence damage has occurred on adjacent farmland). A significant portion of geothermal streams and features in farmland are fenced. Further work is required to complete this work, although this should be done with careful management to control pest plant invasion of these areas.

Feral pigs have caused extensive damage in the southern and western wetlands, with abundant tracks observed. Possum sign was also abundant and feral deer are also likely to graze the site.

Adjoining land use:

Plantation forest, farmland, Scenic Reserve, industrial and carparking, roads, tourism.

Site Change:

Recent change:

Ngapouri part: Additional areas that were previously not known were added to the site in 2014 and 2023. This is as a result of new information rather than any new surface manifestations of geothermal activity becoming apparent since 2004. All of the geothermal areas surrounded by farmland south of Waikite Valley Road had been fenced to exclude stock prior to the 2014 survey.

Waiotapu North part: Several previously unmapped areas were mapped in 2023, however these were mostly found due to increased visibility through recently cleared pine plantation and better quality/higher resolution aerial photographs. Minor loss of geothermal vegetation has occurred in places following harvesting of pine trees; however, in most instances it appears that the land manager(s) has taken reasonable care to avoid damage to geothermal sites. Replanting of plantation trees has generally taken place outside of geothermal habitats.

Waiotapu South part: Several small areas in the eastern part of the site have been destroyed as a result of plantation pine harvest and replanting. The mapping of the geothermal wetland in the south has improved in each survey, but there may be additional areas that have not been found in surveys to date. Pest pines continue to degrade parts of the site where control has not taken place. In areas where pines have been controlled, particularly to the northeast of the site, the quality of the habitat present is greatly improved, and is now dominated by indigenous vegetation. This has resulted in changes to vegetation descriptions for many parts of the site since 2011. Overall, the extent of geothermal habitat at Waiotapu South is considered to be stable.

*Historical:*¹

Ngapouri part: Based on historic aerial photographs², it appears geothermal vegetation and habitat may have been more extensive, particularly west of

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.
² Historical photos: SN172 Run 1158, Photo 4, 5 - 1941.

the Waiotapu Hotel. Several pools evident on the 1941 aerial photographs are no longer present; this may be a result of wetland drainage in order to modify the land for farming. It also appears that there were unvegetated bare areas in what is now farmland on the north side of Waikite Valley Road, particularly upslope toward Maungaongaonga. These may have been geothermal habitat which has been destroyed during land modification. However, most areas of geothermal vegetation at this site are unlikely to be visible in the 1941 aerial photographs as geothermal areas are either in gullies or covered in vegetation that appears similar to other adjacent vegetation in the 1941 aerial photographs.

Waiotapu North part. Historic aerial photographs¹ were compared with 2007 aerial photographs. The boundaries between geothermal vegetation and non-geothermal vegetation, particularly scrub and shrubland, is difficult to determine on aerial photographs for this site. The southern part of the site is now in plantation forest. The extent of the site in 2007 is only approximately two-thirds of the site extent visible in the 1941 aerial photographs. Some of the bare ground evident in 1941 has been invaded by shrubs and pine trees. These areas are probably areas of lower geothermal activity.

It is difficult to determine change (if any) in the area marked C. Wilding pines have established in parts of the site, but otherwise the geothermal vegetation in these areas appears similar in 1941 and 2007 photos.

The areas identified as D on the accompanying map were in a poor condition in 1941. It appears that stock had access to the western and southern parts of these areas and vegetation had been cleared through part of the site, possibly for power lines. The extent of raw geothermal soilfield within Area D in 1941 was about 10-15% greater than current extent, and pines and shrubs have since colonised some areas that were raw-soilfield habitat in 1941. There has also been a 25-50% reduction of shrubland habitats because of plantation forestry, and wilding pine establishment. Few wilding pines were present in the southern part of Area D in 1941.

Little change was evident in the area marked E.

Overall, a crude estimate of loss of geothermal vegetation at this site since 1941 would be in the order of 25%. It is likely that some geothermal vegetation would have already been cleared prior to 1941.

Waiotapu South: An assessment was made comparing 1941² to 2007 aerial photographs. The most significant change since 1941 is the establishment of wilding pines since 1941. In the south of the site, the wetland extended most of the way to State Highway 5 and the wetland may have been approximately one-third larger than it is today. However, it is unlikely that much of this wetland would have been geothermal. There was also a wider buffer between geothermal features and plantation forest in many parts of the site.

A considerable change in geothermal vegetation and habitat has occurred in the area marked as Whangaioterangi South on the accompanying map. This

¹ Historical photos: SN 172 Run 1158 Photos 6-7, 1941.

² Historical photos: SN 172 Run 1158 Photo 6, 1941; SN 172 Run 1159 Photos 1-4, 1941; SN 172 Run 1160 Photos 2-5, 1941.

area may now be only approximately half the size it was in 1941. The area of raw-soilfield is also reduced by about half.

Approximately 5-15% of the geothermal vegetation at this site has been lost since 1941, and wilding pines have caused degradation to 25% of the site, however some of these pines have been controlled in recent years.

**Management
Requirements:**

Ngapouri part: Pest plant control, particularly of blackberry, wilding pines, and wattle species would enhance the ecological and amenity values of this site. The small areas that are not currently fenced should be fenced to exclude domestic stock. Regular management of pest plants, particularly wilding trees should be undertaken. A restoration plan should be prepared and implemented to enhance the ecological values of this site. Formal protection is recommended.

Waiotapu North part: Wilding pines in core geothermal areas, particularly those in the geothermal kānuka scrub, need to be removed.

Care needs to be taken during plantation management and harvesting in adjacent plantation forests. The forest managers have taken reasonable care in the latest harvest and this should continue.

Parts of the geothermal vegetation and habitats are not protected and are subject to grazing; extensive areas are also dominated by pest plants. The unprotected areas provide important linkages between the protected areas of geothermal habitat and regular management of pest plants, particularly wilding trees, should be undertaken. These areas should be monitored regularly. A restoration plan should be prepared and implemented to enhance the highly significant ecological values of this site. Formal protection is recommended.

Waiotapu South part: Pest plant spread should continue to be controlled, particularly within the main area of geothermal activity within the reserve. An area of high priority for exotic tree control is between Waiotapu Loop Road and State Highway 5 (some pine control work has been done in this area since the 2011 survey). Fences should be checked on a regular basis where the site adjoins farmland. Pigs should be controlled in the wetlands in the southern part of the site.

Significance Level:

Ngapouri part: Regional (Criteria 3, 4, 5, 6, 7, 11).

Waiotapu part: International (Criteria 1, 3, 4, 5, 6, 7, 9, 10).

**Significance
Justification:**

Ngapouri part: This site is regionally significant because it is a buffer and linkage between the largest network of geothermal manifestations in the Taupō Volcanic Zone located at Mangaongaonga, Maunga Kākamea and Waiotapu sites. It contains examples of geothermal habitat (some of which are degraded).

Waiotapu part: the site is internationally significant because it is the largest area of geothermal vegetation and habitat in Aotearoa/New Zealand, large parts of which are in very good ecological condition. It has extensive areas of geothermal kānuka and other shrubland habitat. The site includes a large range of geothermal features including wetlands, terraces, mudpools, and fumaroles.

Notes:

Ngapouri part: Parts of the geothermal vegetation and habitats are subject to grazing and extensive areas are dominated by pest plant species. Although these areas are degraded, they provide important links between the protected areas of geothermal habitat.

Waiotapu North part: Ecological surveys and assessments were undertaken of the parts of this site managed by Kaingaroa Timberlands in April 2004 (Wildland Consultants 2004a). These areas were identified as “high conservation value forest” using the Forest Stewardship Council criteria for assessment of high conservation value forests.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.

Waiotapu South part: Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category A - the highest category.

Some parts of this site are too dangerous to access on foot. The exact extent of geothermal habitat is difficult to safely determine in both the wetland to the south near Lake Orotu, and in the area between Waiotapu Loop Road and State Highway 5.

A geophysical assessment of the surface geothermal manifestations at this site is presented in Appendix 4. This assessment was undertaken in 2010.

Macroinvertebrate taxa found in geothermally influenced streams here was in general typical of those recorded in non-geothermal streams, but which can tolerate high temperatures or unusual pH (Duggan and Boothroyd 2002).

References:

Beadel 1995b; Beadel and Bill 2000; Beadel and Bishop 1997; Clarkson 1982a; Duggan and Boothroyd 2002; Given 1995 & 1996; Hobbs 2002; Miller and Miller 1983; Rasch 1989; Spring-Rice 1996; Wildland Consultants 2000, 2004a, 2004c, 2012, 2014a.



A geothermal lake on the north side of the 'old' Waikaremoana Road, at the northern end of the Waiotapu site. NZTM E1895229 N5752181.10 November 2022.



There are a number of fenced geothermal gullies surrounded by blackberry in the eastern farmland of the greater Waiotapu site (mapped in Wildland Consultants 2014a as Ngapuna). NZTM E1894117 N5752060. 23 February 2023.



Geothermal pools opposite the Waiotapu Tavern on State Highway 5. Considerable wilding pine control has been undertaken in the vegetation surrounding the pools in the last 15 years. NZTM E1893774 N5750785. 2 March 2023.



Whangioterangi/Echo Lake.
NZTM E1894961 N5748833.
2 March 2023.



Many of the features in the tourist part of Waiotapu (Wai-O-Tapu Thermal Wonderland) are surrounded by scrub and shrubland dominated by geothermal kānuka and mingimingi. NZTM E1894368 N5749203. 3 March 2023.



Scattered wilding pines are a threat to the Waiotapu site. NZTM E1894139 N5748627. 3 March 2023.



Lake Ngakoro from the steep hillslopes to the west of the lake. NZTM E1894075 N5748230. 3 March 2023.

VASCULAR PLANT SPECIES RECORDED AT SURFACE GEOTHERMAL SITES IN THE WAIKITE-WAIOTAPU GEOTHERMAL SYSTEM

1. WAIKITE GEOTHERMAL SYSTEM (Northern Paeroa Range and Waikite Valley)

Scientific Name	Common Name	Northern Paeroa Range	Waikite Valley
INDIGENOUS SPECIES			
Monocot. trees and shrubs			
<i>Cordyline australis</i>	Ti kōuka, cabbage tree		✓
Dicot. trees and shrubs			
<i>Coprosma propinqua</i> var. <i>propinqua</i>	Mingimingi		✓
<i>Coprosma robusta</i>	Karamū, karamuramu		✓
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taupuku		✓
<i>Knightia excelsa</i>	Rewarewa		✓
<i>Kunzea robusta</i>	Kānuka		✓
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	✓
<i>Leptospermum scoparium</i>	Mānuka	✓	✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	✓
<i>Litsea calicaris</i>	Mangeao		✓
<i>Myrsine australis</i>	Māpou, matipou, mēpau		✓
<i>Pittosporum colensoi</i>	Rautāwhiri, rautāhiri		✓
<i>Pittosporum kirkii</i>	Kirk's kōhūhū		✓
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri		✓
<i>Pseudopanax arboreus</i>	Whauwhaupaku, puahou, five finger		✓
<i>Pterophylla racemosa</i>	Kāmahi		✓
<i>Toronia toru</i>	Toru		✓
Dicot. lianes			
<i>Calystegia sepium</i> subsp. <i>roseata</i>	Pōhue		✓
<i>Clematis paniculata</i>	Puawānanga		✓
<i>Muehlenbeckia australis</i>	Puka	✓	✓
Lycopods and psilopsids			
<i>Lycopodiella cernua</i>	Mātukutuku		✓
Ferns			
<i>Asplenium flaccidum</i> subsp. <i>flaccidum</i>	Makawe, ngā makawe o raukatauri, drooping splenwort		✓
<i>Azolla rubra</i>	Kārearea, rotoreto, returetu		✓
<i>Blechnum minus</i>	Swamp kiokio		✓
<i>Cheilanthes sieberi</i> subsp. <i>sieberi</i>	Rock fern		✓
<i>Christella</i> aff. <i>dentata</i> (b) (AK 126902 "thermal")			✓
<i>Cyclosorus interruptus</i>			✓
<i>Deparia petersenii</i> subsp. <i>congrua</i>			✓
<i>Dicksonia fibrosa</i>	Whekī-ponga, kurīpākā		✓
<i>Dicksonia squarrosa</i>	Whekī		✓
<i>Dicranopteris linearis</i>			✓
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	✓
<i>Hiya distans</i>			✓
<i>Hypolepis ambigua</i>			✓
<i>Hypolepis dicksonioides</i>	Giant hypolepis		✓
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pāraharaha, hound's tongue fern		✓
<i>Nephrolepis flexuosa</i>	Indigenous ladder fern		✓
<i>Paesia scaberula</i>	Mātātā, hard fern		✓
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	✓
<i>Pteris tremula</i>	Turawera, shaking brake		✓
<i>Thelypteris confluens</i>	Marsh fern		✓
Grasses			
<i>Isachne globosa</i>	Swamp millet		✓
Sedges			
<i>Carex geminata</i> agg.	Rautahi	✓	✓

Scientific Name	Common Name	Northern Paeroa Range	Waikite Valley
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio	✓	✓
<i>Carex virgata</i>	Pūrei		✓
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata		✓
<i>Eleocharis acuta</i>	Spike sedge		✓
<i>Isolepis prolifera</i>			✓
<i>Machaerina arthropphylla</i>			✓
<i>Machaerina juncea</i>			✓
<i>Machaerina rubiginosa</i>			✓
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā		✓
Rushes			
<i>Apodasmia similis</i>	Oioi		✓
<i>Juncus prismatocarpus</i>		✓	
Monocot. herbs (other than orchids, grasses, sedges, and rushes)			
<i>Lemna disperma</i>	Karearea		✓
<i>Phormium tenax</i>	Harakeke, flax		✓
<i>Triglochin striata</i>	Arrow grass		✓
<i>Typha orientalis</i>	Raupō		✓
Dicot. herbs (other than composites)			
<i>Drosera binata</i>	Sundew, wahu		✓
<i>Gonocarpus micranthus</i>	Piripiri	✓	
NATURALISED AND EXOTIC SPECIES			
Gymnosperms			
<i>Chamaecyparis lawsoniana</i>	Lawson's cypress		✓
<i>Pinus patula</i>	Patula pine	✓	
Dicot. trees and shrubs			
<i>Berberis glaucocarpa</i>	Barberry		✓
<i>Betula pendula</i>	Silver birch	✓	
<i>Betula</i> sp.	Birch		✓
<i>Cytisus scoparius</i>	Broom	✓	✓
<i>Erica lusitanica</i>	Spanish heath		✓
<i>Eucalyptus</i> sp.	Eucalyptus	✓	
<i>Feijoa sellowiana</i>	Feijoa		✓
<i>Populus nigra</i> 'Italica'	Lombardy poplar		✓
<i>Prunus serrulata</i>	Japanese hill cherry		✓
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓
<i>Salix cinerea</i>	Grey willow	✓	✓
Dicot. lianes			
<i>Hedera helix</i>	Ivy		✓
Grasses			
<i>Agrostis stolonifera</i>	Creeping bent	✓	
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓	✓
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass		✓
<i>Cortaderia selloana</i>	Pampas		✓
<i>Cynodon dactylon</i>	Indian doab		✓
<i>Dactylis glomerata</i>	Cocksfoot		✓
<i>Holcus lanatus</i>	Yorkshire fog	✓	✓
<i>Leersia oryzoides</i>			✓
<i>Lolium perenne</i>	Rye grass	✓	
<i>Paspalum distichum</i>	Mercer grass		✓
Sedges			
<i>Carex longibrachiata</i>	Australian sedge		✓
<i>Cyperus alternifolius</i> subsp. <i>flabelliformis</i>			✓
Rushes			
<i>Juncus effusus</i> var. <i>effusus</i>	Soft rush, leafless rush	✓	✓
Composite herbs			
<i>Bidens frondosa</i>	Beggars' ticks	✓	
Dicot. herbs (other than composites)			
<i>Digitalis purpurea</i>	Foxglove		✓
<i>Epilobium</i> sp.			✓

Scientific Name	Common Name	Northern Paeroa Range	Waikite Valley
<i>Galium aparine</i>	Cleavers		✓
<i>Lotus pedunculatus</i>	Lotus		✓
<i>Ludwigia palustris</i>	Water purslane		✓
<i>Persicaria maculosa</i>	Willow weed	✓	
<i>Persicaria</i> sp.			✓
<i>Portulaca oleracea</i>	Wild portulaca		✓
<i>Prunella vulgaris</i>	Selfheal	✓	
<i>Ranunculus flammula</i>	Spearwort		✓
<i>Ranunculus repens</i>	Creeping buttercup	✓	✓
<i>Rumex obtusifolius</i>	Broad-leaved dock	✓	



VASCULAR PLANT SPECIES RECORDED AT SURFACE GEOTHERMAL SITES IN THE WAIKITE-WAIOTAPU GEOTHERMAL SYSTEM

2. WAIOTAPU GEOTHERMAL SYSTEM (Maungaongaonga, Waiotapu, and Maunga Kākaramaea)

Scientific Name	Common Name	Maungaongaonga	Waiotapu	Maunga Kākaramaea
INDIGENOUS SPECIES				
Gymnosperms				
<i>Dacrydium cupressinum</i>	Rimu			✓
<i>Pectinopitys ferruginea</i>	Miro			✓
<i>Phyllocladus toatoa</i>	Toatoa			✓
<i>Podocarpus totara</i> var. <i>totara</i>	Tōtara			✓
Monocot. trees and shrubs				
<i>Cordyline australis</i>	TT kōuka, cabbage tree		✓	✓
<i>Cordyline banksii</i>	TT ngahere, forest cabbage tree			✓
Dicot. trees and shrubs				
<i>Aristotelia serrata</i>	Makomako, wineberry		✓	✓
<i>Brachyglottis repanda</i>	Rangiora		✓	✓
<i>Coprosma foetidissima</i>	Hūpiro			✓
<i>Coprosma grandifolia</i>	Kanono, raurēkau, raurākau, manono			✓
<i>Coprosma lucida</i>	Karamū, kāramuramu, glossy karamū	✓	✓	✓
<i>Coprosma propinqua</i> var. <i>propinqua</i>	Mingimingi		✓	
<i>Coprosma robusta</i>	Karamū, kāramuramu		✓	✓
<i>Coriaria arborea</i> var. <i>arborea</i>	Tutu			✓
<i>Corokia buddleioides</i>	Korokio, korokio tāra			✓
<i>Dracophyllum strictum</i>	Tōtorowhiti			✓
<i>Dracophyllum subulatum</i>	Monoao	✓	✓	✓
<i>Fuchsia excorticata</i>	Kōtukutuku, kōnini			✓
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taupuku			✓
<i>Gaultheria oppositifolia</i>	Niniwa			✓ (Rotorua Botanical Society 2006)
<i>Gaultheria paniculata</i>	Koropuka			✓
<i>Gaultheria antipoda</i> × <i>G. oppositifolia</i>	Koropuka			✓
<i>Geniostoma ligustrifolium</i> var. <i>ligustrifolium</i>	Hangehange			✓
<i>Griselinia littoralis</i>	Kāpuka			✓
<i>Knightia excelsa</i>	Rewarewa	✓	✓	✓
<i>Kunzea robusta</i>	Kānuka		✓	✓
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	✓	✓
<i>Leptecophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi	✓	✓	✓
<i>Leptospermum scoparium</i>	Mānuka	✓	✓	✓
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	✓	✓
<i>Leucopogon fraseri</i>	Pātōtara			✓
<i>Meliclytus ramiflorus</i> subsp. <i>ramiflorus</i>	Māhoe			✓
<i>Metrosideros robusta</i>	Northern rātā			✓
<i>Myrsine australis</i>	Māpou, matipou, māpau	✓	✓	✓
<i>Olearia arborescens</i>	Tree daisy			✓
<i>Olearia furfuracea</i>	Akepiro, tanguru			✓
<i>Pimelea prostrata</i>				✓
<i>Pittosporum eugenioides</i>	Tarata; lemonwood		✓	✓
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri		✓	✓
<i>Pseudopanax arboreus</i>	Whauwhaupaku, puahou, five finger	✓	✓	✓
<i>Pseudopanax colensoi</i> var. <i>colensoi</i>	Orihou, mountain five finger			✓ (Rotorua Botanical Society 2006)
<i>Pseudopanax crassifolius</i>	Horoeka, lancewood			✓
<i>Pseudowintera colorata</i>	Mountain horopito			✓ (Clarkson 1984)

Scientific Name	Common Name	Maungaongaonga	Waiotapu	Maunga Kākaramaea
<i>Pterophylla racemosa</i>	Kāmahi	✓	✓	✓
<i>Quintinia serrata</i>	Tāwheowheo			✓
<i>Schefflera digitata</i>	Patē			✓
<i>Toronia toru</i>	Toru	✓	✓	✓
<i>Veronica stricta</i> var. <i>stricta</i>	Koromiko, kōkōmuka		✓	✓
Dicot. lianes				
<i>Calystegia sepium</i> subsp. <i>roseata</i>	Pōhue		✓	✓
<i>Clematis forsteri</i>	Poananga, puawānanga			✓
<i>Clematis paniculata</i>	Puawānanga		✓	✓
<i>Metrosideros diffusa</i>	Rātā			✓
<i>Muehlenbeckia australis</i>	Puka			✓
<i>Muehlenbeckia complexa</i>	Pōhuehue		✓	
<i>Rubus cissoides</i> agg.	Tātārāmoa, tātarake, bush lawyer			✓
Lycopods and psilopsids				
<i>Lycopodium scariosum</i>	Mātukutuku, creeping clubmoss			✓
<i>Lycopodiella cernua</i>	Mātukutuku	✓	✓	✓
<i>Lycopodium volubile</i>	Waewaekoukou, climbing clubmoss		✓	✓
<i>Lycopodium deuterodensum</i>	Puakarimu			✓
<i>Psilotum nudum</i>	Fork fern			✓
<i>Tmesipteris elongata</i>				✓
<i>Tmesipteris tannensis</i>				✓
Ferns				
<i>Asplenium bulbiferum</i>	Mouku, mouki, mauku, hen and chicken fern			✓
<i>Asplenium flaccidum</i> subsp. <i>flaccidum</i>	Makawe, ngā makawe o raukauri, drooping spleenwort	✓	✓	✓
<i>Asplenium oblongifolium</i>	Huruhuru whenua, shining spleenwort			✓
<i>Asplenium polyodon</i>	Petako, paratao, sickle spleenwort	✓	✓	✓
<i>Asplenium bulbiferum</i> × <i>A. flaccidum</i>				✓
<i>Blechnum chambersii</i>	Rereti, nini, lance fern			✓
<i>Blechnum discolor</i>	Piupiu, petipeti, crown fern			✓
<i>Blechnum filiforme</i>	Pānako, thread fern			✓
<i>Blechnum fluviatile</i>	Kiwikiwi, kiwakiwa, creek fern			✓
<i>Blechnum minus</i>	Swamp kiokio		✓	
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio		✓	✓
<i>Blechnum parrisiae</i>	Pukupuku			✓
<i>Blechnum penna-marina</i> subsp. <i>alpina</i>	Little hard fern			✓
<i>Blechnum procerum</i>	Small kiokio			✓
<i>Blechnum deltoides</i>	Korokio			✓
<i>Cyathea cunninghamii</i>	Pūnui, gully tree fern			✓
<i>Cyathea dealbata</i>	Ponga, silver fern		✓	✓
<i>Cyathea medullaris</i>	Mamaku, black tree fern		✓	✓
<i>Cyathea smithii</i>	Kātote, soft tree fern			✓
<i>Cyclosorus interruptus</i>			✓	
<i>Deparia petersenii</i> subsp. <i>congrua</i>				✓
<i>Dicksonia fibrosa</i>	Whekī-ponga, kurīpākā		✓	✓
<i>Dicksonia squarrosa</i>	Whekī		✓	✓
<i>Dicranopteris linearis</i>			✓	✓
<i>Diplazium australe</i>				✓
<i>Gleichenia microphylla</i>	Waewaekākā, carrier tangle fern	✓	✓	✓
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	✓	✓
<i>Hiya distans</i>			✓	✓
<i>Hymenophyllum bivalve</i>	Mauku, filmy fern			✓ (Hobbs 2018)

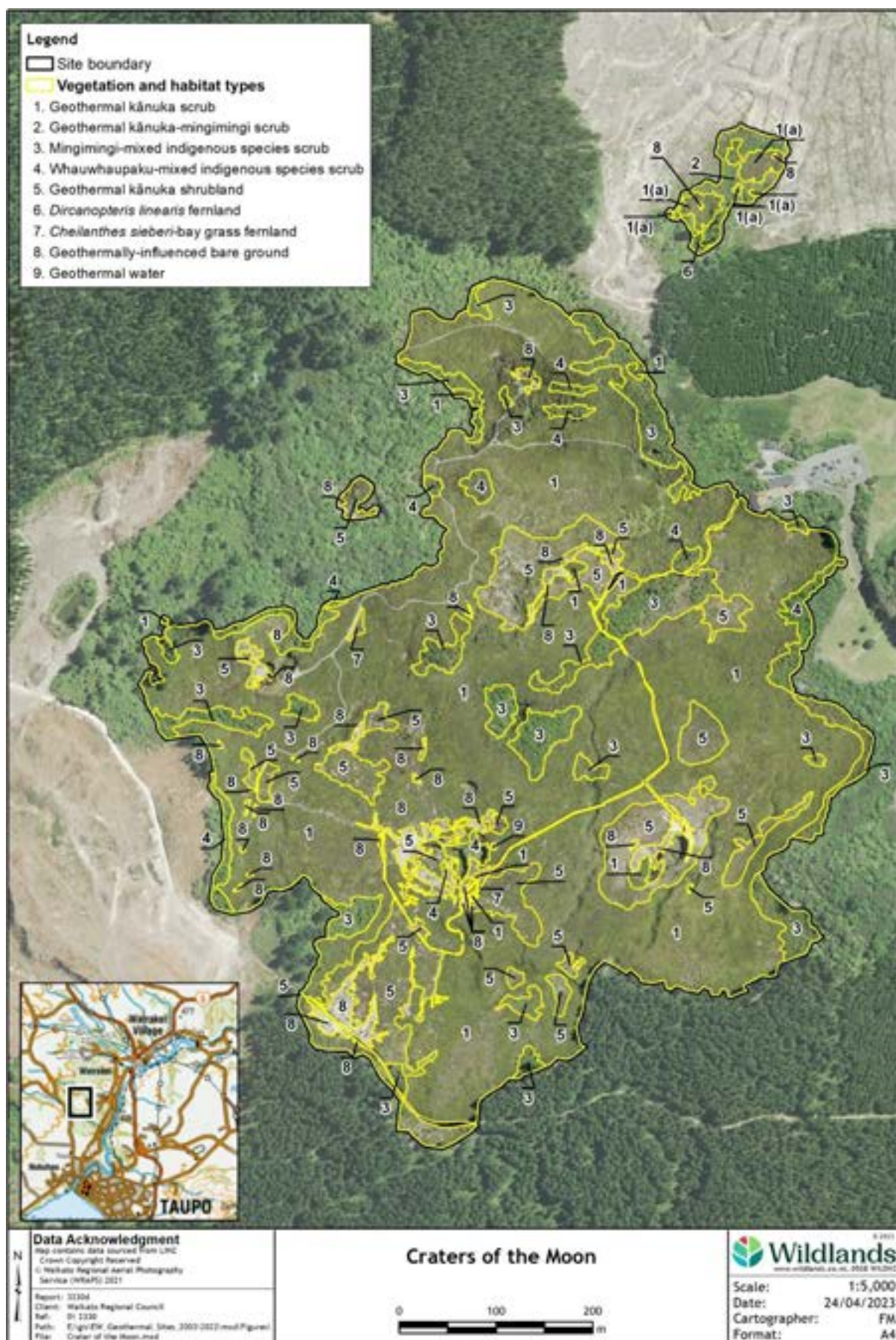
Scientific Name	Common Name	Maungaongaonga	Waiotapu	Maunga Kākaramea
<i>Hymenophyllum demissum</i>	Irirangi, pipiri, drooping filmy fern			✓
<i>Hymenophyllum dilatatum</i>	Matua mauku, filmy fern			✓
<i>Hymenophyllum flabellatum</i>	Mauku, fan-like filmy fern			✓
<i>Hymenophyllum multifidum</i>	Mauku, much-divided filmy fern			✓
<i>Hymenophyllum nephrophyllum</i>	Kidney fern, konehu raurenga, kopakopa			✓
<i>Hymenophyllum rarum</i>	Mauku, tufted filmy fern			✓ (Hobbs 2018)
<i>Hymenophyllum revolutum</i>	Mauku, filmy fern			✓ (Hobbs 2018)
<i>Hymenophyllum sanguinolentum</i>	Piripiri, filmy fern			✓
<i>Hypolepis ambigua</i>			✓	✓
<i>Hypolepis rufobarbata</i>	Sticky pig fern			✓ (Hobbs 2018)
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pārahara, hound's tongue fern	✓	✓	✓
<i>Lastreopsis hispida</i>	Tuakura			✓
<i>Lindsaea trichomanoides</i>				✓
<i>Nephrolepis flexuosa</i>	Indigenous ladder fern			✓
<i>Notogrammitis heterophylla</i>				✓
<i>Notogrammitis billardiarei</i>	Paretao			✓
<i>Paesia scaberula</i>	Mātātā, hard fern		✓	✓
<i>Pakau pennigera</i>	Piupiu, pākaurōharōha, feather fern, gully fern			✓
<i>Polystichum wawranum</i>				✓
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	✓	✓
<i>Pteris tremula</i>	Turawera, shaking brake		✓	
<i>Pyrrosia elaeagnifolia</i>	Leather-leaf fern		✓	✓
<i>Schizaea dichotoma</i>				✓
<i>Schizaea fistulosa</i>				✓ (Hobbs 2018)
<i>Trichomanes venosum</i>				✓
Orchids				
<i>Caladenia chlorostyla</i>				✓ (iNaturalist)
<i>Calochilus paludosus</i>				✓
<i>Calochilus robertsonii</i>				✓
<i>Chiloglottis comuta</i>				✓
<i>Corybas oblongus</i>				✓ (iNaturalist)
<i>Dendrobium cunninghamii</i>				✓
<i>Drymoanthus adversus</i>				✓
<i>Earina autumnalis</i>	Raupeka			✓
<i>Earina mucronata</i>	Peka-a-waka			✓
<i>Microtis unifolia</i> agg.			✓	✓
<i>Prasophyllum colensoi</i>				✓ (iNaturalist)
<i>Pterostylis banksii</i>	Tutukiwi			✓
<i>Pterostylis trullifolia</i>				✓ (Hobbs 2018)
<i>Thelymitra</i> sp.			✓	
<i>Thelymitra longifolia</i>				✓
<i>Thelymitra nervosa</i>				✓ (iNaturalist)
<i>Thelymitra pauciflora</i>	Slender sun orchid			✓ (iNaturalist)
Grasses				
<i>Austroderia fulvida</i>	Toetoe		✓	✓
<i>Microlaena avenacea</i>	Bush rice grass		✓	
<i>Microlaena stipoides</i>	Pātiti, meadow rice grass		✓	✓
<i>Pentapogon avenoides</i>				✓
<i>Pentapogon crinitus</i>	Plume grass		✓	
<i>Rytidosperma gracile</i>			✓	✓
Sedges				
<i>Carex forsteri</i>				✓ (Rotorua Botanical Society 2006)
<i>Carex geminata</i> agg.	Rautahi		✓	
<i>Carex maorica</i>				✓ (Rotorua Botanical Society 2006, Hobbs 2018)

Scientific Name	Common Name	Maungaongaonga	Waiotapu	Maunga Kākaramaea
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio		✓	✓
<i>Carex solandri</i>				✓
<i>Carex uncinata</i>	Kamu matau a Maui, kamu		✓	✓
<i>Carex virgata</i>	Pūrei		✓	✓
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata		✓	✓
<i>Eleocharis acuta</i>	Spike sedge		✓	✓
<i>Gahnia pauciflora</i>	Takahikahi			✓
<i>Gahnia setifolia</i>	Māpere			✓
<i>Lepidosperma australe</i>			✓	✓
<i>Machaerina juncea</i>			✓	
<i>Machaerina rubiginosa</i>			✓	✓
<i>Machaerina tenax</i>			✓	✓
<i>Morelotia affinis</i>				✓
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā		✓	
<i>Schoenus tendo</i>	Wīwī			✓
Rushes				
<i>Juncus australis</i>	Wi, wīwī			✓ (Rotorua Botanical Society 2006)
<i>Juncus edgariae</i>	Wi, wīwī		✓	✓
<i>Juncus planifolius</i>			✓	
<i>Juncus prismatocarpus</i>				✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)				
<i>Astelia fragrans</i>	Kakaha			✓
<i>Astelia solandri</i>	Kōwharawhara		✓	✓
<i>Dianella nigra</i>	Tūrutu		✓	✓
<i>Lemna disperma</i>	Karearea		✓	
<i>Phormium tenax</i>	Harakeke, flax		✓	✓
<i>Typha orientalis</i>	Raupō		✓	✓
Composite herbs				
<i>Celmisia gracilentia</i>	Pekapeka, tikumu			✓
<i>Euchiton audax</i>				✓
<i>Euchiton sphaericus</i>				✓ (Rotorua Botanical Society 2006)
<i>Lagenophora pumila</i>	Papataniwhaniwha			✓
<i>Pseudognaphalium luteoalbum</i> agg.	Pukatea		✓	✓
<i>Senecio bipinnatisectus</i>	Australian fireweed		✓	
Dicot. herbs (other than composites)				
<i>Acaena anserinifolia</i>	Piripiri, hutiwai		✓	✓
<i>Centella uniflora</i>			✓	
<i>Drosera auriculata</i>	Sundew, wahu		✓	✓
<i>Drosera spatulata</i>	Sundew, wahu			✓
<i>Epilobium nummularifolium</i>				✓ (Rotorua Botanical Society 2006)
<i>Epilobium pedunculare</i>				✓ (Rotorua Botanical Society 2006)
<i>Epilobium rotundifolium</i>				✓ (Rotorua Botanical Society 2006)
<i>Geranium potentilloides</i> var. <i>potentilloides</i>				✓ (Rotorua Botanical Society 2006)
<i>Gonocarpus micranthus</i>	Piripiri		✓	✓
<i>Haloragis erecta</i> subsp. <i>erecta</i>	Toatoa		✓	
<i>Hydrocotyle moschata</i> var. <i>moschata</i>				✓
<i>Lobelia angulata</i>	Pānakenake		✓	✓
<i>Nertera depressa</i>			✓	✓
<i>Pelargonium inodorum</i>	Kopata			✓ (Hobbs 2018)
<i>Persicaria decipiens</i>	Tutunawai		✓	✓
<i>Ranunculus amphitrichus</i>	Kawariki			✓ (Hobbs 2018)
<i>Ranunculus reflexus</i>	Maruru			✓
<i>Solanum americanum</i>	Raupeti			✓
<i>Stellaria parviflora</i>	Kohukohu			✓
NATURALISED AND EXOTIC SPECIES				
Gymnosperms				
<i>Chamaecyparis lawsoniana</i>	Lawson's cypress		✓	
<i>Cryptomeria japonica</i>	Japanese cedar		✓	
<i>Larix decidua</i>	European larch			✓

Scientific Name	Common Name	Maungaongaonga	Waiotapu	Maunga Kākaramea
<i>Pinus contorta</i>	Lodgepole pine			✓
<i>Pinus muricata</i>	Bishop pine			✓ (Rotorua Botanical Society 2006)
<i>Pinus nigra</i>	Black pine		✓	✓ (Hobbs 2018)
<i>Pinus pinaster</i>	Maritime pine		✓	✓
<i>Pinus ponderosa</i>	Ponderosa pine			✓ (Rotorua Botanical Society 2006)
<i>Pinus radiata</i>	Radiata pine	✓	✓	
<i>Pinus strobus</i>	Strobus pine		✓	✓
<i>Pseudotsuga menziesii</i>	Douglas fir		✓	✓
<i>Sequoia sempervirens</i>	Coast redwood		✓	
Dicot. trees and shrubs				
<i>Acacia dealbata</i>	Silver wattle		✓	
<i>Acacia mearnsii</i>	Black wattle		✓	
<i>Acacia melanoxylon</i>	Tasmanian blackwood		✓	
<i>Berberis darwinii</i>	Darwin's barberry			✓ (Rotorua Botanical Society 2006)
<i>Berberis glaucocarpa</i>	Barberry			✓
<i>Betula pendula</i>	Silver birch		✓	✓
<i>Calluna vulgaris</i>	Heather			✓ (Rotorua Botanical Society 2006)
<i>Cotoneaster franchetii</i>			✓	
<i>Cotoneaster glaucophyllus</i>	Cotoneaster		✓	
<i>Crataegus monogyna</i>	Hawthorn			✓
<i>Cytisus scoparius</i>	Broom		✓	✓
<i>Erica lusitanica</i>	Spanish heath	✓	✓	✓
<i>Hakea sericea</i>	Prickly hakea			✓ (Rotorua Botanical Society 2006)
<i>Hydrangea macrophylla</i>	Hydrangea			✓ (Rotorua Botanical Society 2006)
<i>Ligustrum sinense</i>	Chinese privet			✓
<i>Liquidambar styraciflua</i>	Liquidambar		✓*planted	
<i>Lupinus arboreus</i>	Lupin			✓
<i>Paulownia tomentosa</i>	Paulownia		✓	
<i>Prunus persica</i>	Peach tree, nectarine			✓
<i>Prunus ×domestica</i>	Plum		✓	
<i>Prunus</i> sp.	Ornamental cherry			✓
<i>Pyracantha</i> sp.			✓	
<i>Quercus robur</i>	English oak		✓	
<i>Robinia pseudoacacia</i>	False acacia, black locust, robinia		✓	
<i>Rosa</i> sp.	Climbing rose		✓	
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓	✓
<i>Salix cinerea</i>	Grey willow		✓	✓
<i>Salix ×fragilis</i>	Crack willow			✓
<i>Teline stenopetala</i>	Sweet broom			✓
<i>Ulex europaeus</i>	Gorse	✓	✓	✓
Dicot. lianes				
<i>Hedera helix</i>	Ivy			✓ (Rotorua Botanical Society 2006)
<i>Lonicera japonica</i>	Japanese honeysuckle			✓ (Rotorua Botanical Society 2006)
<i>Rubus nemoralis</i>	Blackberry		✓	
<i>Vitis vinifera</i>	Grape		✓	
Ferns				
<i>Dryopteris filix-mas</i>	Male fern		✓	
Grasses				
<i>Agrostis capillaris</i>	Browntop		✓	✓
<i>Anthoxanthum odoratum</i>	Sweet vernal		✓	✓
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass		✓	
<i>Cortaderia jubata</i>	Purple pampas			✓
<i>Cortaderia selloana</i>	Pampas		✓	✓
<i>Holcus lanatus</i>	Yorkshire fog		✓	✓
<i>Miscanthus nepalensis</i>	Himalaya fairy grass			✓
<i>Paspalum dilatatum</i>	Paspalum		✓	✓
<i>Paspalum distichum</i>	Mercer grass		✓	
<i>Paspalum urvillei</i>	Vasey grass		✓	

Scientific Name	Common Name	Maungaongaonga	Waiotapu	Maunga Kākaramaea
Rushes				
<i>Juncus bufonius</i> var. <i>bufonius</i>	Toad rush		✓	
<i>Juncus effusus</i> var. <i>effusus</i>	Soft rush, leafless rush		✓	✓
<i>Juncus tenuis</i> var. <i>tenuis</i>	Track rush		✓	✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)				
<i>Crocsmia ×crocsmiiflora</i>	Montbretia		✓	
Composite herbs				
<i>Achillea millefolium</i>	Yarrow		✓	
<i>Cirsium arvense</i>	Californian thistle			✓
<i>Cirsium vulgare</i>	Scotch thistle		✓	✓
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane			✓
<i>Gamochaeta coarctata</i>	Purple cudweed		✓	
<i>Helminthotheca echioides</i>	Oxtongue		✓	
<i>Hypochaeris radicata</i>	Catsear		✓	✓
<i>Jacobaea vulgaris</i>	Ragwort		✓	✓
<i>Lactuca serriola</i>	Prickly lettuce		✓	
<i>Leucanthemum vulgare</i>	Oxeye daisy		✓	✓
<i>Mycelis muralis</i>	Wall lettuce		✓	
<i>Callitriche stagnalis</i>	Starwort		✓	
<i>Centaureum erythraea</i>	Centaury			✓
<i>Digitalis purpurea</i>	Foxglove		✓	✓
<i>Foeniculum vulgare</i>	Fennel		✓	
<i>Galeobdolon luteum</i>	Aluminium plant		✓	
<i>Galium aparine</i>	Cleavers			✓
<i>Lotus pedunculatus</i>	Lotus		✓	
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	Scarlet pimpernel			✓
<i>Ornithopus perpusillus</i>	Wild seradella		✓	✓
<i>Orobanche minor</i>	Broomrape		✓	
<i>Oxalis incarnata</i>	Lilac oxalis			✓
<i>Persicaria maculosa</i>	Willow weed		✓	
<i>Phytolacca octandra</i>	Inkweed		✓	✓
<i>Polygonum aviculare</i>	Wireweed		✓	
<i>Ranunculus flammula</i>	Spearwort			✓
<i>Ranunculus repens</i>	Creeping buttercup		✓	✓
<i>Rumex acetosella</i>	Sheep's sorrel		✓	✓
<i>Rumex conglomeratus</i>	Clustered dock		✓	
<i>Rumex obtusifolius</i>	Broad-leaved dock		✓	
<i>Solanum nigrum</i>	Black nightshade		✓	
<i>Stellaria media</i>	Chickweed		✓	
<i>Urtica dioica</i>	Stinging nettle			✓
<i>Veronica arvensis</i>	Field speedwell			✓ (Rotorua Botanical Society 2006)
<i>Viola</i> sp.				✓ (Rotorua Botanical Society 2006)

26. WAIRĀKEI-TAUHARA GEOTHERMAL SYSTEM



CRATERS OF THE MOON

Ecological District: Atiamuri **GPS Reference:** NZTM E1867064 N5718041
Geothermal System: Wairākei-Tauhara **Altitude:** c.420-480 m
Geothermal System: Wairākei
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.36.4 ha
Extent of Geothermal Vegetation: c.36.4 ha
Date of Most Recent Field Survey: 25 June 2021 and 30 March 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Two subtypes are identified under this type. 1a. Geothermal kānuka (generally short prostrate shrubs ranging in height from 0.1 to 1 metre tall, but occasionally local areas to up to c.2 metres tall) dominate this vegetation type with scattered mingimingi and monoao, and local patches of <i>Lycopodiella cernua</i> . A number of patches of the geothermal ferns, <i>Nephrolepis flexuosa</i> , and <i>Dicranopteris linearis</i> occur locally. Patches of <i>Campylopus</i> spp. and lichens are common, and <i>Trentepholia</i> is common on geothermal kānuka branches. <i>Histiopteris incisa</i> is often present in the base of craters. There are a few wilding pines (mostly radiata pine) and pampas plants particularly in the southwest of the site and near the margins of the mapped site. In less geothermally active areas, whauwhaupaku, karamū, and other indigenous broadleaved species are present. 1b. The small geothermal area in the north comprises geothermal kānuka (c.0.3 to 2 metres tall) with occasional monoao. Mingimingi and mānuka are often present on the margins. Local karamū and Chinese privet to c.4 metres tall are present with occasional wilding pines (c.5% cover), mostly on the upper slopes, and local pampas and blackberry. There are local patches of <i>Lycopodiella cernua</i> and of <i>Dicranopteris linearis</i> (at least one 10 × 5 metre patch occurs on a cliff). One geothermal spring visited in June 2021 had a water temperature of c.34 °C. Other pest plants present include Spanish heath, pampas, blackberry, and buddleia.	Flat, hillslope, craters	c.26.4 ha
2.	Geothermal kānuka-mingimingi scrub (04.02) Geothermal kānuka-mingimingi scrub (04.02.01) Dominated by geothermal kānuka and mingimingi.	Hillslope	c.0.4 ha
3.	Mingimingi-dominant scrub (04.03) Mingimingi-mixed indigenous species scrub. (04.03.03) Mingimingi-mānuka-whēkī-whauwhaupaku-karamū-geothermal kānuka/bracken scrub. A mixture of mingimingi, mānuka, whēkī, whauwhaupaku, karamū, and geothermal kānuka forms a dense scrub cover,	Flat	c.3.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	with small patches of bracken, blackberry, whekī, Himalayan honeysuckle, and <i>Dicranopteris linearis</i> shrubland around the margins. Near the main entrance of the reserve, Himalayan honeysuckle and bracken dominate a recently cleared hillslope, with broom and mingimingi scattered throughout and patches of <i>Dicranopteris linearis</i> on steep banks at the base of the hillslope.		
4.	Whauwhaupaku dominant scrub Mingimingi-mixed indigenous species scrub (04.05.01) Mingimingi-whauwhaupaku-karamū-geothermal kānuka/bracken scrub. This type occurs locally within the geothermal area and on its margins. The vegetation is a mixture of mingimingi and scattered geothermal kānuka, whauwhaupaku (often emergent). Other locally common species include karamū, mānuka, prickly mingimingi, and broom with patches of bracken and occasional cotoneaster. <i>Asplenium polyodon</i>, blackberry, tūrutu, and <i>Lycopodium volubile</i> are scattered throughout the understorey, with patches of <i>Dicranopteris linearis</i> common. The height of the vegetation ranges from one to five metres.	Hillslope, flat	c.0.9 ha
5.	Geothermal kānuka-dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Geothermal kānuka to a height of c.0.1-0.5 metres dominates this shrubland. There are local patches of <i>Lycopodiella cernua</i> and <i>Dicranopteris linearis</i>, and areas of non-vegetated raw soilfield. Mossfields and lichenfield are locally common, comprising a mixture of lichens, liverworts, and mosses including: <i>Racomitrium lanuginosum</i>, <i>Campylopus</i> spp., <i>Chiloscyphus semiteres</i>, and <i>Cladonia</i> spp.	Flat	c.4.5 ha
6.	Indigenous fernland (07.01) <i>Dicranopteris linearis</i> fernland (07.01.01) <i>Dicranopteris linearis</i> is dominant.	Flat and hillslope	<0.1 ha
7.	<i>Cheilanthes sieberi</i>-bay grass fernland (07.01.13) Two small areas are dominated by <i>Cheilanthes sieberi</i> subsp. <i>sieberi</i> and dead mixed exotic grasses, including bay grass. Both areas are near a walking track and may have developed following disturbance.	Flat	<0.1 ha
8.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Sinter pavement. Small patches of <i>Campylopus clavatus</i> mossfield with occasional <i>Lycopodiella cernua</i> are present.	Flat	c.1.0 ha
9.	Water (22.01) Geothermal water (22.01.01) Geothermal pool and mudpools.	Crater	<0.1 ha

Indigenous Flora:	Geothermal kānuka (Threatened-Nationally Endangered), <i>Dicranopteris linearis</i> (Threatened-Nationally Endangered), and <i>Nephrolepis flexuosa</i> (At Risk-Declining) are abundant and relatively common at this site. <i>Hypolepis dicksonioides</i> has been recorded from the site in the past. <i>Lycopodiella cernua</i>, <i>Campylopus</i> sp., <i>Psilotum nudum</i> and <i>Cheilanthes sieberi</i>, which are characteristic of geothermal areas, are also present. Given (1989a) recorded <i>Asplenium flabellifolium</i> growing on hot siliceous soil (which is not its usual habitat) and <i>Fimbristylis velata</i>, which was reported to be at its southern limit. <i>A. flabellifolium</i> and <i>F. velata</i> have not been recorded from this site since 1989.
Fauna:	Indigenous bird species that have been recorded at the site include pīhoihoi/New Zealand pipit (At Risk-Declining), pōpokotea/whitehead, toutouwai/North Island robin (At Risk-Declining), kāhu/swamp harrier, spur-winged plover, tūi, korimako/bellbird, piwakawaka/North Island fantail, riroriro/grey warbler, and tauhou/ silvereye. Introduced birds that have been recorded at the site include Eurasian blackbird and European goldfinch.
Geothermal Ecosystems:	Heated ground (dry), hydrothermally altered ground (now cool), geothermal streamsides, fumaroles, geothermal wetland.
Current Condition:	This is a large site that is in good condition. There is clear vegetation zonation in response to different levels of heat flux (Given 1980). Commissioning of the Wairākei geothermal power station resulted in an increase in steam-heated activity at Karapiti, which has increased the size of the site and the extent of geothermal vegetation present (Burns <i>et al.</i> 1996; Cave <i>et al.</i> 1993). A small area of geothermal vegetation in the northern part of the site has been damaged and destroyed by recent harvesting of the surrounding plantation pine forest. The site is threatened by wilding pines and other weed species. Continued control of these species will be necessary to maintain the ecologically intact areas of geothermal vegetation at the site.
Threats/Modification/ Vulnerability:	<i>Invasive pest plants:</i> Despite some recent wilding pine control, several wilding pines (particularly radiata pine and maritime pine), and eucalyptus are scattered through the site. The Waikato Regional Council has recently undertaken aerial control of pampas at this site. Other invasive plant species present include blackberry (3% cover), Chinese privet (<1% cover), lupin (<1% cover), cotoneaster (<1% cover), <i>Cotoneaster franchetii</i> (<1% cover), black wattle (<1% cover), grey willow (<1% cover), lodgepole pine (<1% cover), Himalayan honeysuckle (<1% cover), broom (3% cover), Montpellier broom (<1% cover), ornamental cherry (<1% cover), buddleia (2% cover), pampas (1% cover), Spanish heath (<1% cover), narrow-leaved carpet grass (3% cover), and Mercer grass (<1% cover). Where present, these species are having a negative impact on the indigenous character of the site.

The cover of pest plants is higher in the small area to the north of the main geothermal area. The following pest plant covers were recorded in this area in 2021: wilding pines (5% cover), pampas (2% cover), blackberry (2% cover on margins), Chinese privet (2% cover), Spanish heath (2% cover), and buddleia (<1% cover).

Human impacts :

The extent of heated ground around Craters of the Moon increased significantly following the development of the Wairakei Geothermal System for electricity generation. As a result, there have been many changes in geothermal activity. The vegetation and geothermal features of this site continue to respond to the heating and cooling of soils (Given 1989a). A small part of the area to the north of the main geothermal area was destroyed during harvest of the surrounding pine plantation forest.

This area is a popular spot for visitors. There are numerous walking tracks (many disused), but visitors are now encouraged to keep to the main path which is maintained by the Craters of the Moon Trust. The site caretaker is utilising a variety of techniques to discourage people from walking off the main path.

The substrate of informal tracks created by visitors is compacted. This limits the potential for indigenous plants to recolonise these areas. In addition, there may be a significant effect of compaction on soil micro-organisms.

The removal of some wilding pines from the reserve has improved the long-term viability of the site. Spraying of some areas with herbicide has adversely affected some indigenous communities (e.g. *Cheilanthes fernland*).

Grazing:

Livestock are not a threat to this site, however possum, hares, and rabbit are present and are browsing the vegetation. Pig sign was recorded in the area to the north of the main geothermal area in 2021.

Adjoining land use:

Plantation forest, recreational mountain biking, and horse trekking.

Site Changes:

Recent change:

Some pest plant control work has been undertaken recently by site managers. Techniques to discourage the use of informal tracks have been implemented by the Craters of the Moon Trust. The Waikato Regional Council undertook control of patches of pampas at this site in April 2011 by the aerial application of herbicide.

Harvesting of plantation forest occurred very close to the boundary of the small northern area located c.80 metres to the north of the larger Craters of the Moon area between September 2019 and December 2020 (time of clearance based on viewing images on Google Earth Pro¹). The change in the mapped boundary indicates some geothermal vegetation loss at the northern part of this area, but it is very minor and may be mapping error,

¹ Images viewed on Google Earth Pro: September 2020 (Image © 2021 CNES/Airbus) and December 2020 (Image © 2021 Planet.com).

as the boundaries of the site prior to harvesting were obscured by tree canopy.

In the 2000s an additional area of geothermal vegetation was observed during mountain biking in the area. This was mapped in a 2016 study of the site (Wildland Consultants 2016d). This area was identified based on the higher quality aerial photography taken for this project by a UAV (Uncrewed Aerial Vehicle, or drone). The area was not clearly visible on lower quality earlier photography used for mapping of this site, and because of the presence of pine plantation.

*Historical:*¹

Burns *et al.* (1996) assessed vegetation change at this site using aerial photographs from 1945 to 1993 and found that there had been an eight-fold increase in geothermal vegetation. However, there is no information on changes of structure or composition of this vegetation in the Burns *et al.* (1996) study.

**Management
Requirements:**

Control of wilding pines and other pest plants needs to continue. Continued monitoring of this area will be invaluable for assessing the impacts of geothermal power extraction (refer to Burns *et al.* 1996; Merrett and Burns 1998a, 1998b). The practice of discouraging the use of informal tracks should be continued. A buffer should be established around the site to prevent further damage during harvest of the surrounding plantation forest.

Significance Level:

National (Criteria 3, 5, 7, 9).

**Significance
Justification:**

Craters of the Moon is of national significance because it contains a good quality representative example of geothermal vegetation that includes ecosystems that were nationally uncommon prior to human settlement (geothermal). It contains one of the best examples of geothermal vegetation zonation in New Zealand, which has developed in response to varying soil temperatures, and is an area of high geothermal activity (Given 1980). Four plant species classified as Threatened or At Risk are present: geothermal kānuka, *Dicranopteris linearis*, *Hypolepis dicksonioides*, and *Nephrolepis flexuosa*.

Notes:

Given (1996) assessed the botanical values of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category A - the highest category.

References:

Burns *et al.* 1996; Given 1980, 1989a, 1996; Merrett and Burns 1998a, 1998b; Spring-Rice 1996; Wildland Consultants 2000, 2004b, 2007d, 2012, 2014a, 2016d.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.



Craters in the central part of the Craters of the Moon site. There is a wide diversity of vegetation types present, ranging from geothermal kānuka scrub and shrubland, to *Lycopodiella cernua* fernland, and *Campylopus mossfield*. Note the pampas in the crater. NZTM E1866922 N5717807. 2 June 2016.



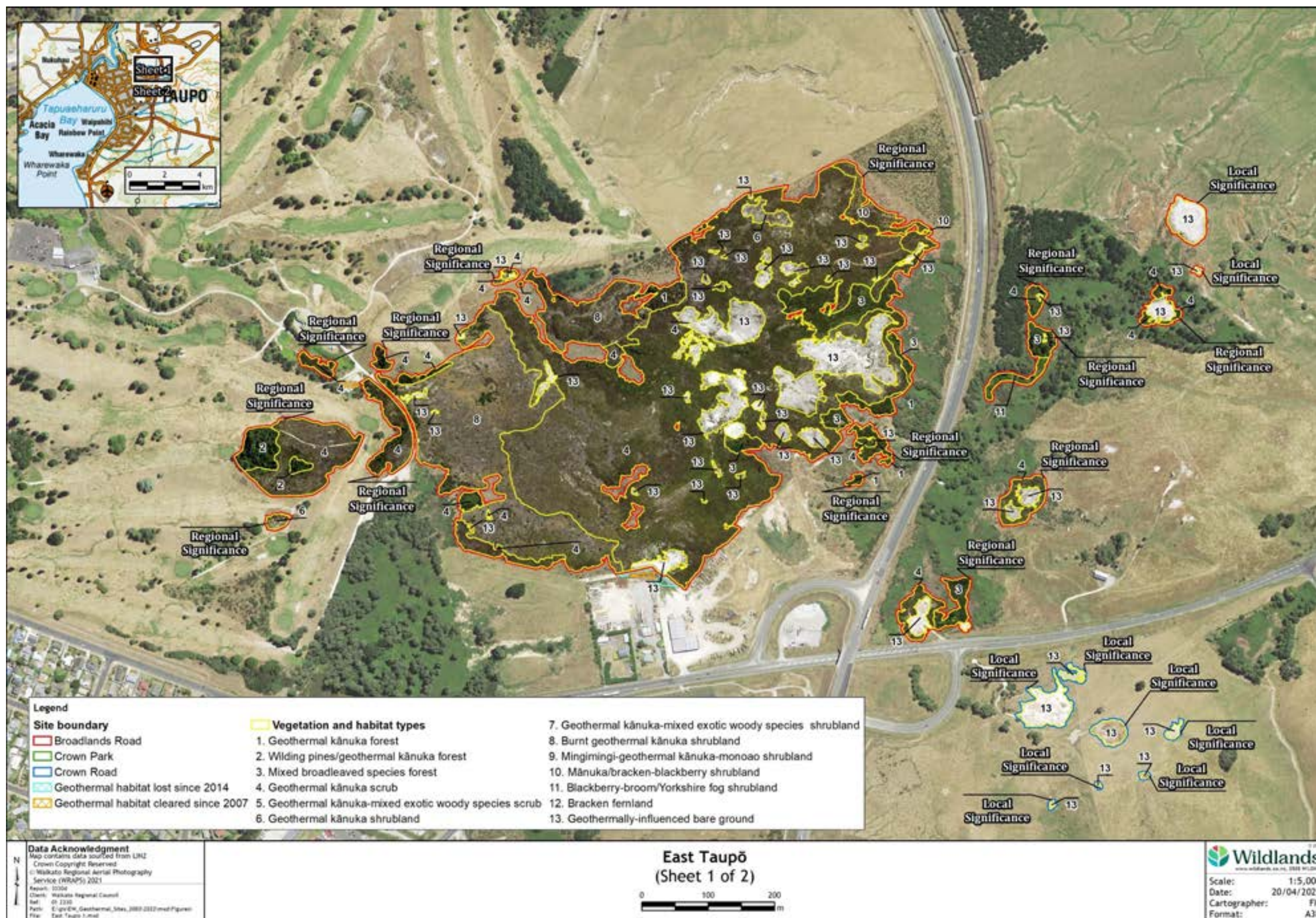
View in some of the craters from the southern part of the Craters of the Moon walking track. Note the abundant geothermal kānuka on crater sides. 30 March 2022. NZTM E1866944 N5717739.

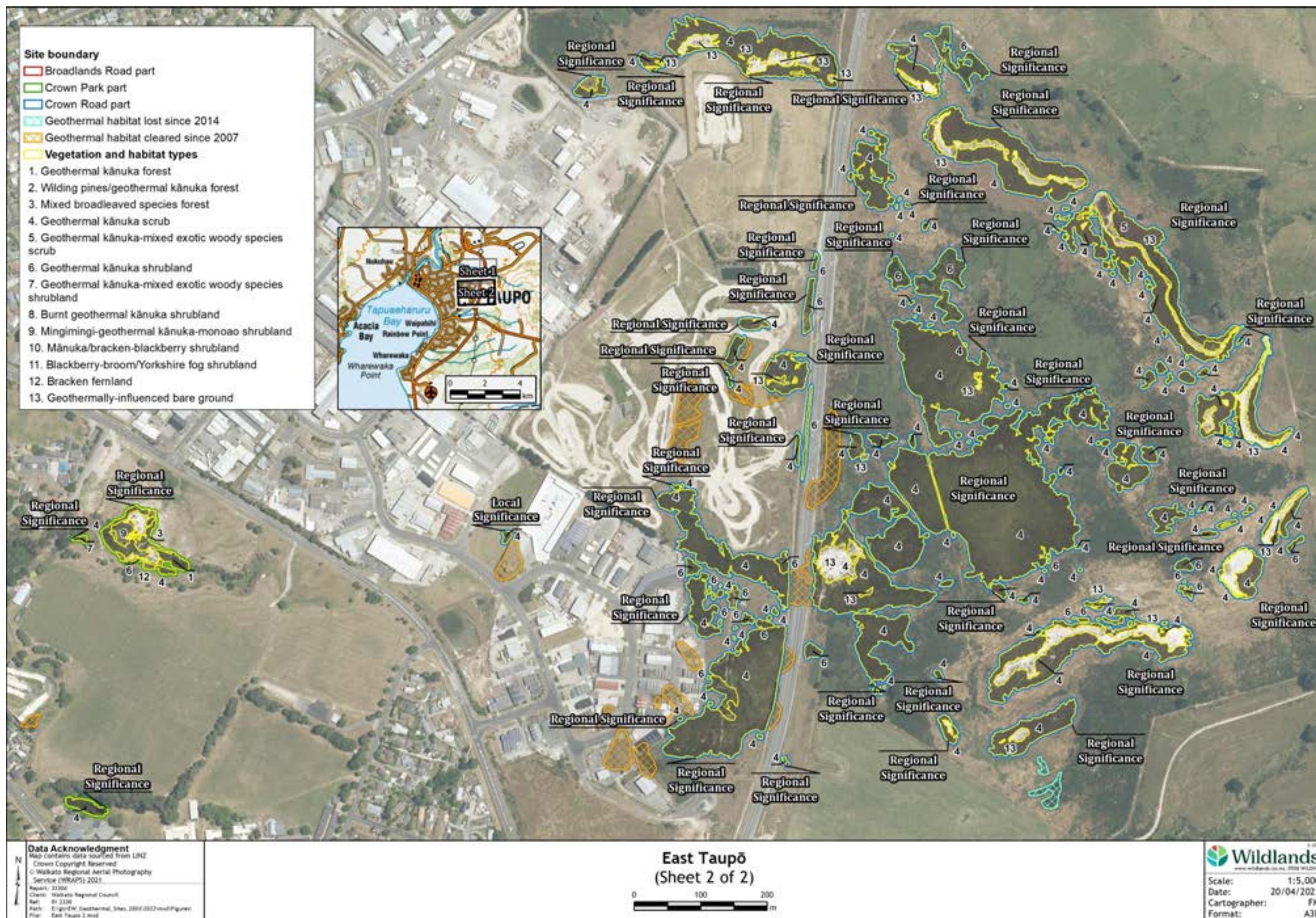


A local patch of *Dicranopteris linearis* amongst geothermal kānuka scrub, in the northern part of the Craters of the Moon site. Note scattered pampas and wilding radiata pines (both pest plant species). NZTM E1867176 N5718559. 25 June 2021.



A crater in the southwest corner of Craters of the Moon. Note the populations of the ferns *Dicranopteris linearis*, *Nephrolepis flexuosa* and *Lycopodiella cernua*. There is also an abundant cover of the moss *Campylopus*. 30 March 2022. NZTM 1E866754 N5717901.





EAST TAUPŌ¹

Ecological District: Taupō; Atiamuri **GPS Reference:** NZTM E1871212 N5712890
Geothermal System: Wairākei-Tauhara **Altitude:** c. 420-485 m
Geothermal System: Tauhara
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.56.8 ha
Extent of Geothermal Vegetation: c.56.8 ha
Date of Most Recent Field Survey: 1 and 16 September 2020, 29 March 2022.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Indigenous forest (01.01) Geothermal kānuka forest (01.01.03) Geothermal kānuka forms a canopy up to c.5 metres tall with occasional blackberry, <i>Hypolepis ambigua</i> , and broom on the margins. Scattered indigenous and exotic species are present in the understorey including whauwhaupaku, mānuka, karamū, ornamental cherry, and tūrutu. Occasional banksia, and eucalyptus are also present.	Flat and undulating plateau, gully	c.0.6 ha
2.	Exotic forest (01.02) Wilding pines/geothermal kānuka forest (01.02.07) Scattered radiata pine, maritime pine, broom, and strawberry tree occur at 1-5% cover, above local areas of forest dominated by geothermal kānuka. Over time, the cover of geothermal kānuka has reduced and the cover of woody exotic trees has increased.	Flat and undulating plateau, gully	c.0.4 ha
3.	Mixed indigenous broadleaved species forest (01.04) Mixed indigenous broadleaved species forest (01.04.01) Whauhaupaku-kōhūhū-geothermal kānuka-karamū forest. Small pockets of forest amongst geothermal vegetation, with local areas of geothermal influence both from beneath the canopy, and from steam. The canopy often ranges from 5 to 10 metres and has abundant whauwhaupaku, kōhūhū, karamū, geothermal kānuka, and Chinese privet. A few local gorse and blackberry present. The understorey often has abundant mingimingi, kōwaowao, turutu, and bracken.	Rolling hills, flat, gullies	c.1.5 ha
4.	Geothermal kānuka-dominant scrub (04.01) Geothermal kānuka scrub (04.01.01) Crown Road part: Geothermal kānuka (c.1.5-3 metres tall) is abundant in association with occasional mingimingi. Occasional broom and emergent wilding pines (maritime pine and radiata pine) are scattered throughout and there are local patches of blackberry, local monoao, and occasional broom. Mosses and local patches of <i>Lycopodiella cernua</i> are present,	Flat and undulating plateau, gully	c.38.3 ha

¹ The site East Taupō amalgamates the sites from Wildland Consultants (2014a): Broadlands Road, Crown Road and Crown Park.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	particularly around steam vents. A few whauwhaupaku occur on areas of cooler ground. Broadlands Road part: Geothermal kānuka, up to c.1 metre tall, forms a dense canopy with occasional monoao. The ground cover tier includes lichens, mosses, liverworts, and occasional <i>Lycopodiella cernua</i>. Smaller areas on the plateau or within explosion craters are covered in geothermal kānuka shrubland. Geothermal kānuka to c.0.5 metres tall forms a broken canopy, interspersed with patches of <i>Lycopodiella cernua</i> and narrow-leaved carpet grass. Where geothermal activity is greatest, patches of bare ground occur, characterised by occasional geothermal kānuka, lichens, and mosses. On the margins of the site, blackberry, broom, and exotic grasses, including paspalum, browntop, Indian doab, and Yorkshire fog are common. Within the golf course, the margins of geothermal areas are often fringed by radiata pine, maritime pine, broom, and strawberry tree. Since 2006, the State Highway 1 bypass has been constructed near eastern parts of the site, although this did not result in any loss of geothermal vegetation. A fire burnt through part of this reserve in late 2015 and had an adverse effect on a large area of geothermal kānuka vegetation and habitat (Wildland Consultants 2016c). See Vegetation Type 7. Within the golf course, an outlying area of geothermal vegetation is dominated by geothermal kānuka 0.75 to 1.0 m tall. Scattered radiata pine, maritime pine, broom, and strawberry tree occur at 5% cover. Patches of bare ground and lichenfield dominated by <i>Cladia retipora</i> are common. Crown Park part: Scrub dominated by dense geothermal kānuka (to c.5 metres tall; average c.2 metres tall) with abundant mingimingi, local bracken, and a few mānuka, occurs in the gully and slopes surrounding the craters. Broom is scattered in places and monoao is occasional on the margins of this type towards the craters. The understorey is dominated by leaf litter, with patches of the liverwort <i>Chiloscyphus semiteres</i>, a few tūrutu, and scattered seedlings of Chinese privet.		
5.	Geothermal kānuka-mixed exotic woody species scrub (04.01.11) This type occurs in the Crown Road part of the East Taupō site. Abundant geothermal kānuka and less common mingimingi occur around the margins of several geothermal areas. Broom, blackberry, and occasional emergent maritime pine are also present.	Gully	c.0.5 ha
6.	Geothermal kānuka-dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Geothermal kānuka (c.1.5 metres tall) is common with scattered broom, blackberry and exotic grasses. An area of geothermal kānuka that had previously been burned in 2002 has since re-established as geothermal kānuka shrubland. Local patches of broom, bracken, buddleia, and blackberry are also present.	Explosion crater; flat and undulating plateau, gully	c.1.7 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	Geothermal kānuka shrubland (up to c.2 metres tall) occurs on the slopes and floor of a shallow gully. There are patches of narrow-leaved carpet grass and local patches of bare ground. Bracken is present on the sides of the gully in places. Other species present include occasional tūrutu, blackberry, monoao, mingimingi, broom, and banksia. Small areas of bare ground are present, with exotic grasses present on the margins, in particular, narrow-leaved carpet grass and cocksfoot.		
7.	(Wilding pine)/geothermal kānuka-exotic species shrubland (05.01.03) This type occurs in Crown Park. Scattered emergent maritime pine, radiata pine, and eucalyptus (to c.15 metres tall), are present above shrubland dominated by geothermal kānuka that contain patches of exotic species including blackberry, broom, and Japanese honeysuckle. There are also patches of bracken and occasional ornamental cherry, <i>Cotoneaster franchetii</i> , Chinese privet, and pampas present.	Flat and undulating plateau, gully	<0.1 ha
8.	Burnt geothermal kānuka shrubland (05.01.09) A fire burnt through part of the Broadlands Road part of this site in late 2015 and had an adverse effect on a large area of geothermal kānuka vegetation and habitat (Wildland Consultants 2016c). However, the geothermal kānuka appears to be recovering slowly, with abundant small saplings present in 2020. The area is predominantly bare ground with a low cover of pest plant species including broad-leaved fleabane.	Flat and undulating plateau, gully	c.6.1 ha
9.	Mingimingi dominant shrubland (05.02) Mingimingi-geothermal kānuka-monoao shrubland (05.02.02) This type occurs in Crown Park. This area contains shrubland (to c.3 metres tall; average c.1 metre tall) with a variable canopy of mingimingi, geothermal kānuka and scattered monoao. Part of this area was burnt during a fire which occurred sometime between 2012 and 2013. There are patches of bare ground and mossfield, bracken, narrow-leaved carpet grass and browntop on some of the informal tracks. There are also occasional broom, pampas, tūrutu, and scattered banksia seedlings present.	Plateau	<0.1 ha
10.	Mānuka dominant shrubland (05.04) Mānuka/bracken-blackberry shrubland (05.04.02) A large area dominated by exotic shrubs (broom and blackberry) with occasional emergent mānuka and maritime pine. Small areas of geothermal kānuka shrubland (too small to map) are also present. Bracken and kiokio are abundant throughout, and Mercer grass and Indian doab are dominant in open areas.	Flat and undulating plateau, gully	c.0.6 ha
11.	Exotic shrubland (05.09) Blackberry-broom/Yorkshire fog shrubland (05.09.03) This type is dominated by blackberry, broom, Himalayan honeysuckle, and Yorkshire fog along a narrow strip on a valley floor. Scattered geothermal kānuka are present. Small	Gully	c.0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	wetland areas are present that are dominated by <i>Carex virgata</i> and <i>Machaerina rubiginosa</i> . These areas of wetland are surrounded by Yorkshire fog.		
12.	Indigenous fernland (07.01) Bracken fernland (07.01.19) This type occurs in Crown Park and contains local areas of fernland dominated by bracken, with a few local patches of browntop and occasional geothermal kānuka.	Gully sides	<0.1 ha
13.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Heated and steaming ground, mud pools, explosion craters, and fumaroles. Small patches of geothermal kānuka and exotic grasses occur on the margins. There are local patches of moss (<i>Campylopus</i> sp.) on the hotter areas of the crater walls, often associated with <i>Lycopodiella cernua</i> . A few patches of narrow-leaved carpet grass occur on the floor of the crater along with scattered sheep's sorrel, narrow-leaved plantain, and browntop. There is occasional broom in Crown Road. No sinter was observed in the site.	Plateau	c.6.8 ha
14.	Water (22.01) Geothermal water (22.01.01) Geothermal pond.	Explosion crater	<0.1 ha

Indigenous Flora:

The site supports one of the largest (although disjunct) areas of geothermal kānuka (Threatened-Nationally Endangered) scrub and shrubland. The largest contiguous stand within this site occurs in Broadlands Road (c.25 hectares). The area of geothermal kānuka scrub and shrubland that was burnt in 2002 (c.1 hectares) to the west of State Highway 1 in the Crown Road part of the site has recovered well. The western end of the Broadlands Road site (c.8 hectares) was burnt in late 2015, and is slowly recovering.

Dicranopteris linearis (1-2 plants) (Threatened-Nationally Endangered) and *Psilotum nudum* have previously been recorded from the southeast corner of the Crown Road part of the site, but have not been observed for over ten years.

Other plant species that are typical of geothermal habitats are present including *Lycopodiella cernua* and mingimingi, and a range of mosses, liverworts, and lichens such as *Campylopus* sp., *Chiloscyphus semiteres*, and *Cladia retipora*.

Fauna:

Indigenous bird species recorded at the site include pūtangitangi/paradise shelduck, kāhu/swamp harrier, karoro/black-backed gull, spur-winged plover, pīhoihoi/New Zealand pipit (At Risk-Declining), tūi, korimako/bellbird, riroriro/grey warbler, pīwakawaka/North Island fantail. Introduced species present include Eurasian blackbird, Eurasian skylark, house sparrow, yellowhammer, European greenfinch, and Australian magpie.

Rabbits and brown hares were present in the Crown Road part of the site in 2020.

**Geothermal
Ecosystems:**

Heated ground (dry), hydrothermally altered ground (now cool), fumaroles, geothermal streamsides.

Current Condition:

Crown Road part: Between 2007 and 2014, vegetation clearance associated with residential development, highway construction, and motocross track construction was undertaken within three parts of the site. The State Highway 1 bypass around Taupō was constructed through the middle of this site, resulting in destruction of some geothermal vegetation. Other areas of vegetation were destroyed as part of the Ashwood Park retail development to the south of the site (refer to site map).

The site includes more than 20 separate areas of geothermal kānuka scrub and shrubland, with the development and use of a motocross track having caused considerable fragmentation within the site.

Broadlands Road part: Two small areas have been cleared of vegetation within this site. In the western part of the site, adjacent to the Tauhara Golf Course, a small area has been cleared of vegetation and appears to be utilised for the storage of logs (Google maps 2014). A small area in the southern part of the site associated with a commercial property, has also been cleared of vegetation (Google maps 2014). The State Highway 1 bypass around Taupō was constructed adjacent to the site, however no geothermal vegetation or habitat was lost at this part of the site as a result of this development.

A fire burnt through part of this site in late 2015 and had an adverse effect on a large area of geothermal kānuka vegetation and habitat (Wildland Consultants 2016c). In 2017, the geothermal kānuka appeared to be recovering slowly with abundant small seedlings present (Wildland Consultants 2017a).

This site contains a relatively large area of geothermal kānuka shrubland and scrub. Whilst adventive species are common here, the areas of geothermal kānuka are relatively free of invasive pest plants, except for wilding maritime pines and occasional blackberry on the margins.

The geothermal character of the site is in decline, with many features appearing less active in the 2022 site visit than in 2014, and the vegetation growing taller.

Crown Park part: The site condition has improved since 2014. Pest plants are scattered amongst the geothermal kānuka. Between 2012 and 2013, a fire burnt c.30% of the geothermal kānuka shrubland and scrub within the site. In areas that were subject to fire, most of the *Lycopodiella cernua* was completely dead by 2017, but had recovered or re-established by 2020. Little evidence of the fire remained in 2020. Geothermal kānuka, bracken, and mingimingi have re-established on the burnt soils since 2013. Occasional maritime pine saplings (more than 1 metre tall) survived the fire, but most of these have been controlled since 2013. Maritime pine saplings that remained in 2020 were generally less than one metre tall. Some restoration works have been undertaken since 2006, including the

removal of pines above the valley wall scarps. Rubbish is common within the site, and walking tracks dissect the areas of geothermal kānuka.

Threats/Modification/ Vulnerability:

Invasive pest plants:

Crown Road part: The most abundant pest plants at the site are broom and blackberry, which occur both as scattered shrubs and dense scrub, and cover 1-5% of the site. Other adventive species present include Chinese privet (<1% cover), wilding maritime and radiata pines (<1% cover), buddleia (<1% cover), Montpellier broom (<1% cover), and silver birch (<1% cover). This site is vulnerable to further weed invasion because of continual disturbance, particularly in the southwestern part of the site (motocross track and neighbouring industrial area). Control of broom and wilding pines in areas adjoining State Highway 1 has previously been carried out by the Waikato Regional Council, particularly within areas of geothermal kānuka scrub and shrubland.

Broadlands Road part: Invasive pest plant species at the site include blackberry (25-50% cover), wilding pines (including radiata and maritime pine, 5-25% cover), occasional gorse (1-5% cover), broom (5-25% cover), poplars (<1%), grey willow (<1%), silver birch (<1% cover) and strawberry tree (1-5% cover) (one strawberry tree was recorded in 2007, but it was becoming more abundant in the area near the Golf Course in 2017). A few male fern (*Dryopteris affinis*) were recorded at the Broadlands Road site in 2022.

Crown Park part: The most abundant pest plants at the site are broom and blackberry, which occur both as scattered shrubs and dense scrub, and cover 1-5% of the site. Other adventive species present include Chinese privet (<1% cover), wilding maritime and radiata pines (<1% cover), buddleia (<1% cover), Montpellier broom (<1% cover), silver birch (<1% cover), montbretia (<1%), male fern (<1%), Cretan brake (<1%), and lupin (<1%). This site is vulnerable to further weed invasion because of continual disturbance, particularly in the southwestern part of the site (motocross track and neighbouring industrial area). Control of broom and wilding pines in areas adjoining the state highway has previously been carried out by the Waikato Regional Council, particularly within areas of geothermal kānuka scrub and shrubland.

Human impacts:

Crown Road part: The site has been bisected by the State Highway 1 bypass around Taupō and is vulnerable to further degradation by farming, motorcycles, and further development for industrial use. A fire in the southwestern part of the site in March 2002 greatly reduced the cover of geothermal kānuka scrub; however in 2020 this vegetation type appears to be recovering and the evidence of the fire is minimal. Geothermal prospecting and field development for energy use have the potential to impact surface geothermal features and their character. Changes in the geothermal vegetation and habitats due to energy extraction should be monitored. Over the last 20 years there has been incremental loss of small areas of geothermal habitat at this site, in addition to the loss as a result of the bypass construction.

Broadlands Road part: A small area in the western part of the site has been cleared of vegetation. The State Highway 1 bypass around Taupō

was constructed over part of the site. Although no geothermal vegetation or habitats have been affected by the construction of this highway, the construction has made part of the site more accessible to people. This may increase the likelihood of dumping of litter, the creation of informal tracks, weed invasion, and vegetation trampling at this site. The site is still vulnerable to further degradation from farming activities and golf course expansion. A fire burned near the site on 7 June 2007 and a larger fire occurred at the site in late 2015. In both situations, the geothermal kānuka has slowly recovered without intervention. Over the last ten years there has been incremental loss of small areas of geothermal habitat at this site.

Crown Park part: Little evidence of the fire that was reported on in Wildland Consultants (2014a) remains in 2020. Geothermal kānuka, bracken, and mingimingi have re-established on the burnt soils since 2013. The site has been modified through rubbish dumping, and informal tracks created by people wandering through the geothermal area. Informal tracks are causing notable erosion on banks and steep gully faces. This part of the site is surrounded by a recreational park. Between 2006 and 2014, a small area of geothermal kānuka scrub that was present next to the BMX track was cleared for construction of a building associated with the BMX track.

Grazing and other pest animals:

The eastern part of the site (Crown Road) is farmed and has not been fenced to exclude domestic stock. Scattered areas on the margins and southern end of the Broadlands Road part of the site are also farmed, predominantly with sheep, and an equestrian area is present. The remaining areas are not farmed.

Feral cats, rabbits and brown hares were observed at this site in 2020.

Adjoining land use:

Farmland, motocross track, State Highway 1, industrial area, golf course, and parkland.

Site Change:

Recent change:

Crown Road part: In areas of the western side of the site which were fenced to exclude domestic stock in 2014, the extent and cover of geothermal vegetation has increased slightly. The cover of pest plants in areas of geothermal kānuka scrub and shrubland that adjoin State Highway 1 has reduced slightly following pest control conducted by the Waikato Regional Council since about 2014.

Approximately 1.9 hectares of geothermal vegetation was lost between 2004 and 2014. This loss was due, in part, to roading development, residential subdivision, expansion of the motocross track and construction of an industrial subdivision. Geothermal kānuka shrubland has recovered since a fire in 2002. There has been a small amount of incremental loss due to industrial development since 2014.

Broadlands Road part: A small area in the western part of the site has been cleared of vegetation. There has been some small areas of loss near industrial developments in the southern part of the site, as well as alongside the golf course. Considerable invasion of wilding pines and strawberry trees has occurred within the area near the golf course. The biggest change was due to a large fire that occurred at the site in 2015.

However, it is anticipated that this area will recover naturally. Some pest plant control (e.g. wilding pine control) has been undertaken by the Department of Conservation, however further pest plant management is required. Other changes to the site map are a result of better quality aerial photographs. The new State Highway 1 bypass around Taupō now dissects the site.

Crown Park part: Some control of woody pest plant species has been undertaken since 2014, although some pest plant infestations are still present. Geothermal kānuka and *Lycopodiella cernua* have recovered since the fire which occurred sometime between 2012 and 2013. Geothermal kānuka has increased in height significantly since 2006. The extent of geothermally-influenced bare ground has decreased since 2014. Based on observations of steaming ground and vegetation patterns, there appears to have been a decrease in geothermal activity at this site since 2014. Some restoration planting of indigenous species has been undertaken on the non-geothermal margins of the site since 2014.

*Historical:*¹

Crown Road part: Photographs from 1946 indicate that there was more bare ground at that time than is currently present. Burns *et al.* (1995), following a study of aerial photographs taken in 1963, indicates that this site has declined in size due to the establishment of a motocross track and encroachment of adjacent industrial land uses. Geothermal activity at this site probably increased briefly following the Wairākei Power Station development, and then steadily declined in intensity (Bromley *et al.* 2010).

Broadlands Road part: In 1946 there was bare ground in the vicinity of the site. Burns *et al.* (1995) noted that the 1938 and 1963 photographs showed that “no” and “little” geothermal shrubland was present, although two bare sinter areas with pools suggest some geothermal activity. Urban, road, and farming development have all reduced the size of this site. Two hydrothermal eruption craters formed in 1974 and 1981 (Bromley *et al.* 2010).

Crown Park part: The 1946 aerial photographs were at a too small scale and resolution to identify any evidence of change when comparing the 1946 aerial photographs with the 2007 digital aerals. However Burns *et al.* (1995) found that the 1963 aerial photographs showed a 10-20% loss of the gully area due to infilling.

Management Requirements:

Crown Road part: Development and implementation of a restoration and management plan for this site should be considered to ensure no further loss of geothermal habitat occurs and that effective control of pest plants is undertaken. Large parts of the site contain good examples of geothermal kānuka shrubland and associated areas of hydrothermally altered ground (now cool), and geothermally heated dry ground. The restoration plan should consider management of the transition zone between geothermally-influenced and non-geothermally-influenced soils. Broom, wilding pines, and blackberry should be controlled. Changes in vegetation cover associated with draw-off from the geothermal system should be

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

monitored. The parts of the site that are currently grazed should be fenced, and existing fencing should be checked regularly.

Broadlands Road part: Wilding pines and other pest plants (e.g. strawberry tree, silver birch and grey willow) should continue to be monitored and removed from areas where geothermal kānuka is dominant. Changes in vegetation associated with draw-off from the geothermal system should be monitored.

Crown Park part: Ongoing monitoring and control of pest plants should be undertaken, particularly control of wilding pines, banksia, strawberry tree, male fern, broom, silver birch, blackberry, and any naturalised seedlings of *Leptospermum grandifolium* that establish. Changes in vegetation cover associated with draw-off from the geothermal system should be monitored.

Significance Level: R: Regional (Criteria 3, 5, 7, 9).
L: Local (Criterion 5)

Significance Justification R: The majority of this site is of regional significance because it comprises a relatively large example of geothermal habitat, which includes ecosystems that were nationally uncommon prior to human settlement (heated ground (dry), hydrothermally altered ground (now cool), geothermal streamsides, fumaroles; Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013). It contains a large area of vegetation dominated by geothermal kānuka (Threatened-Nationally Endangered).

L: Remaining areas are locally significant because they contain small lower quality and isolated areas of geothermal vegetation and habitat amongst farmland and other developed land including heated ground, a naturally uncommon habitat type (Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013).

Notes: In 2014, the Crown Road and Broadlands Road parts of this site were classed as being of regional significance, and the Crown Park part was classed as being of local significance (Wildland Consultants 2014a).

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study the Crown Road and Broadlands Road parts of East Taupō were classed as Category B - the second highest category for protection.

References: Bromley *et al.* 2010; Burns *et al.* 1995; Burns 1996; Given 1989a, 1996; Grove *et al.* 1999; Wildland Consultants 2000, 2004b, 2007b, 2012, 2014a, 2016c, 2017a, 2019b, 2021a, 2021b.



East Taupō, Crown Road part of the site. A rift of geothermally-influenced bare ground that is surrounded by geothermal kānuka scrub and shrubland. NZTM E1871428 N5713052. 30 September 2020.



East Taupō, Crown Road part of the site. Panorama view from the above location. NZTM E1871428 N5713052. 30 September 2020.



East Taupō, eastern section of the Crown Road part of the site. NZTM E1870710 N5712551. 16 September 2020



Geothermal kānuka scrub and shrubland near Taupō Golf Club, Broadlands Road part of the East Taupō site. Note the invasion of young wilding pines. NZTM E1870127 N5714062. 10 April 2017.



Strawberry tree, maritime pine and radiata pine amongst geothermal kānuka scrub and shrubland near Taupō Golf Club, Broadlands Road part of the East Taupō site. NZTM E1870127 N5714062. 1 September 2020.



Data Acknowledgment
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 Service (WRAPS) 2021

Report: 22004
 Client: WRC
 Ref: 21-1108
 Path: E:\gird\Geothermal Sites 2003-2022\road figures\
 File: Hall of Fame Stream.mxd

Hall of Fame Stream

0 50 100 m

Wildlands
 www.wildlands.co.nz, 0800 WILD42

Scale: 1:2,500
 Date: 19/03/2023
 Cartographer: FM
 Format: A4

HALL OF FAME STREAM

Ecological District: Atiamuri **GPS Reference:** NZTM E1868965 N5718516
Geothermal System: Wairākei-Tauhara **Altitude:** c.360 m
Geothermal System: Wairākei
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.0.3 ha
Extent of Geothermal Vegetation: c.0.2 ha
Date of Most Recent Field Survey: 29 January 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic species-dominant scrub (04.10) Blackberry scrub (04.10.01) Scrub dominated by blackberry, Himalayan honeysuckle, radiata pine and scattered pampas with local emergent whekī is located on the margins of a stream within a steep-sided gully in which there are several hot springs. Māhoe, <i>Deparia petersenii</i> subsp. <i>congrua</i> , and <i>Paku pennigera</i> are locally common. There is occasional Chinese privet, kōtukutuku, <i>Carex geminata</i> , kiokio, and bracken. Local areas dominated by māhoe and kiokio are present in the mid-reaches of this type. Chinese privet is common near the confluence with the Waikato River. Water temperatures within the stream in 2014 ranged from c.23-27 °C. Steam was visible at the western end of the site.	Gully	c.0.2 ha
2.	Chinese privet scrub (04.10.03) Chinese privet scrub with scattered blackberry and karamū forms a dense canopy, c.2 metres tall. Ten clumps of <i>Christella</i> aff. <i>dentata</i> (“thermal”) plants were counted in this type, though more are likely to be present as it is difficult to access along the river margin.	Riparian margin	<0.1 ha
3.	Indigenous fernland (07.01) Mixed fernland (07.01.07) A warm seepage (c.28.2 °C in 2014) surrounded by bare ground is recessed into the base of a cliff. On the cliff face above the seepage, scattered ferns are present, predominantly korokio and kiokio, with occasional whekī and <i>Adiantum cunninghamii</i> . The ground south of the spring is mostly bare, but supports scattered woody species including makomako, blackberry, and rangiora. <i>Urtica sykesii</i> and wall lettuce are also present. The <i>Christella</i> aff. <i>dentata</i> (“thermal”) was observed in this location in 2004 but was not seen in 2014 or 2022.	Steep hillslope	<0.1 ha
4.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Warm sandy sediments on river margin.	River margin	<0.1 ha
5.	Water (22.01) Geothermal water (22.01.01) A geothermal spring on the margin of the Waikato River. <i>Glossostigma elantinioides</i> is common, submerged in the water around the spring. Water temperature at the spring was c.74.9 °C in 2014.	River margin	c.0.1 ha

Indigenous Flora:	A small population of <i>Christella</i> aff. <i>dentata</i> (“thermal”) (Threatened-Nationally Endangered) is present around a series of hot springs on the margins of the Waikato River, south of the confluence of Hall of Fame Stream and the Waikato River.
Geothermal Ecosystems:	Geothermal streamsides
Fauna:	Common indigenous and introduced bird species typical of the habitat are present.
Current Condition:	Most of the site is dominated by blackberry and radiata pine. Some pine control work has been undertaken. Parts of the site alongside the track within the gully have been cleared of exotic vegetation.
Threats/Modification/Vulnerability:	
<i>Invasive pest plants:</i>	Exotic pest plant species are common to dominant within this site. Blackberry is abundant (50% cover). Other pest plant species present include Chinese privet (20% cover), Himalayan honeysuckle (2% cover), and broom (<1% cover).
<i>Human impacts:</i>	A track is present within the gully. Track maintenance has not adversely affected geothermal vegetation or features within the site.
<i>Grazing :</i>	Livestock are not a threat to this area.
<i>Adjoining land use:</i>	Previously Scenic Reserve administered by Department of Conservation, now administered by iwi. A walking track passes through the site.
Site Change:	
<i>Recent change:</i>	Little change has been observed at this site since 2014.
<i>Historical:</i> ¹	This site is too small to identify any evidence of change since 1941 ² .
Management Requirements:	Control of Chinese privet should be considered near the hot springs on the margin of the Waikato River.
Significance Level:	Regional (Criteria 3, 5).
Significance Justification:	This site is of regional significance because it contains a small population of a Threatened plant taxon (<i>Christella</i> aff. <i>dentata</i> (“thermal”) and an ecosystem that was nationally uncommon prior to human settlement (geothermal streamsides; Williams <i>et al.</i> 2007; Holdaway <i>et al.</i> 2012; Wiser <i>et al.</i> 2013).

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 172 Run 1174 Photos 2, 3, 1941.

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category C - the third highest category.

Bromley *et al.* (2021) identified a new spring – the ETA Spring – located near the SH1 bridge at the Wairakei Power Station, along the banks of the Waikato River. This area has not yet been field visited to determine if any geothermal vegetation is associated with it.

References:

Bromley *et al.* 2021; Given 1989a, 1996; Merrett and Burns 1998a, 1998b; Wildland Consultants 2004b, 2012, 2014a.



Geothermal springs on the edge of the Waikato River at the Hall of Fame Stream site. The springs occur underneath a band of grey willow and Chinese privet.

Scattered *Christella* aff. *dentata* “thermal” are present along river margins.

29 January 2022. NZTM E1869076 N5718499.



Christella aff. *dentata* “thermal” alongside the Waikato River. Hall of Fame Stream. NZTM E1869073 N5718502. 29 March 2022.



LOWER SECTIONS: TE KIRI O HINEKAI STREAM AND WAIRĀKEI STREAM

Ecological District: Atiamuri **GPS Reference:** NZTM E1869566 N5720255
Geothermal System: Wairākei-Tauhara **Altitude:** c.340-395 m
Geothermal System: Wairākei
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.3.0 ha
Extent of Geothermal Vegetation: c.2.6 ha
Date of Most Recent Field Survey: 29 September 2020, 5 October 2022

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic vineland (03.01) Japanese honeysuckle-(<i>Cyperus ustulatus</i>) vineland (03.01.03) The stream margins (true right) in the northwest of the Lower Wairākei Stream site comprise Japanese honeysuckle vineland with locally common <i>Cyperus ustulatus</i> , and local Montpellier broom, gorse, montbretia, blackberry, and buddleia. Occasional <i>Christella</i> aff. <i>dentata</i> ("thermal") (three clumps observed) are present between the outlet of geothermal water into the Wairākei Stream and where the stream enters a culvert. Clearance of weeds has recently been undertaken on stream margins.	Stream margins	<0.1 ha
2.	Mixed indigenous and exotic shrubland (05.08) Mixed indigenous and exotic shrubland (05.08.08) The lower section of the Te Kiri o Hinekai Stream site is a geothermal stream with quite variable vegetation composition throughout (too variable to map at the scale of this study). There are local areas of sinter, and mown exotic grassland close to the stream edge. Areas of indigenous and exotic plantings occur throughout. Parts of the site downstream of the Wairākei Resort are amongst exotic plantation forest that contains a network of mountain bike tracks. Also present alongside the stream is mixed exotic scrub comprising Chinese privet, common alder, maritime pine, silver birch, Tasmanian blackwood, areas of pampas tussockland, ivy vineland, Japanese honeysuckle vineland, blackberry vineland, bracken fernland, and montbretia herbfield. Immediately above the bridge near the BP Service Station, there is a small infestation of the pest plant, Asiatic knotweed. Mixed broadleaved species forest dominated by kāmahī and whekī, with abundant mamaku, kōhūhū, makomako, whauwhaupaku, and patē with a few radiata pine and Tasmanian blackwood occurs on the lower section of this stream but above the Wairākei Power Station infrastructure. Small populations of <i>Christella</i> aff. <i>dentata</i> ("thermal") and <i>Hypolepis dicksonioides</i> and local geothermal kānuka shrubs occur on stream margins.	Geothermal streamsides	c.2.1 ha
3.	Pampas tussockland (06.01) Common alder/pampas tussockland (06.01.02) This vegetation type occurs on a low, salicaceous terrace alongside the stream. Common alder form a discontinuous canopy to eight metres tall (having less than 80% cover). There is also pampas and bare ground. The common alder are less than 10 cm diameter, and decrease in diameter from the upstream to	Riparian margins	c.0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	downstream ends of this vegetation type, suggesting vegetative spread by suckering.		
4.	Exotic grassland (08.01) Mixed exotic grassland (08.01.15) <i>Lower Wairākei Stream area: Cocksfoot-montbretia grassland</i> Rank exotic grassland dominated by cocksfoot, intermixed with paspalum and sweet vernal, abundant narrow-leaved plantain, and common yarrow and blackberry occurs on the stream margins (true left) in the northwest of the site. Montbretia, fennel, lotus, and cocksfoot are also locally common. <i>Lower Te Kiri o Hinekai Stream area: Mown grass with Agapanthus plantings grassland.</i> Mown lawn with beds of ornamental plantings of agapanthus alongside a concrete lined culvert. Overhead cover is provided by vegetation rooted outside of the stream channel, including Lawson's cypress, and vegetation rooted within the channel, including tutu. A few <i>Christella</i> aff. <i>dentata</i> ("thermal") and <i>Anogramma leptophylla</i> occur on the banks above the culvert.	Stream margins	<0.1 ha
5.	Indigenous sedgeland (09.01) Mixed indigenous sedgeland (09.01.14) <i>Carex secta-Cyperus ustulatus-pampas sedgeland</i> <i>Carex secta</i> and <i>Cyperus ustulatus</i> form a near continuous low cover in a shallow depression. On drier sites around the edge of the depression the vegetation is taller in stature, with pampas, scattered individual shrubs of grey willow, karamū, and two ferns bracken and <i>Histiopteris incisa</i>.	Wetland	<0.1 ha
6.	Loamfield (20.01) Geothermally influenced bare ground (20.01.01) A geothermal terrace with brine released to form an induced geyser and terrace system.	Terrace (artificial)	c.0.2 ha
7.	Water (22.01) Geothermal water (22.01.01) Geothermal stream with a surface water temperature of 32.8 °C at one location. The surface water temperature at an outflow into the stream at E1869871 N5720120 measured 78.2 °C in 2014.	Stream	c.0.4 ha

Indigenous Flora:

Te Kiri o Hinekai Stream: The site supports the second largest known populations of *Christella* aff. *dentata* ("thermal") (Threatened-Nationally Endangered) and *Hypolepis dicksonioides* (At Risk-Naturally Uncommon) of any of the geothermal sites in the Wairākei-Tauhara Geothermal System. Scattered small shrubs of geothermal kānuka (Threatened-Nationally Endangered) occurs at a few locations alongside stream margins. Other indigenous species present that are typical of geothermal habitats include *Cyperus ustulatus*, *Hypolepis ambigua*, tūrutu, and bracken.

A recent survey found a population of *Anogramma leptophylla* (Threatened-Nationally Vulnerable). This population may be maintained by periodic

disturbance associated with silica excavation from the channel bed. This is the first population known from the central North Island.

Lower Wairākei Stream: Three clumps of *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) were recorded in 2020. This compares with six clumps which were recorded in 2014, 47 clumps which were recorded in 2007 (Wildland Consultants 2012 and 2014), and seven clumps which were recorded in 1998 (Merrett and Burns 1999). Recent weed control along the stream margins has made the habitat less suitable for this species. However, the nearby population alongside the Lower Te Kiri o Hinekai Stream is a more viable population of this species. Two plants of *Hypolepis dicksonioides* (At Risk-Naturally Uncommon) were recorded from the true left stream bank in 2014. *H. dicksonioides* had previously been recorded from this site (Merrett and Burns 1998b), but was not recorded in 2007 or 2020.

Fauna: Indigenous bird species recorded at this site include: pīpīwharau/roa/shining cuckoo (in 2014) pōpokotea/whitehead, tūi, riroriro/grey warbler, pīwakawaka/North Island fantail, and korimako/bellbird. Introduced bird species recorded at this site include: mallard, common pheasant, California quail, chaffinch, Eurasian blackbird, and common starling.

Geothermal Ecosystems: Geothermal streamsides.

Current Condition: The margins of Te Kiri o Hinekai Stream are greatly modified due to both the source of the stream water supply, some of which is overflowing from the Wairākei Terraces Resort. The site is nonetheless a natural geothermal stream which probably had greater flows in the past. The margins are very weedy, but the site supports some of the best populations of two species of Threatened or At Risk ferns near Taupō Township.

The lower section of Wairākei Stream is in poor condition and pest plants are common. However, the site provides habitat for plant species of conservation concern and comprises geothermal habitat.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: **Te Kiri o Hinekai Stream:** Wilding pines (*c.*5% cover, including radiata pine and maritime pine) and a wide selection of pest plants present on stream margins threaten geothermal vegetation at this site. Other adventive species present include blackberry (5% cover), pampas (<5% cover), Chinese privet (5% cover), montbretia (1% cover), silver birch (1% cover), periwinkle (1% cover), Himalayan honeysuckle (<1% cover), Montpellier broom (<1% cover), broom (1% cover), lupin (<1% cover), Spanish heath (1% cover), kikuyu grass (1% cover), and narrow-leaved carpet grass (1% cover).

Lower Wairākei Stream: Japanese honeysuckle (35% cover), blackberry (15% cover), montbretia (10% cover), Montpellier broom (5% cover), radiata pine (1% cover), gorse (1% cover), ivy (1% cover), grape (1% cover), Spanish heath (<1% cover), buddleia (<1% cover), lupin (<1% cover), Tasmanian blackwood (<1% cover), pampas (1% cover), purple linaria (<1% cover), and tree lucerne (<1% cover) are present.

<i>Human impacts:</i>	Te Kiri o Hinekai Stream: Access tracks, vehicle tracks, logging, mountain bike tracks, tourist facilities, and geothermal extraction infrastructure all occur along the boundaries of this site. Mountain bike trails traverse through one of the southern areas of this site. Lower Wairākei Steam: Modified as part of the ongoing management of the Wairākei Power Station. Some recent weed control may have been detrimental to fern populations.
<i>Grazing and pest animals:</i>	Domestic livestock are not a threat to this site. No pest animal sign was recorded during the 2020 survey, but the usual suite of pest animal species known to occur in the central North Island are likely to be present.
<i>Adjoining land use:</i>	Pine plantation, geothermal energy extraction infrastructure, farmland.
Site Change:	
<i>Recent change:</i>	Te Kiri o Hinekai Stream has not been surveyed prior to 2020, so there is little information on its previous condition. Pest plants have increased in abundance alongside the stream over time. The current extent of geothermal vegetation alongside Wairākei Stream is similar to that recorded in 2014, although the size of the fern populations have declined, partly as a result of the spread of pest plants, as well as clearing of vegetation alongside stream margins. The gorse shrubland that was present in the southeastern part of the site in 2007 appears to have been sprayed. This area has been fenced and comprises mixed exotic grassland. The two clumps of <i>Christella</i> aff. <i>dentata</i> (“thermal”) that were present in this area in 2007 were not observed in 2014 and there has been a significant reduction in the number of <i>Christella</i> clumps in the northwestern section of the site (from 47 clumps in 2007, six in 2014, and three in 2020). Japanese honeysuckle has increased in cover in the northwestern part of the site and now smothers the blackberry shrubland on the true right side of the stream. Clearance of weeds has recently been undertaken on the immediate stream margins.
<i>Historical:</i> ¹	Te Kiri o Hinekai Stream: Not assessed, not surveyed prior to this 2020 study. Lower Wairākei Steam: This part of the site is too small to see any evidence of change since 1941². However, changes are likely to have been significant as a result of the construction of the nearby Wairākei Power Station. The stream has been channelised, which will have altered the extent of geothermal vegetation. It is likely that draw-down of geothermal water for power generation will have changed the vegetation composition of the site through water table and temperature changes.
Significance Level:	Regional (Criterion 3, 5).

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photo: SN 172 Run 1173 Photo 3, 1941.

**Significance
Justification:**

This site is ranked as being of regional significance because it contains a moderate-sized population of one Threatened and one At Risk plant species - *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) and *Hypolepis dicksonioides* (At Risk-Naturally Uncommon). It also contains an isolated population of a threatened fern: *Anogramma leptophylla* (Threatened – Nationally Vulnerable). It also contains a relatively large area of geothermal streamside habitat (an ecosystem that was nationally uncommon prior to human settlement; Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013).

**Management
Requirements:**

Te Kiri o Hinekai Stream: A weed management plan with a focus on protection and enhancement of the populations of ferns alongside the stream margins would help to enhance the ecological values of this site. Pest plant species that could be controlled include pampas, wilding conifers, buddleia, tradescantia, periwinkle, silver birch, Chinese privet, broom, ivy, Asiatic knotweed, and blackberry.

Lower Wairākei Stream: The population of *Christella* aff. *dentata* (“thermal”) should be monitored at regular intervals. It is threatened by dense infestations of exotic pest plants (e.g. blackberry and Japanese honeysuckle), and the ongoing maintenance of the stream margins as part of an operational industrial site (e.g. spraying of gorse). Management of weeds within areas that contain *Christella* should be undertaken in stages (i.e. not the entire stream length at once) to allow fern populations to recover.

Notes:

The Lower Wairākei Stream part of this site was classed as being of regional significance in 2014 (Wildland Consultants 2014a).

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and classed the Lower Wairākei Stream part of this site as Category B - the second highest category.

References:

Bycroft and Beadel 2007; Given 1989a & 1996; Merrett and Burns 1998a, 1998b, 1999; Wildland Consultants 2004b, 2007c, 2012, 2014a, 2021a, 2021b, 2022b.



Banks with abundant *Christella* aff. *dentata* ("thermal") near the BP Service Station, Lower Te Kiri o Hinekai Stream. Pest plants, including Japanese knotweed and montbretia, are also abundant. NZTM E1868937 N5720125. 29 September 2020.



A section of the lower Te Kiri o Hinekai Stream. The margins of the stream contain abundant pampas. NZTM E1869272 N5719885. 29 September 2020.



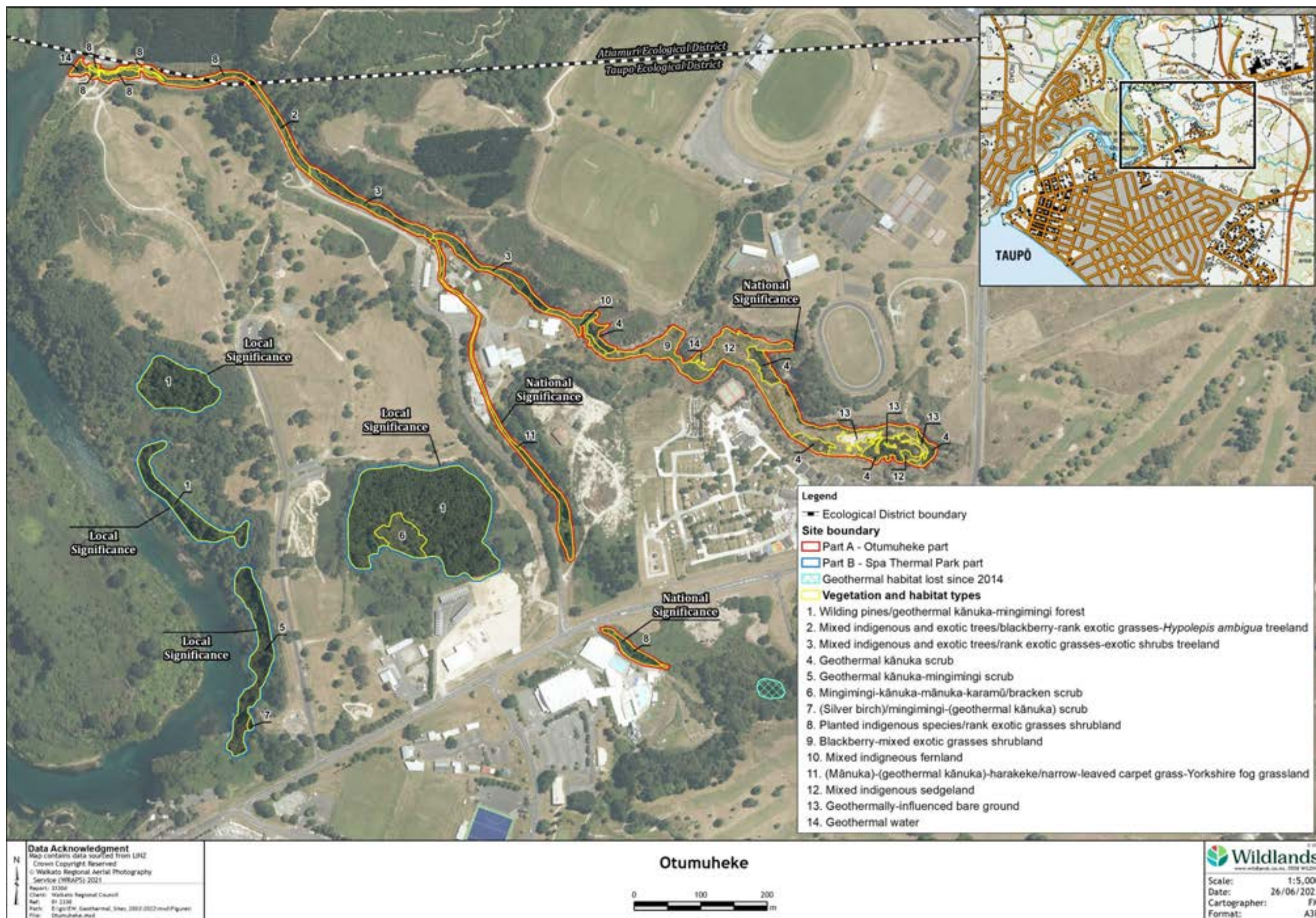
A patch of *Hypolepis dicksonioides* alongside margins of Lower Te Kiri o Hinekai Stream. NZTM E1869183 N5720099. 29 September 2020.



Eastern part of Lower Wairākei Stream, with cocksfoot-montbretia grassland on both margins. NZTM E1870031 N5720010. 29 September 2020.



A mature plant of the tiny annual fern *Anogramma leptophylla*, growing adjacent to the digger access track alongside a channelised section of the lower Te Kiri o Hinekai Stream. Exact location is not given. 5 October 2022.



OTUMUHEKE¹

Ecological District: Atiamuri **GPS Reference:** NZTM E1869068 N5715075
Geothermal System: Wairākei-Tauhara **Altitude:** c.360-400 m
Geothermal System: Tauhara
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.8.6 ha
Extent of Geothermal Vegetation: c.8.5 ha
Date of Most Recent Field Survey: 1, 11, and 16 September 2020

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic forest (01.02) Wilding pines/geothermal kānuka-mingimingi forest (01.02.07) Scattered wilding pines (mostly radiata pine c.18 metres tall) are present above geothermal kānuka and mingimingi (c.2-3 metres tall). Bracken is common in the understorey, and <i>Hypolepis ambigua</i> , tūrutu, and whekī are occasionally present. This vegetation type is located around historically active geothermal craters.	Flat and gully sides	c.3.9 ha
2.	Indigenous treeland (02.01) Mixed indigenous and exotic trees/blackberry-rank exotic grasses-Hypolepis ambigua treeland (02.01.03) Scattered trees of whekī and geothermal kānuka (c.5-6 metres tall) occur above <i>Hypolepis ambigua</i> fernland with patches of rank exotic grasses, such as Yorkshire fog, and occasional bracken. There are local whauwhaupaku and whekī-ponga present. There are a few karamū, local harakeke, and patches of water fern, and <i>Gleichenia microphylla</i> . Tradescantia and montbretia are locally abundant on the stream margins between the weir and the upstream bridge. A small population of <i>Christella</i> aff. <i>dentata</i> (“thermal”) occurs along the stream margins. Indigenous restoration plantings (including toetoe) are present on the upper slopes of the stream margin at both ends of this vegetation type.	Riparian margin	c.0.2 ha
3.	Geothermal kānuka-mixed exotic trees/Yorkshire fog-Hypolepis ambigua treeland (02.01.04) This type comprises scattered trees of geothermal kānuka above Yorkshire fog on the true left side of the stream and <i>Hypolepis ambigua</i> on the true right side of the stream. This vegetation type occurs alongside Otumuheke Stream in the middle of the site. Exotic tree species that are scattered on the true left side of the stream include feijoa, plum, and silver birch. Scattered whekī, whekī-ponga, kōhūhū, Lawson’s cypress, kahikatea (planted), karamū, and Japanese honeysuckle are also present. Blackberry, broom, <i>Carex virgata</i> , and <i>Cyperus ustulatus</i> are common alongside stream margins. <i>Cotoneaster franchetii</i> is scattered on banks above the true right side of the stream, and ornamental cherry are scattered on the true left of the side stream.	Riparian margin	c.0.5 ha

¹ The site Otumuheke amalgamates the sites Otumuheke Stream, Kathleen Springs, and Spa Thermal Park of Wildland Consultants (2014a).

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	A small population of <i>Christella</i> aff. <i>dentata</i> ("thermal") is present at the downstream end of this type, and the entire length of the stream margin within this type appears to provide suitable habitat for this species.		
4.	Geothermal kānuka scrub (04.01) Geothermal kānuka scrub (04.01.01) Small areas of geothermal kānuka scrub to c.3-7 metres tall. Tūrutu and hound's tongue fern are common in the understorey, along with patches of exotic grasses and <i>Microlaena stipoides</i>. The groundcover is a dense mossfield in places. On the lower slopes there are occasional emergent kōhūhū, and bracken occurs in the understorey in places. A few pampas, koromiko, and buddleia are also present.	Gully, slopes	c.0.6 ha
5.	Geothermal kānuka-mingimingi scrub (04.02) Geothermal kānuka-mingimingi scrub (04.02.01) Geothermal kānuka forms a scrub canopy, c.2-4 metres tall, with locally common mingimingi and occasional broom, bracken, and gorse. Several emergent radiata pine and silver birch occur within the scrub. A few <i>Lycopodiella cernua</i> are also present.	Steep slopes	c.0.7 ha
6.	Mingimingi dominant scrub (04.03) Wilding pine/mingimingi-blackberry-bracken-geothermal kānuka scrub (04.03.02) Sapling wilding maritime and radiata pines (to c.5 metres tall) are densely scattered around a historically active geothermal crater. Patches of mingimingi, blackberry, bracken, and geothermal kānuka, tūrutu and Himalayan honeysuckle occur throughout. There are occasional ornamental cherry and a few monoao, whauwhaupaku, Douglas fir, Tasmanian blackwood, and pampas. The vegetation within this area is recovering following a fire in 2012 and there is some treefall of larger wilding pines.	Crater margins and sides	c.0.3 ha
7.	(Silver birch)/mingimingi-geothermal kānuka scrub (04.03.06) Scattered emergent silver birch (to c.15 metres tall) is present over scrub dominated by mingimingi, with locally common geothermal kānuka (c.2 metres tall) and one eucalyptus tree (c.20 metres tall). Patches of English ivy and German ivy are present on the western margin of the type.	Steep slopes	<0.1 ha
8.	Mixed indigenous species shrubland (05.07) Planted indigenous species/rank exotic grasses shrubland (05.07.02) The area of this vegetation type that occurs in the lower Otumuheke Stream valley is quite variable. It comprises planted indigenous tree species above rank exotic grasses that include ripgut brome, cocksfoot, broad-leaved fleabane, and Yorkshire fog. Planted indigenous species which are dominant along sections of the stream margins are geothermal kānuka, tōtara, kōhūhū, harakeke, whekī-ponga, toetoe, kōwhai, and tarata. Other planted indigenous species present include koromiko, tānekaha, karamū, <i>Coproma dumosa</i>, kahikatea, and <i>Cyperus</i>	Riparian margin	c.0.4 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	<i>ustulatus</i>. Patches of blackberry and <i>Hypolepis ambigua</i> are also present. <i>Christella</i> aff. <i>dentata</i> (“thermal”) is common along most of the length of this section of the stream. A discharge of geothermal water occurs adjacent to the AC Baths complex. It discharges water into the channel, downstream of the former Kathleen Springs. This channel has an orange streambed and leads into the Otumuheke Stream. Indigenous restoration plantings occur along both sides of this channel, including akeake, toetoe, <i>Pittosporum colensoi</i>, ribbonwood, and karamū. There are also scattered <i>Cyperus ustulatus</i>, water fern, and patches of rank exotic grasses and herbs (including Yorkshire fog and narrow-leaved plantain) present.		
9.	Mixed indigenous and exotic species shrubland (05.09) Blackberry-bracken-broom-(geothermal kānuka) shrubland (05.09.07) Within this vegetation type, Otumuheke Stream flows through a flat valley floor that is covered with shrubland dominated by dense blackberry and scattered bracken and broom. There are occasional geothermal kānuka, and a few patches of exotic grasses, <i>Carex secta</i>, and raupō reedland also present. These areas of shrubland also contain Himalayan honeysuckle, and a few mānuka, koromiko, karamū, whekī, and whekī-ponga. <i>Christella</i> aff. <i>dentata</i> (“thermal”) is scattered along the stream margins with a few <i>Cyclosorus interruptus</i> also present. <i>Hypolepis dicksonioides</i> and <i>Lycopodiella cernua</i> were recorded within this vegetation type in 2020.	Valley	c.0.3 ha
10.	Indigenous fernland (07.01) Mixed indigenous fernland (07.01.07) <i>Hypolepis ambigua</i>-bracken fernland Dense fernland dominated by <i>Hypolepis ambigua</i> with scattered bracken and occasional blackberry occurs alongside this section of the stream. There are a few geothermal kānuka and whekī (to c.3 metres tall), and a few patches of water fern and Yorkshire fog.	Valley, stream margin	c.0.1 ha
11.	Exotic grassland (08.01) (Mānuka)-(geothermal kānuka)-harakeke/narrow-leaved carpet grass-Yorkshire fog grassland (08.01.06) Within the grounds of the Spa Hotel, the stream margins comprise exotic grassland dominated by narrow-leaved carpet grass and Yorkshire fog, which, in places, are mown to the stream edge. In places, the stream has been confined to a channel of concrete rock walls and culverts. There are a few clumps of <i>Christella</i> aff. <i>dentata</i> (“thermal”) on the stream margins. Scattered shrubs that are present on the stream margins include mānuka, geothermal kānuka, and whekī-ponga; some of which have been planted. Planted harakeke is also common. Other species present include tūrutu, water fern, and <i>Cyperus eragrostis</i>. Dense blackberry which dominated this area in 2004, has been cleared.	Stream margin	c.0.4 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	In the southern area of this vegetation type, there are scattered exotic trees including tree lucerne, Tasmanian blackwood, ornamental cherry, and silver birch. There are also patches of tradescantia and veldt grass, a few mamaku and tī kōuka, and local Cretan brake, buddleia, and agapanthus. Historically, this section of the stream was fed by Kathleen Springs and surrounding geothermal springs. In 2020, stream temperatures measured ranged from 28 °C to 34 °C. Hot seepages are present in the stream.		
12.	Indigenous sedgeland (09.01) Mixed indigenous sedgeland (09.01.14) <i>Carex virgata</i>-<i>Cyperus ustulatus</i>-mānuka/bare ground sedgeland This area in the eastern end of the Otumuheke Stream valley comprises bare ground and widespread patches of sedgeland dominated by <i>Carex virgata</i> and <i>Cyperus ustulatus</i>. The bare ground includes areas of cooled sinter and associated sediments. There are local patches of mānuka shrubland present. A patch of raupō reedland occurs at the western end of this vegetation type and extends eastwards in a narrow band along about two-thirds of the area. There is occasional bracken and karamū, scattered swamp kiokio, and a few whekī-ponga, and <i>Machaerina rubiginosa</i>. Exotic grasses, including pampas, are scattered in places. Blackberry is sparsely scattered throughout. Most of the <i>Cyclosorus interruptus</i> population known to occur at the Otumuheke site previously occurred within this area, with approximately 200-300 plants present in 2010. However, in 2020 most of the <i>Cyclosorus interruptus</i> plants appeared to be dead. This may be due to a reduction in geothermal activity at the site. Soil temperatures of 18 °C were recorded next to one of the dead <i>Cyclosorus interruptus</i> plants in 2020. A geothermal spring is present at E1869378 N5714946. In 2020, a temperature reading of 70.9 °C was taken from this spring. A few <i>Cyclosorus interruptus</i> occurred within 15 metres of this spring in 2020. Most of the naturally occurring geothermal kānuka within the Otumuheke site also occurs within this area. <i>Lycopodiella cernua</i> was common within this part of the site in 2010, but was not observed in 2020.	Valley floor	c.1.1 ha
13.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Bare geothermal soils occur on a cliff near the Waikato River. Occasional geothermal kānuka and mingimingi saplings are present in parts of this area.	Steep slopes	c.0.1 ha
14.	Geothermal water and mudpools (22.01) Geothermal water (22.01.01) At the mouth of Otumuheke Stream, geothermal water flows under a bridge and over a series of rocky pools and waterfalls	Stream	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	before joining the Waikato River. The rocky pools are surrounded by patches of bare ground, exotic grasses (including Yorkshire fog and cocksfoot), toetoe, tūrutu, whekī, and a few planted kōhūhū and koromiko. Boulders have recently been placed on some of the slopes surrounding the areas that are used for bathing, to reduce erosion.		

Indigenous Flora:

Populations of four ‘Threatened’ or ‘At Risk’ indigenous plant species are present within the site: *Cyclosorus interruptus* (At Risk-Declining), *Hypolepis dicksonioides* (At Risk-Naturally Uncommon), *Christella* aff. *dentata* (“thermal”), and geothermal kānuka (both Threatened-Nationally Endangered).

In 2020 there were an estimated 75-100 clumps of *Christella* aff. *dentata* (“thermal”) at the site, the majority of which occur in the western half of the site. These clumps vary in size from a few centimetres to c.0.75 metres in length. Large parts of the stream cannot easily be viewed in the lower section due to the high temperatures of the stream and dense blackberry on the stream margins, so this number is likely to be a conservative estimate.

Cyclosorus interruptus was previously abundant in the eastern part of the site in Vegetation Type 12 (*Carex virgata*-*Cyperus ustulatus*-mānuka/bare ground sedgeland), with c.200-300 clumps present in 2010. This was a rough estimate as large parts of the lower section of the stream could not be easily viewed safely, due to the growth of dense blackberry. Plants varied from a few centimetres high to c.50 centimetres tall. In September 2020, most of the *C. interruptus* at this site appeared dead. This may have been due to a reduction in geothermal activity at this site, or damage from frost and decreased water levels. This is the largest population of *C. interruptus* in or near Taupō township and as such it should be monitored regularly to see if it recovers. There is a real threat of losing *Cyclosorus interruptus* from the Wairākei-Tauhara Geothermal System if the apparent decline of geothermal activity at this site continues, because all other populations of *Cyclosorus interruptus* near Taupō are small.

In 2010, two small populations of *Nephrolepis flexuosa* (At Risk-Naturally Uncommon), each comprising c.0.5 × 0.5 metres, were present immediately downstream of the bridge that is second closest to the Waikato River. The populations were growing amongst blackberry scrub on the true right side, and rank exotic grassland on the true left. These populations remained present in 2014. In 2020, both of these populations appeared to have gone, however one small patch was rediscovered in 2023.

A small population of geothermal kānuka is present in the eastern part of this site. Geothermal kānuka has also been planted in the western part of the site alongside the Otumuheke Stream.

Lycopodiella cernua (a species characteristic of geothermal areas) was abundant at the eastern end of the site (*Carex virgata*-*Cyperus ustulatus*/mānuka-bare ground sedgeland) in 2010, but was not recorded in this type in 2020. A few *Lycopodiella cernua* were recorded in Vegetation Type 5 in 2020.

Hypolepis dicksonioides has been recorded from the site in the past (Wildland Consultants 2004b), and was also recorded in 2020 (at NZTM E1869287 N5714962).

Fauna: Indigenous avifauna present include: pōpokatea/whitehead, pīpīwharau/shining cuckoo, warou/welcome swallow, kōtare/sacred kingfisher, riroriro/grey warbler, tūi, korimako/bellbird, tauhou/silvereye, and pīwakawaka/North Island fantail. Exotic species present include: California quail, eastern rosella, Eurasian blackbird, song thrush, dunnoek, chaffinch, European goldfinch, yellowhammer, house sparrow, and common myna.

Geothermal Ecosystems: Geothermal streamsides, hydrothermally altered ground (now cool), geothermal wetland, heated ground (dry).

Current Condition: The geothermal wetland in the northeastern arm of the site (Vegetation Type 12) has declined in geothermal activity since 2010 and is now in relatively poor condition. Some of the geothermal springs are no longer active. Several species recorded in this area in 2010 were not found in 2020. It is one of few areas of sinter wetland remaining around Taupō. Extensive pest plant control and restoration planting has been undertaken since 2010 (particularly in the western half of the site). Some modification of the stream channel downstream from the Spa Hotel has occurred in the past and a geothermal wetland once occurred at the site of the Spa Hotel (Given 1989a).

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Blackberry (25% cover) dominates the stream margins in places. Other invasive pest plant species present include Himalayan honeysuckle (<1% cover), tradescantia (1% cover), pampas (<1% cover), grey willow and crack willow (<1% cover), Tasmanian blackwood (<1% cover), *Cotoneaster franchetii* (<1% cover), cotoneaster (<1% cover), holly (<1% cover), Chinese privet (1% cover), silver birch (<1% cover), montbretia (<1% cover), ornamental cherry (<1% cover), agapanthus (<1% cover), ivy (<1% cover), Cretan brake (<1% cover), Japanese honeysuckle (1% cover), buddleia (<1% cover), lupin (<1% cover), and broom (1% cover). Ongoing control of wilding pines, pampas, and grey willow is a priority for this site, in order to prevent further spread of these species. While the ongoing restoration works have improved the condition of parts of this site, further ongoing control of pest plants is recommended to maintain and improve the condition of the habitats that are present.

Human impacts: Most of the lower part of this site has been highly modified through human use. A wide walking track occurs along most of the western section of the stream margin that leads to the popular Hipapatua Bay bathing spot and the confluence of Otumuheke Stream with the Waikato River. The bathing area was upgraded in 2018 to include changing rooms, toilets and seating areas. Additional tracks, bridges, and ornamental trees are present in the western part of the site.

Grazing: Domestic livestock are not currently a threat to this site.

Adjoining land use: Forest and scrub comprising adventive and indigenous species, accommodation, and recreation grounds.

Site Change:

Recent change: Between 2009 and 2014, disturbance near the stream mouth destroyed two *Nephrolepis flexuosa* populations and a few plants of *Christella* aff. *dentata* (“thermal”). Since 2009, extensive restoration planting has been undertaken along the lower stream margins and at the stream mouth.

Since 2010, control of pest plants has been undertaken in the upper and lower parts of the stream gully (Waikato Regional Council 2011), including removal of pines from the gully walls, and control of pampas, Tasmanian blackwood, false acacia, ornamental cherry, and silver birch. Exotic trees remain alongside the stream adjacent to the Spa Hotel grounds.

The upper part of the site has declined in condition since 2010; most of the extensive areas of sinter have cooled and the majority of geothermal springs are no longer active. Most of the *Cyclosorus interruptus* appeared dead in September 2020, although a few small populations are present, particularly near an active geothermal spring.

Kathleen Springs supported a small population of *Cyclosorus interruptus* until at least 2006 (Merrett and Fitzgerald 2006; Burns *et al.* 1995), but no plants have been seen during the surveys conducted between 2013 and 2020 (Wildland Consultants 2014a, 2016c, 2017a and current survey). Bromley *et al.* 2010 suggested that the spring ceased to flow between 1997 and 2000. Vegetation surrounding the previous location of this spring is currently dominated by exotic species and does not provide suitable habitat for plant species typical of geothermal habitat.

*Historical:*¹

A review of historical aerial photographs² between 1938 and today shows that geothermal vegetation appears to have been present in the upper part of the Otumuheke Valley system for much of this time. It is also known that a geothermal wetland once occurred at the site of the Spa Hotel (Given 1989a).

The extent of bare ground appears to have declined alongside the Waikato River (part of the site previously identified as Spa Thermal Park). This may be related to a decline in geothermal activity, but also the increased spread of wilding pines. Geothermal activity also appears to have declined in the central area of the site (also part of the site previously identified as Spa Thermal Park), where geothermally-influenced bare ground has been replaced by wilding conifers.

Management Requirements:

Given (1989a) suggested that this site could be restored as it is an “interesting geothermal site on a walkway route down the Waikato River and is highly accessible”. Wildland Consultants have recently prepared a restoration plan for this site (Wildland Consultants 2022i). Pest plant

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Sourced from: <http://retrolens.nz> and licensed by LINZ CC-BY 3.0.

control has been undertaken in the western and eastern parts of the site since 2010. Restoration planting has been undertaken in the western area of the site.

Ongoing restoration of this site would enhance and sustain its ecological values and would be valuable for educational purposes. In particular, the geothermal wetland, and the stream and its margins should be managed to ensure that the ecological sequences present are preserved. Weed control efforts should focus on preventing further establishment of blackberry, pampas, and wilding pines in the geothermal wetland.

Any restoration of the site or its margins needs to be planned and undertaken using a conservative approach that minimises any further disturbance of the threatened plant species present. Specifically, herbicide should not be applied to the areas where key fern species (*Hypolepis dicksonioides*, *Nephrolepis flexuosa*, *Cyclosorus interruptus*, *Christella* aff. *dentata* (“thermal”)) and *Lycopodiella cernua* are present. Initially, no more than 25% of the total area of geothermal vegetation should be cleared of blackberry or other dense pest plant infestations at any one time. One population of *Nephrolepis flexuosa* and a few plants of *Christella* aff. *dentata* (“thermal”) were previously destroyed during site disturbance by people near the stream mouth.

Changes in vegetation cover composition and extent associated with draw-off from the geothermal system should be monitored.

Significance Level:

A: National (Criteria 3, 4, 5, 6, 9).
B: Local (Criteria 3, 5).

**Significance
Justification:**

A:

This part of the site is of national significance because it is a good quality example of geothermal habitat, which includes ecosystems that were nationally uncommon prior to human settlement (geothermal streamsides, hydrothermally altered ground (now cool)) (Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013). The geothermal wetland at the head of the Otumuheke Stream was previously in excellent condition, but has declined in condition since 2010. It contains the largest geothermal wetland in the Wairākei-Tauhara Geothermal System. This part of the site contains populations of four Threatened or At Risk plant species, including a sizeable population of *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered), and populations of geothermal kānuka (Threatened-Nationally Endangered), *Cyclosorus interruptus* (At Risk-Declining), and *Hypolepis dicksonioides* (At Risk-Naturally Uncommon).

B:

This part of the site is of local significance because it is a modified example of geothermal vegetation and habitat, which includes ecosystems that were nationally uncommon prior to human settlement (geothermal streamsides, heated ground (dry), hydrothermally altered ground (now cool)) (Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013).

Notes:

Otumuheke was classed as being of national (Part A) and local (Part B) significance in 2014 (Wildland Consultants 2014a). Spa Thermal Park and Kathleen Springs were classed as being of local significance in 2014 (Wildland Consultants 2014a).

The part of this site previously identified as Kathleen Springs has declined in condition to such an extent that it no longer has any ecological significance and is now dominated by exotic plant species. However, the stream that flows between AC Baths and Otumuheke Stream is of ecological significance because it supports a range of geothermal plant species including *Christella* aff. *denata* (“thermal”).

The Otumuheke Stream part of the site comprises two areas, “Upper Spa Stream” and “Lower Spa Stream”, ranked in Given (1996) as Category B and C sites, respectively.

References:

Bromley *et al.* 2010; Burns *et al.* 1995; Given 1989a, 1996; Merrett and Fitzgerald 2006; Waikato Regional Council 2011; Wildland Consultants 2000, 2004b, 2012, 2013c, 2014a, 2017a, 2021a, 2021b, 2022h.



Upper reaches of Otumuheke Stream. Since 2010, control of wilding pines has been undertaken on the banks. Vegetation present on the valley floor has changed in recent years following the apparent decline in geothermal activity since 2010. NZTM E1869673 N5714812. 11 September 2020.



One of the two most important *Christella* aff. *dentata* ("thermal") populations in the Wairākei-Tauhara Geothermal System, which occurs alongside Otumeheke Stream, between the Spa Hotel and the Waikato River. NZTM E1868682 N5715386. 11 September 2020.



Western end of Otumuheke Stream. This bathing area has been developed since 2014. NZTM E1868452 N5715398. 11 September 2020.



Wilding pines currently dominate areas of hydrothermally altered ground (now cool) at Otumuheke (in an area that was previously identified as Spa Thermal Park). NZTM E1868925 N5714688. 16 September 2020



Approximate location of the area that was previously identified as Kathleen Springs.

This area is now dominated by exotic species and no species typical of geothermal habitats are present. NZTM E1869502 N5714450. 16 September 2020.



TAUHARA SOUTH¹

Ecological District: Taupō **GPS Reference:** NZTM E1872910, N5710515
 E1873365, N5710734,
 E1873145, N5711064
Geothermal System: Wairākei-Tauhara **Altitude:** 540 m
Geothermal System: Tauhara
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.0.1 ha
Extent of Geothermal Vegetation: c.0.1 ha
Date of Most Recent Field Survey: 29 September 2020

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka dominant shrubland (05.01) Geothermal kānuka shrubland (05.01.01) A small area of geothermally heated soil occurs in a roadside ditch on the northern side of State Highway 5. Shrubland containing geothermal kānuka (up to 1.5 metres tall) is present above exotic grasses, particularly narrow-leaved carpet grass, and patches of the mosses <i>Campylopus</i> sp., <i>Wijkia extenuata</i> , <i>Racomitrium lanuginosum</i> and <i>Hypnum cupressiforme</i> . Indian doab and paspalum occur on the margins of the ditch. The liverwort <i>Chiloscyphus semiteres</i> is also present. One patch of <i>Psilotum nudum</i> was present in 2020 (1 metre long, 30 centimetres tall).	Roadside ditch	<0.1 ha
2.	Exotic grassland (08.01) Mixed exotic grassland (08.01.15) A small area of geothermally heated soil with a cover of Indian doab, narrow-leaved carpet grass, paspalum, Mercer grass, cocksfoot, and red fescue grassland is located in a roadside ditch on the southern side of State Highway 5. Local blackberry is establishing. Occasional <i>Lycopodiella cernua</i> is present on the banks of the ditch. A steam vent surrounded by rocks, moss, and grass is present.	Roadside ditch	<0.1 ha
3.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Geothermally-influenced bare ground that is surrounded by exotic grasses including narrow-leaved carpet grass, cocksfoot, and browntop occurs within the farmland. Steam was observed rising from a hole in the ground, which appears to be used for cooking. Loose pumice is present on the surface. Soil temperatures up to 63.2 C (2014 measurement) were recorded from within these areas and steam rising from the hole was c.80 °C.	Flat	<0.1 ha

Indigenous Flora: A very small population of geothermal kānuka (Threatened-Nationally Endangered) is present at this site. *Lycopodiella cernua*, a plant characteristic of geothermal habitats, is present in the parts of the site close to State Highway 5. A small patch of *Psilotum nudum* was present in the northern

¹ The site Tauhara South was referred to as Mountain Road in Wildland Consultants (2014a).

roadside ditch in 2020. This species had not been previously recorded at the site, and suggests that the species may have recently colonised the ditch. This population of *P. nudum* is the largest currently known in the Wairākei-Tauhara Geothermal System.

Fauna: Riroriro/grey warbler and korimako/bellbird were recorded during the 2014 field survey. Other common indigenous and exotic bird species typical of these habitat types are likely to be present. No birds were recorded at the site during the 2020 survey.

Geothermal Ecosystems: Heated ground (dry), hydrothermally altered ground (now cool), fumaroles.

Current Condition: This small site has been degraded by human use, trampling by domestic stock, and invasion of pest plant species.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: In the ditches alongside State Highway 5, the cover of blackberry, broom, and narrow-leaved carpet grass has increased slightly since 2013 (Wildland Consultants (2017a) and current survey). Local populations of broom and blackberry occur around the margins of areas of geothermally-influenced bare ground (Vegetation Type 3), but are currently kept in check by domestic stock grazing.

Human impacts: Part of the site is used for cooking food and appears to have been modified for this purpose. The areas within roadside ditches are likely to be disturbed regularly during routine roadside maintenance. The surrounding natural vegetation has been cleared for farming and roading infrastructure. Rubbish is present in the roadside ditches. One part of the site has been destroyed by the development of pasture since 2014.

Grazing: Domestic cattle and horses have access to parts of this site. Areas of geothermally-influenced bare ground are grazed to the margins and trampled by stock.

Adjoining land use: Farming, State Highway 5.

Site Change:

Recent change: The vegetation within the roadside ditches appears to be similar to that described in Merrett and Fitzgerald (2006). One area (<0.1 hectares) of geothermally-influenced bare ground in a paddock has been ploughed and sown in pasture since 2014.

*Historical:*¹ While historic photographs are available for this site since the 1940s, the size of the geothermal sites are too small to reliably assess changes based on the photographs.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

Management Requirements:	The condition of the parts of the site that are grazed within farmland would improve if they are fenced to exclude domestic stock.
Significance Level:	Local (Criteria 3, 5).
Significance Justification:	This site is locally significant because it contains small areas of an ecosystem that was nationally uncommon prior to human settlement (heated ground (dry), fumaroles, hydrothermally altered ground (now cool)) (Williams <i>et al.</i> 2007; Holdaway <i>et al.</i> 2012; Wiser <i>et al.</i> 2013).
Notes:	This small site was classed as locally significant in 2014 (Wildland Consultants 2014a).
References:	Merrett and Fitzgerald 2006; Wildland Consultants 2014a, 2017a, 2021a, 2021b.



Geothermal kānuka shrubland in a roadside ditch on the northern side of State Highway 5, Tauhara South site. NZTM E1872893 N5710515. 30 September 2020.



Psilotum nudum in the roadside ditch, on the northern side of State Highway 5, Tauhara South site. NZTM E1872896 N5710518. 30 September 2020.



Geothermally-influenced bare ground adjacent to Mountain Road, Tauhara South site. NZTM E1873157 N5711115. 10 September 2020.



TAUPŌ SHORELINE

Ecological District: Taupō **GPS Reference:** NZTM E1868290 N5711711
Geothermal System: Wairākei-Tauhara **Altitude:** 355 m
Geothermal System: Tauhara
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.0.5 ha
Extent of Geothermal Vegetation: c.0.3 ha
Date of Most Recent Field Survey: 10 September 2020

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Loamfield (20.01) Geothermally-influenced bare ground and sandfield (20.01.01) Patches of now cool geothermally-influenced bare ground, sinter, and sandfields occur on the margins of Lake Taupō. When lake levels are low, there are patches of open water and herbfield dominated by <i>Glossostigma elatinoides</i> , <i>Hypericum pusillum</i> and <i>Limosella lineata</i> .	Flat	c.0.3 ha
2.	Water (22.01) Geothermal water (22.01.01) A series of geothermal springs arise from the patches of exposed geothermally-influenced bare ground (now cool) and sandfields on the margins of Lake Taupō. The exact locations of these springs are difficult to pinpoint as they are scattered over nearly one kilometre of lake shoreline, and the presence of the springs may vary depending on changes in lake water levels. There are also at least four drains containing geothermal water which also drain onto the lake shore. Key geothermal springs and streams at Taupō Shoreline are described below: - A small spring bubbling out of a crevice in a rock stack. Temperatures of up to 67.2 °C were recorded in 2014, and up to 64 °C in 2020. The rocks surrounding the spring support a low growing sparse cover including Mexican daisy, blackberry, catsear, buddleia, necklace fern, and kiokio. - Hot water (c.62 °C in 2014) flows from a spring in the side of a grassy bank into a small pool (covering c.5 × 2 metres) on the margin of the lake. Vegetation on the bank surrounding the spring comprises a mixture of fern, herbaceous, and grass species including <i>Blechnum pennamarina</i> subsp. <i>alpina</i>, <i>Blechnum parrisiae</i>, annual poa, ratstail, cretan brake, bracken, and broad-leaved fleabane. There are areas of exposed geothermally-influenced bare ground (now cool). - Geothermally-heated water (c.38 °C in 2020) from the Onekeneke Stream emerges onto an area of bare ground on the margin of Lake Taupō.	Springs, streams	c.0.1 ha

Indigenous Flora: Three juvenile plants of *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) were observed around a spring on the margin of Lake

Taupō in 2014 (Wildland Consultants 2014a), however these were not observed in 2020.

Fauna:

Indigenous bird species recorded in 2020 include: tarāpuka/black-billed gull (At Risk-Declining), tarāpunga/red-billed gull (At Risk-Declining), taranui/Caspian tern (Threatened-Nationally Vulnerable), weweia/New Zealand dabchick (Threatened-Nationally Increasing), kawaupaka/little shag (At Risk-Recovering), pūtangitangi/paradise shelduck, pāpango/New Zealand scaup, kuruwhengi/Australasian shoveler, kakīānau/black swan, karoro/black-backed gull, poaka/pied stilt, and warou/welcome swallow. Other indigenous lakeshore and waterbirds that are likely to be present at the site on a regular basis include māpunga/black shag (At Risk-Relict), kawau tūi/little black shag (At Risk-Naturally Uncommon), pārera/grey duck¹, white-faced heron, spur-winged plover, and kōtare/sacred kingfisher.

Introduced bird species recorded in 2020 include: mallard, Eurasian blackbird, yellowhammer, and house sparrow.

**Geothermal
Ecosystems:**

Geothermal streamsides, heated ground (dry).

Current Condition:

The site is generally in good condition, as vegetation in many places is inundated by high lake levels on a regular basis.

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Exotic grasses and herbs are common on the margins of this site. Some short stature pest plants are present in low abundance, including: Mexican daisy (<1% cover), buddleia (<1% cover), blackberry (<1% cover), strawberry dogwood (<1% cover), Japanese honeysuckle (<1% cover), cotoneaster (<1% cover), and Cretan brake (<1% cover).

Human impacts:

This is a heavily used recreation area. The Great Lake Walkway - Lion's Walk occurs alongside this site and is a popular walking and biking track. The spring and small pool on the margin of Lake Taupō are utilised on a regular basis by bathers. The pool is modified regularly by lake waves, and/or recreational bathers creating dams and channels in the sand. Geothermal vegetation beside the spring at this location is vulnerable to human disturbance associated with maintenance of the walking track and grassy margins of the lake.

Grazing:

Livestock are not a threat to this area.

Adjoining land use:

Recreation reserve, walking track, and residential dwellings.

Site Changes:

Recent change:

The extent of geothermal springs on the shoreline appears to have increased slightly since 2014. However, the exact locations of these springs are difficult to define and may vary depending on changes in lake water levels.

¹ Most birds are likely to be hybrids with mallard duck.

Management Requirements:	Pest plant control is a relatively low priority at this site.
Significance Level:	Local (Criteria 5, 6)
Significance Justification:	This site is locally significant because it contains ecosystems that were nationally uncommon prior to human settlement (geothermal streamsides, heated ground (dry)) (Williams <i>et al.</i> 2007; Holdaway <i>et al.</i> 2012; Wiser <i>et al.</i> 2013). It contains geothermal wetland and shoreline habitats on the margins of Lake Taupō, which is at least a nationally ecologically significant site.
Notes:	This site was previously included as part of the Waipahihi Valley site which was classed as regionally significant in 2014 (Wildland Consultants 2014a).
References:	Wildland Consultants 2014a, 2021a, 2021b..



A small spring bubbling out of a crevice in a rock stack at Taupō Shoreline. Water temperatures of up to 64 °C were recorded in 2020. NZTM E1868290 N5711711. 10 September 2020.



Geothermally-heated water emerging onto sandfield before entering Lake Taupō, Taupō Shoreline. NZTM E1868238 N5711977. 10 September 2020.

TE KIRI O HINEKAI¹

Ecological District: Atiamuri **GPS Reference:** NZTM E1866576 N5720644
Geothermal System: Wairākei-Tauhara **Altitude:** c.440-540 m
Geothermal System: Wairākei
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.42.9 ha
Extent of Geothermal Vegetation: c.42.8 ha
Date of Most Recent Field Survey: 9 and 29 September 2020

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic forest (01.02) Exotic conifers/mingimangi-geothermal kānuka forest (01.02.05) Radiata pine and scattered maritime pine are emergent and, in some areas, dominant over mingimangi, geothermal kānuka, tāwiniwini, and bracken. There are patches of whekī, kōhūhū, kāmahi, karamū, and whauwhaupaku in cooler areas, with bracken and tūrutu in the understorey. Patches of <i>Dicranopteris linearis</i> are present.	Hillslopes	c.2.8 ha
2.	Geothermal kānuka scrub (04.01) Geothermal kānuka scrub (04.01.01) The large central area at Te Kiri o Hinekai: Geothermal kānuka forms a dense canopy up to c.1 metre tall, with mingimangi common in places, and local mānuka. The mosses <i>Sphagnum</i> sp., <i>Campylopus introflexus</i> , and <i>Dicranoloma</i> sp., and the liverwort <i>Chiloscyphus semiteres</i> comprise the groundcover. Scattered lichen is also present. Monoao and local patches of mingimangi occur on rocky outcrops throughout, with monoao becoming more common in the scrub on the eastern side of a deep and geothermally active gully. Small fumaroles are scattered throughout the area. Patches of <i>Dicranopteris linearis</i> , <i>Nephrolepis flexuosa</i> , <i>Lycopodiella cernua</i> , and <i>Cheilanthes sieberi</i> are present. Exotic species are abundant throughout, particularly in cooler areas, including Spanish heath, buddleia, pampas, Himalayan honeysuckle, and blackberry. Wairākei Borefield part: An area of geothermal kānuka scrub (up to c.2 metres tall) with occasional emergent broom and local patches of narrow-leaved carpet grass. Gaps in the geothermal kānuka canopy support the moss <i>Chiloscyphus semiteres</i> and scattered <i>Lycopodiella cernua</i> . Blackberry is common on the uphill margins, with a few saplings of karamū and kōhūhū. One small plant of <i>Dicranopteris linearis</i> (c.10 × 10 centimetres) occurs on disturbed ground next to the geothermal well. Average soil temperature at ten centimetres depth was 52.8 °C in 2014 (three measurements) and 83.8 °C in 2020 (five measurements).	Undulating plateau, hillslopes, gullies	c.25.9 ha

¹ The sites mapped as Te Kiri o Hinekai Stream Catchment/Wairoa Hill and Wairākei Borefield in Wildland Consultants (2014a) have been merged and are now referred to as Te Kiri o Hinekai.

CODE	VEGETATION TYPE	LANDFORM	EXTENT
3.	Geothermal kānuka-mingimingi scrub (04.02) Geothermal kānuka-mingimingi scrub (04.02.01) Geothermal kānuka forms the canopy in association with mingimingi and locally scattered monoao. Monoao is abundant in the southern-most area of this vegetation type. There are a few emergent wilding radiata pine, false acacia, and maritime pine, although these species have been partially controlled at the northern end of the site. The groundcover includes local <i>Campylopus</i> sp. and <i>Lycopodiella cernua</i>. Other species present include bracken and tūrutu. Whauwhaupaku occurs on the margins in places. At the northern end of the site, there are small patches of <i>Dicranopteris linearis</i> and <i>Nephrolepis flexuosa</i>.	Hillslopes, gully	c.1.9 ha
4.	Exotic conifers/geothermal kānuka-mingimingi scrub (04.02.03) Emergent radiata pine and maritime pine are scattered to locally common over an understorey dominated by geothermal kānuka and mingimingi. Some wilding pine control has recently been undertaken within local patches of this vegetation type. <i>Dicranopteris linearis</i>, <i>Nephrolepis flexuosa</i>, and tūrutu are scattered throughout, and <i>Lycopodiella cernua</i> is locally common. Moss (<i>Racomitrium</i> sp.) forms the groundcover in places. Other species present include bracken, blackberry, buddleia, Spanish heath, whekī, broom, whauwhaupaku, karamū, patches of exotic grasses and Himalayan honeysuckle.	Hillslopes	c.8.7 ha
5.	Geothermal kānuka shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Geothermal kānuka forms a low canopy (up to c.0.5 metres tall) over abundant <i>Lycopodiella cernua</i> and <i>Campylopus</i> sp. Local patches of mature wilding maritime pine and radiata pine (up to c.10 metres tall) occur within this type. The understorey comprises mingimingi, prickly mingimingi, karamū, tūrutu, and <i>Gleichenia microphylla</i>. At the southern end of the site, geothermal kānuka occurs in association with <i>Dicranopteris linearis</i>, local patches of <i>Nephrolepis flexuosa</i>, and adventive species such as Himalayan honeysuckle, broad-leaved fleabane, foxglove, Yorkshire fog, and wild portulaca. Occasional aloe have been recorded within this type in the past but were not observed in 2020.	Undulating plateau; valley floor, hillslopes	c.1.5 ha
6.	Mixed indigenous shrubland (05.07) Sprayed geothermal shrubland (05.07.04) Sprayed geothermal shrubs (Delich and Singers 2022).	Hillslope	c.0.3 ha
7.	Indigenous fernland (07.01) <i>Dicranopteris linearis</i> fernland (07.01.01) Dominated by <i>Dicranopteris linearis</i> (Delich and Singers 2022).	Hillslope	<0.1 ha
8.	<i>Nephrolepis flexuosa</i> fernland (07.01.10) Dominated by <i>Nephrolepis flexuosa</i> fernland (Delich and Singers 2022).	Hillslope	<0.1 ha
9.	<i>Cheilanthes sieberi</i> fernland (07.01.13) A small area (c.5 × 2 metres) of <i>Cheilanthes sieberi</i> fernland is present on the edge of geothermal kānuka scrub near the	Flat	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	southwestern boundary of the site (NZTM E1866341 N5720032). The moss, <i>Campylopus</i> sp., and a few scattered exotic grasses and herbs (including bay grass, Vasey grass, sweet vernal, Indian doab, and wild serradella) are also present within this area.		
10.	Sprayed <i>Nephrolepis flexuosa</i> fernland (07.01.22) Sprayed <i>Nephrolepis flexuosa</i> fernland (Delich and Singers 2022).	Hillslope	c.0.1 ha
11.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Geothermal clays, mud pools, and fumaroles that contain scattered patches of geothermal kānuka shrubland. Mingimingi, mānuka, pampas, kiokio, water fern, radiata pine saplings, and bracken also occur in these areas.	Hillslopes, undulating plateau, crater	c.1.5 ha
12.	Water (22.01) Geothermal water (22.01.01) Hot water and mud lakes, including Alum Lake. The two northernmost lakes are located within a steep sided depression. Pampas, <i>Carex secta</i> , raupō, and water fern occur on the margins, with <i>Lemna disperma</i> present on the surface of areas of cooler water.	Lakes	c.0.1 ha

Indigenous Flora:

Geothermal kānuka, *Dicranopteris linearis* (both Threatened-Nationally Endangered), and *Nephrolepis flexuosa* (At Risk-Naturally Uncommon) occur at this site. The site supports the largest populations of both *Nephrolepis flexuosa* and *Dicranopteris linearis* of any of the geothermal sites in the Wairākei-Tauhara Geothermal System. A patch of *D. linearis* covering 10 × 20 metres was recorded at NZTM E1866540 N5720420.

Christella aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) was recorded near geothermal lakes at this site in 2001 (Nick Singers pers. comm. 2007) but has not been recorded since. *Hypolepis dicksonioides* (At Risk-Naturally Uncommon) (or a hybrid of *H. dicksonioides* and *H. ambigua*) is present at Alum Lake (viewed from a distance in 2020).

Fauna:

Pīhoihoi/New Zealand pipit (At Risk- Declining) is present at this site (recorded in 2014, but not in 2020). Other indigenous species recorded are pōpokatea/whitehead (recorded in 2020) pūtangitangi/paradise shelduck (flew over in 2020), kāhu/swamp harrier, spur-wing plover, pīpīwharau/shining cuckoo (recorded in 2014), kōtare/sacred kingfisher (recorded in 2014), tūi, korimako/New Zealand bellbird (recorded in 2014), riroriro/grey warbler, pīwakawaka/North Island fantail, tauhou/silvereye, and miromiro/North Island tomtit. Introduced species recorded include mallard, common pheasant, California quail, Eastern rosella, Eurasian blackbird, song thrush, dunnoek, chaffinch, and Australian magpie. Skink and gecko have also been reported from this site (Spring-Rice 1996).

Geothermal Ecosystems:

Heated ground (dry), hydrothermally altered ground (now cool), fumaroles, geothermal streamsides.

Current Condition:

A large and mostly contiguous area of geothermal features and vegetation surrounded by pine plantation forest and geothermal extraction operations. The central part of the site contains extensive areas of geothermal kānuka

scrub and other geothermal vegetation types that are in relatively good condition. However, the site is vulnerable to, and has been compromised by, pest plant invasion in the past, particularly by wilding pines. Wilding pine control has recently (2017 and ongoing) been undertaken within most of this site (excluding the southern areas). Weeds remain common on the margins of the site and the condition of geothermal vegetation is likely being altered by geothermal extraction, which is ongoing.

Pest animal control (bait stations) have recently been installed near Alum Lake.

A suspected asbestos dump located within the Te Kiri o Hinekai site (near NZTM E1866417 N5720060) is reverting to geothermal kānuka shrubland.

The small area that was previously identified as Wairākei Borefield contains geothermal kānuka scrub that is surrounded by an industrial site. There is a relatively low cover of pest plants.

Threats/Modification/ Vulnerability:

Invasive pest plants: Wilding pines (15-20% cover, including radiata pine and maritime pine) threaten geothermal vegetation at this site. Other adventive species present include blackberry (<5% cover), pampas (<1% cover), Himalayan honeysuckle (<1% cover), Montpellier broom (<1% cover), broom (1% cover), lupin (<1% cover), false acacia (1% cover), narrow-leaved carpet grass (1% cover), and Spanish heath (<1% cover).

In the Wairākei Borefield part: broom (<1% cover) and blackberry (<1% cover, on margins).

Human impacts: Access tracks, vehicle tracks, logging, farming, and geothermal extraction infrastructure all occur along the boundaries of this site. A suspected asbestos disposal site is present (near NZTM E1866417 N5720060). A mountain bike trail traverses through one of the southern parts of this site.

Grazing: Farmland which borders a small area on the southern margin of this site is fenced to prevent intrusion of stock into the geothermal area. Feral pig sign was observed in the southern part of the site during the 2020 field survey.

Adjoining land use: Pine plantation, industrial geothermal energy extraction plant, farmland.

Site Change:

Recent change: Between 2007 and 2014, the cover of wilding pines increased significantly. For example, since 2007 wilding pines have invaded mingimingi scrub at the southern end of the site, and radiata pine has colonised an area of geothermal kānuka-mingimingi scrub in the middle of the site.

Ongoing wilding pine control has been undertaken throughout much of this site since 2017. There has also been some recent control of false acacia and pampas in northern parts of the site.

In recent years, the geothermal activity on the boundaries of some well-known areas appear to have declined. The abundance of *Nephrolepis flexuosa* has declined between 2014 and 2020.

The small areas of geothermal kānuka scrub in the part of the site that was previously identified as Wairākei Borefield have expanded from c.125 m² in 2007 to c.295 m² in 2020. The two areas which were mapped in 2014 have now expanded in area and are contiguous. The canopy height of the geothermal kānuka has also increased and there are fewer canopy gaps. The cover and diversity of weeds has reduced since 2014.

*Historical:*¹

Burns *et al.* (1996) assessed vegetation change at this site using aerial photographs from 1945 to 1993, and found that the extent of geothermal vegetation decreased by 20% between these time periods. In addition, an assessment of aerial photographs from 1961² compared with more recent aerial photographs indicates a marked increase in the presence of wilding pines at the site.

Management Requirements:

A management plan was recently prepared for this site which includes suggestions for pest plant control. Control of wilding pines and false acacia should be continued throughout the site, because most threatened geothermal species do not tolerate the dense shade that can be created by these pest plants. Pampas and gorse should be controlled locally (where achievable) within geothermal habitat to prevent further spread of these species.

Significance Level:

N. National (Criteria 3, 5, 7, 9).
R. Regional (Criteria 3, 5, 7, 9).
L. Wairākei Borefield part: Local (Criteria 3, 5).

Significance Justification:

N.
Part of this site is mapped as being of national significance because it is one of the larger areas of geothermal kānuka scrub and shrubland. It also includes ecosystems that were nationally uncommon prior to human settlement (heated ground (dry), hydrothermally altered ground (now cool), fumaroles; Williams *et al.* 2007, Holdaway *et al.* 2012, Wiser *et al.* 2013a). It contains relatively large populations of three Threatened or At Risk plant species (geothermal kānuka, *Dicranopteris linearis*, and *Nephrolepis flexuosa*). The populations of both *Nephrolepis flexuosa* and *Dicranopteris linearis* are the largest when compared with other sites in the Wairākei-Tauhara Geothermal System.

R.
These parts of the site are of regional significance because they includes ecosystems that were nationally uncommon prior to human settlement (heated ground (dry), hydrothermally altered ground (now cool), fumaroles; Williams *et al.* 2007, Holdaway *et al.* 2012, Wiser *et al.* 2013a). They also contains populations of three Threatened or At Risk plant species: geothermal kānuka, *Dicranopteris linearis*, and *Hypolepis dicksonioides* (or a hybrid of *H. dicksonioides* and *H. ambigua*).

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 1394 Run 3187 Photos 22, 23, 1961; SN 1394 Run 3188 Photos 23, 24, 1961.

L.

The Wairākei Borefield part of this site is of local significance because it is a small example of an ecosystem that was nationally uncommon prior to human settlement heated ground (dry); Williams *et al.* 2007, Holdaway *et al.* 2012, Wiser *et al.* 2013). It also contains small populations of two Threatened plant species (geothermal kānuka and *Dicranopteris linearis*).

Notes:

Te Kiri o Hinekai Stream was classed as being of regional significance in 2014 (Wildland Consultants 2014a). The part of the site that was previously identified as Wairākei Borefield was classed as being of local significance in 2014 (Wildland Consultants 2014a).

This site comprises two areas that were ranked in Given (1996) as Category A (the highest category) - “Wairākei: Waiora Hill” and “Wairākei: Upper Wairākei Stream”.

A large part of this site is very dangerous to traverse, and the assessment of some areas is based on inference of vegetation types based on assessment of aerial photographs.

References:

Burns *et al.* 1996; Given 1989a; Merrett and Burns 1988a, 1988b, Spring-Rice 1996; Wildland Consultants 2000, 2004c, 2007a, 2007c, 2012, 2014a, 2021a, 2021b.



Geothermal kānuka scrub in the southern part of the largest area of geothermal vegetation at Te Kiri o Hinekai. NZTM E1866712 N5720377. 29 September 2020.



A large crater in the northern part of the Te Kiri o Hinekai site. NZTM E1866475 N5720902. 9 September 2020.



Wilding pines that have been controlled amongst geothermal kānuka scrub in the southwestern part of Te Kiri o Hinekai since 2017. NZTM E1866289 N5720320. 9 September 2020.



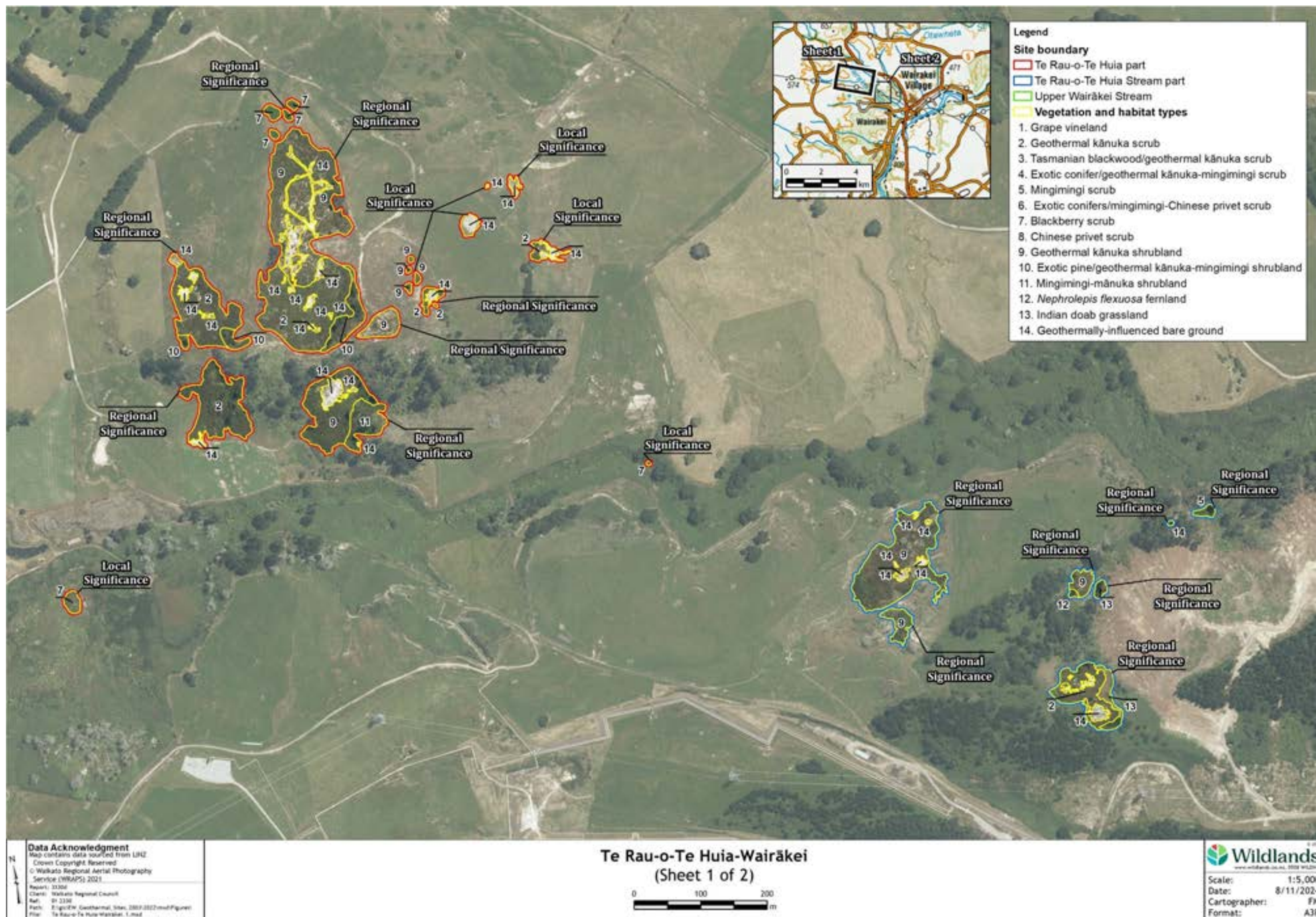
The very active central part of the Te Kiri o Hinekai site. NZTM E1866377 N5720437. 9 September 2020.

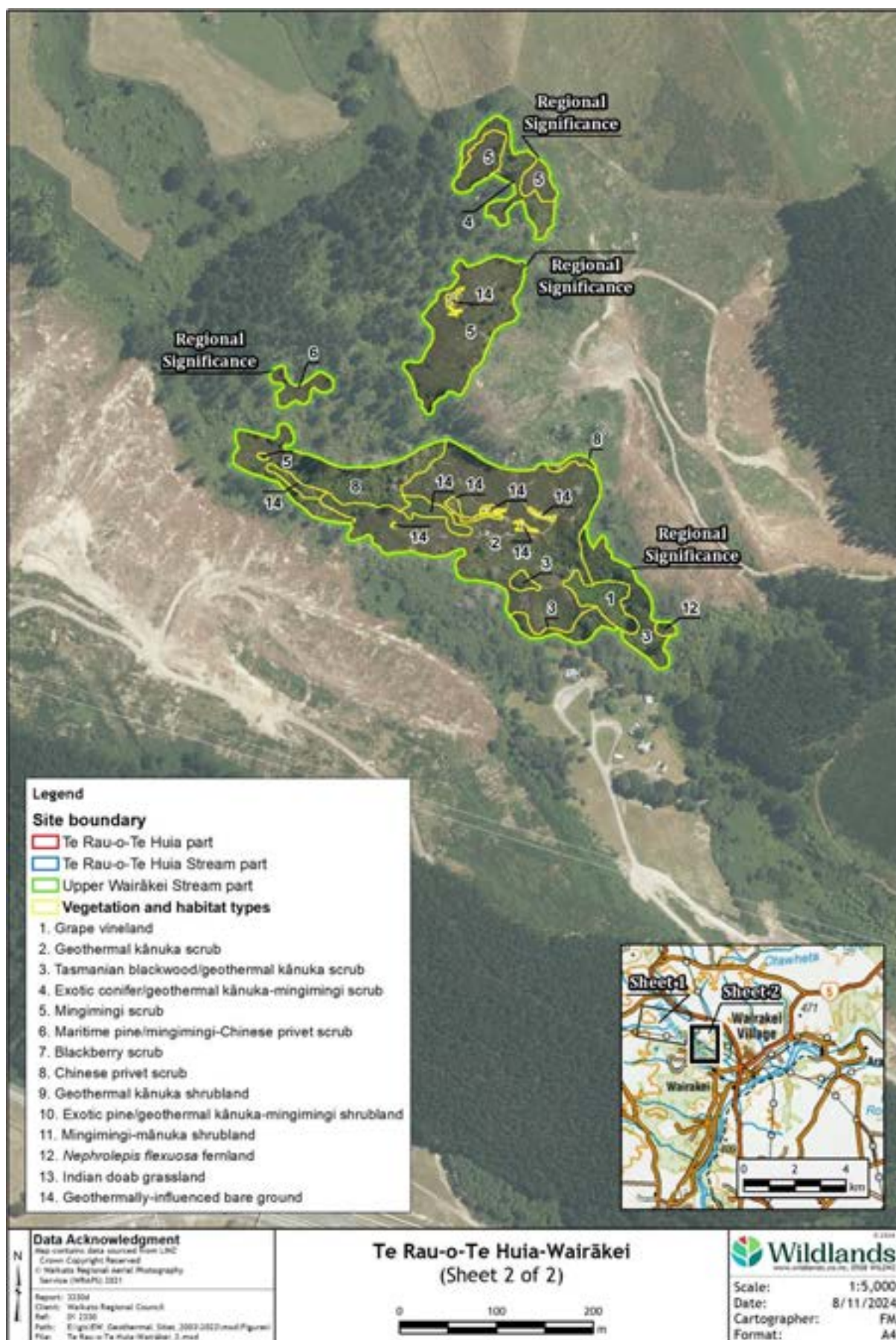


Mud pools in the central part of the Te Kiri o Hinekai site. NZTM E1866523 N5720531. 9 September 2020.



Alum Lake crater in the northern part of the Te Kiri o Hinekai site. NZTM E1866496 N5720950. 9 September 2020.





TE RAU-O-TE HUIA-WAIRĀKEI¹

Ecological District: Atiamuri **GPS Reference:** NZTM E1866262 N5722450
Geothermal System: Wairākei-Tauhara **Altitude:** c. 372-530 m
Geothermal System: Wairākei
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c. 15.2 ha
Extent of Geothermal Vegetation: c. 15.2 ha
Date of Most Recent Field Survey: 25 June 2021 (Te Rau-o-Te Huia part), 30 September 2020 (Te Rau-o-Te Huia Stream part), 11 September 2020 and 25 June 2021 (Upper Wairākei Stream (Geyser Valley) part).

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic vineland (03.01) Grape vineland (03.01.02) An area dominated by grape vines is present in the southwestern corner of the site on the true right side of Wairākei Stream. It has smothered the geothermal kānuka shrubland that was present previously. Chinese privet is abundant in small gaps in the grape vine canopy. There are scattered patches of indigenous trees (c. 10-15 metres tall) including māhoe, kāmahī, whekī, māpou, mingimingi and mānuka. A few Himalayan honeysuckle, Spanish heath, and broom are present, along with local tradescantia. <i>Muehlenbeckia australis</i> is also locally present in the canopy. There have been some recent slips on the hillslope.	Hillslope	c. 0.2 ha
2.	Geothermal kānuka scrub (04.01) Geothermal kānuka scrub (04.01.01) Te Rau-o-Te Huia Stream part: Geothermal kānuka up to c. 1 metre tall dominates this vegetation type, with local patches of <i>Lycopodiella cernua</i> and <i>Nephrolepis flexuosa</i> . Upper Wairākei Stream (Geyser Valley) part: Geothermal kānuka forms a canopy averaging c. 1 metre tall (up to c. 3 metres tall) with local mingimingi, and local patches of <i>Lycopodiella cernua</i> and <i>Dicranopteris linearis</i> . Around the margins, tūrutu is locally common and hound's tongue fern is occasionally present. Fumaroles and dried mud pools occur throughout. Some patches of geothermally-influenced bare ground and mossfield are present (too small to map separately). Blackberry, watercress, water fern, and <i>Carex secta</i> are common along geothermal stream margins within this vegetation type. A few whekī and Chinese privet are also scattered along the stream margins. Monoao is scattered on the main central geothermal hillslope above the stream. There are occasional Tasmanian blackwood and local patches of pampas, some of which have been controlled recently. Pampas remains relatively common in the location of the 2012 fire. Narrow-leaved carpet grass is common on the track margins. Spanish heath is scattered in cooler areas.	Valley sides	c. 5.7 ha

¹ The site Te Rau-o-Te Huia-Wairākei amalgamates the sites from Wildland Consultants (2014a) Te Rau-o-Te Huia, Te Rau-o-Te Huia Stream, and Upper Wairākei Stream (Geyser Valley).

CODE	VEGETATION TYPE	LANDFORM	EXTENT
3.	Tasmanian blackwood/geothermal kānuka scrub (04.01.02) Two subtypes are identified under this broad type. 3a. Tasmanian blackwood forms a patchy canopy over geothermal kānuka, and common mingimingi and māpou, along with a few Chinese privet. The groundcover is dominated by leaf litter with scattered hound's tongue fern and mosses, occasional tūrutu, and scattered Chinese privet seedlings. A patch of <i>Nephrolepis flexuosa</i> (c.7×5 metres) occurs within a few metres from the walking track. 3b. Scattered Tasmanian blackwood (to c.7-8 metres tall) occurs above scrub dominated by geothermal kānuka (up to c.3 metres tall) with scattered mingimingi, māpou, māhoe, kāmahī (c.10-15 metres tall), whekī, wilding pine, broom, and Chinese privet. Bracken is abundant in places. Occasional mānuka, pampas, Spanish heath, blackberry, and tūrutu are present on the track margins. <i>Dicranopteris linearis</i> and <i>Nephrolepis flexuosa</i> occur locally. Some wilding pine control has been undertaken since 2014.	Hillslope; terrace, gully	c.0.6 ha
4.	Geothermal kānuka-mingimingi scrub (04.02) Exotic conifer/geothermal kānuka-mingimingi scrub (04.02.03) Exotic conifers over geothermal kānuka and mingimingi (Delich and Singers 2022).		c.0.3 ha
5.	Mingimingi scrub (04.03) Mingimingi scrub (04.03.01) Scattered emergent wilding pines are present over a canopy dominated by mingimingi. Kānuka, mānuka, and whekī are common throughout.	Hillslope	c.1.3 ha
6.	Exotic conifers/mingimingi-Chinese privet scrub (04.03.07) Emergent exotic conifers (maritime pine and a few Japanese cedar (c.15-20 metres tall)) are scattered above mingimingi, which forms a canopy (c.3 metres tall) with common Chinese privet, occasional geothermal kānuka and whekī-ponga. Locally common Spanish heath, scattered whauwhaupaku, kōhūhū, karamū, and local broom are also present. Bracken is scattered in the canopy in places. Narrow-leaved carpet grass is common on the track margins along with scattered sweet vernal and paspalum. Blackberry is present in places, particularly alongside the stream with local Chinese privet. Kōhūhū and whauwhaupaku have increased in extent within this vegetation type since 2011. Some control of exotic conifers has been undertaken recently.	Hillslope	c.0.1 ha
7.	Exotic species dominant scrub (04.10) Blackberry scrub (04.10.01) Dense blackberry surrounds a small heated spring (73 °C in 2011), with occasional pōhue, and less common broom and lotus. Water purslane is present on the cooler margins of the pool. Dense blackberry scrub also occurs around a small steam vent in the northern part of the site.	Shallow gully	c.0.2 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
8.	Chinese privet scrub (04.10.03) Chinese privet dominates an area alongside the geothermal stream in the western part of the site. This vegetation type has expanded slightly over time.	Hillslope	c.0.9 ha
9.	Geothermal kānuka shrubland (05.01) Geothermal kānuka shrubland (05.01.01) Te Rau-o-Te Huia part: Geothermal kānuka forms a low, discontinuous canopy c.0.3-0.75 metres tall, with mingimingi scattered throughout and a few monoao. Groundcover includes liverwort cushions (mainly <i>Chiloscyphus semiteres</i>) and local <i>Lycopodiella cernua</i>. Grasses (including Indian doab, narrow-leaved carpet grass, sweet vernal, browntop, bay grass, and paspalum) and a herb (wild serradella) occur locally on cooler and disturbed ground. There are scattered emergent radiata pine and maritime pine, and patches of blackberry and Spanish heath, and small areas of bare, steaming ground occur throughout. <i>Gleichenia microphylla</i>, mānuka, and kōhūhū occur in a few places locally. Te Rau-o-Te Huia Stream part: Geothermal kānuka forms a low canopy (up to c. 1 metre tall), with scattered mingimingi, abundant <i>Lycopodiella cernua</i> and the moss <i>Campylopus capillaceus</i>, and occasional emergent maritime pine and radiata pine. Some geothermally-influenced bare ground is present. There is scattered bracken, water fern, Spanish heath, monoao, mānuka, broom, blackberry, karamū, prickly mingimingi, and tūrutu throughout. Occasional patches of paspalum, Indian doab, narrow-leaved carpet grass, radiata pine seedlings, and pampas are also present within this vegetation type.	Plateau and hillslope	c.3.9 ha
10.	Exotic pine/geothermal kānuka-mingimingi shrubland (05.01.02) Scattered radiata pine and maritime pine occur over geothermal kānuka and mingimingi shrubland.	Hillslope	c.0.4 ha
11.	Mingimingi-mānuka shrubland (05.03) Mingimingi-mānuka shrubland (05.03.01) Occasional maritime pine are emergent over scrub dominated by mingimingi and mānuka. Geothermal kānuka occurs on heated soils near the margins of this type where it adjoins geothermal kānuka shrubland.	Hillslope	c.0.3 ha
12.	<i>Nephrolepis flexuosa</i> fernland (07.01.10) These areas comprise small patches of <i>Nephrolepis flexuosa</i> fernland that are surrounded by exotic grasses (e.g. Indian doab and paspalum). Bracken, geothermal kānuka, and <i>Lycopodiella cernua</i> occur throughout. Blackberry is encroaching from the margins. This type was not surveyed in 2020.	Hillslope	<0.1 ha
13.	Exotic grassland (08.01) Indian doab grassland (08.01.07) Indian doab occurs around the margins of areas of heated soil.	Shallow gullies, hillslopes	c.0.2

CODE	VEGETATION TYPE	LANDFORM	EXTENT
14.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Te Rau-o-Te Huia part: Heated clays, fumaroles, and mud pools. Occasional geothermal kānuka, <i>Lycopodiella cernua</i>, and water fern are also present. Patches of the mosses, <i>Spaghnum</i> sp. and <i>Campylopus</i> sp., occur near the large fumarole. Heated fumaroles present in open pasture have Indian doab on the margins. Te Rau-o-Te Huia Stream part: Fumaroles, a geothermal crater (with boiling mud), and heated sinter clays. Geothermal kānuka, mingimingi, water fern, <i>Hypolepis ambigua</i>, maritime pine, radiata pine, pampas, blackberry, Spanish heath, and <i>Lycopodiella cernua</i> are present on the margins. Upper Wairākei Stream (Geyser Valley) part: Bare ground, clay soils, and areas of old and young sinter. Occasional small areas of <i>Lycopodiella cernua</i>, geothermal kānuka, monoao, tūrutu, and the mosses <i>Racomitrium</i> sp. and <i>Campylopus</i> sp. are present (too small to map out separately). There has been a slight decrease in the extent of this vegetation type over time.	Scarp, terrace, shallow gullies, crater, hillslope	c.1.1 ha

Indigenous Flora:

Geothermal kānuka (Threatened-Nationally Endangered) is the dominant species at this site. *Lycopodiella cernua*, and *Campylopus* sp., characteristic of geothermal areas, are also present.

A relatively large population of *Dicranopteris linearis* (Threatened-Nationally Endangered) occurs in the Upper Wairākei Stream part of this site (NZTM E1868448 N5721416). A small patch of *D. linearis* is present in the Te Rau-o-Te Huia part of this site.

Nephrolepis flexuosa (At Risk-Naturally Uncommon) occurs at the Te Rau-o-Te Huia Stream and Upper Wairākei Stream (c.7 × 5 metres at NZTM E1868504 N5721367) parts of this site. *N. flexuosa* was recorded in the Te Rau-o-Te Huia part of this site in 2006 but has not been recorded there since.

Given (1976) recorded *Christella* aff. *dentata* (“thermal”) (Threatened-Nationally Endangered) in the Upper Wairākei Stream part of this site in the early 1970s, but it has not been recorded from this site during recent surveys (Wildland Consultants 2012, Bycroft and Beadel 2007, Merrett and Burns 1998) and was not recorded in 2020.

Fauna:

In September 2020 and June 2021, the following indigenous bird species were recorded at this site: pīhoihoi/New Zealand pipit (At Risk-Declining), pōpokotea/whitehead, tūi, pīwakawaka/ North Island fantail, spur-winged plover, riroriro/grey warbler, and tauhou/silvereye.

In September 2020 and June 2021, the following introduced bird species were recorded at this site: Californian quail, chaffinch, dunnoek, European greenfinch, European goldfinch, yellowhammer, Eurasian blackbird, and Australian magpie.

Other common indigenous and introduced bird species typical of the habitat that have previously been recorded at this site include toutouwai/North Island robin (At Risk-Declining, recorded in 2014), pīpīwharau/shining cuckoo, kāhu/swamp harrier, korimako/bellbird, pūtangitangi/paradise shelduck, house sparrow, and song thrush.

Farmed deer, cattle, and sheep graze the geothermal kānuka shrubland and fumaroles in the Te Rau-o-Te Huia and Te Rau-o-Te Huia Stream parts of this site. Goats and brown hares were observed at the site in 2021, along with signs of possums and feral pigs.

**Geothermal
Ecosystems:**

Heated ground (dry), hydrothermally altered ground (now cool), fumaroles, geothermal streamsides.

Current Condition:

Te Rau-o-Te Huia part:

This site comprises several small geothermal areas surrounded by farmland. Domestic livestock, particularly deer, have access to most geothermal areas, although parts have been fenced off to exclude stock. The overall condition is good with few weeds; however, areas that are grazed are more degraded. Mingimingi scrub in the south of the site appears to have declined in condition, since 2011.

Te Rau-o-Te Huia Stream part:

This part comprises several areas of geothermal expressions. It is surrounded by plantation pine forest and farmland. Stock access and trampling is occurring within the western portion. Blackberry and scattered wilding pines are present. If the site is fenced and stock were excluded, the quality of geothermal vegetation is likely to improve markedly. Only the western area of this part of the site was visited in 2020.

Upper Wairākei Stream (Geyser Valley) part:

It appears that some geothermal features have become less active since 2011, however some areas of geothermal vegetation and habitats remain relatively intact and in good condition. Lower soil temperatures have enabled the establishment of many adventive plant species and has contributed to further degradation in quality of the remaining geothermal vegetation. However, some pest plant control (particularly of wilding pines and pampas) has been undertaken recently. Grape, wilding pines, Tasmanian blackwood, Chinese privet, and pampas are the dominant invasive pest plant species present. Geothermal vegetation has recovered considerably since a fire in late 2012.

**Threats/Modification/
Vulnerability:**

Invasive pest plants:

Te Rau-o-Te Huia part:

Wilding pines (c.5-25% cover) are a key threat to this site. Blackberry (c.5% cover), broom, and buddleia (both <1% cover) are present at low density. Exotic grasses (total cover of c.5%, particularly Indian doab, sweet vernal, browntop, and paspalum) occur in cooler areas and on the margins of geothermal habitat.

Te Rau-o-Te Huia Stream part:

Wilding radiata pines occur locally within the geothermal vegetation (c.1% cover). Occasional blackberry and broom are also present (5-25% cover). Cover of broom and blackberry has increased in the eastern areas that have been retired from grazing since about 2014.

Upper Wairākei Stream (Geyser Valley) part:

Parts of this site are highly modified by invasive pest plants, particularly on cooler ground at the southwestern end of the valley. Grape vines cover a large area in the eastern side of the valley (20% cover). Tasmanian blackwood (20% cover) and Chinese privet (20% cover) are also significant threats to the site. Although there has been some control undertaken recently, wilding pines (radiata pine (<1% cover) and lodgepole pine (10% cover)) and pampas (5% cover) remain scattered in places. Other invasive pest plants present within the site include: brush wattle (2% cover in 2014, not seen in 2020), broom (1% cover), purple pampas (1% cover in 2014, not seen in 2020), Douglas fir (<1% cover), lodgepole pine (<1% cover), Japanese cedar (<1% cover), narrow-leaved carpet grass (2% cover), ratstail (<1% cover), Himalayan honeysuckle (<1% cover), tradescantia (1% cover), Spanish heath (1% cover), cotoneaster (<1% cover), blackberry (5% cover), heather (<1% cover in 2014, not seen in 2020), Ovens wattle (1% cover) and buddleia (2% cover).

*Human impacts:***Te Rau-o-Te Huia part:**

This site is on private property and is seldom visited, so direct human impact is low. Tracks have been established on the ridges in the northern part of the site since 2017. This has resulted in some vegetation clearance. Notable control of wilding pines has also been undertaken since 2017.

Te Rau-o-Te Huia Stream part:

Ongoing farming and plantation operations are having a negative impact within some parts of this site.

Upper Wairākei Stream (Geyser Valley) part:

The geothermal valley is run as a tourism venture with a formed circuit walking track; no evidence of visitors creating informal tracks in the vegetation was observed. Some geothermal features described as part of the tourist venture (and for which this valley was once renowned) have become quiescent due to the continued field drawdown for geothermal power generation (Given 1989a). Lowered soil temperatures have enabled the establishment of many adventive plant species, although in some areas in 1998 the soil temperatures were increasing (Merrett and Burns 1998c).

A small part of the site was negatively affected by a fire that resulted from a discarded cigarette butt in late 2012. Geothermal vegetation was burnt in the fire and the resultant bare ground provided opportunities for weed invasion, particularly Spanish heath and pampas. Since 2012, geothermal vegetation has regenerated considerably and some weed control (including control of wilding pines and pampas) has been undertaken.

Chickens and other domesticated fowl from the tea rooms associated with the tourism venture have free access to the site, but are unlikely to have

significant negative impacts. Pest animal traps have recently been established for control of rats and possums.

Grazing:

Te Rau-o-Te Huia part: The site is mostly fenced, however deer, cattle, and sheep graze in the northern part of this site.

Te Rau-o-Te Huia Stream part: The western part of this site is grazed and disturbance of vegetation within the area is significant.

Upper Wairākei Stream (Geyser Valley) part: Livestock do not have access. Landowners have reported recent intrusion of feral pigs, and sign of feral pigs was observed during the 2020 field survey.

Adjoining land use:

Farmland, plantation pine forest; scrub dominated by woody exotic species; indigenous scrub.

Site Change:

Recent change:

Te Rau-o-Te Huia part:

Tracks have been established on the ridges in the northern part of the site since 2017. This has resulted in some vegetation clearance. Notable control of wilding radiata and maritime pines has also been undertaken since this time, although some remain present. Deer access the fenced geothermal kānuka shrubland; tracks and signs of ongoing trampling are common throughout.

The mingimingi scrub in the southern part of the site appears to have declined in condition, and no longer appears to be influenced by current or previous geothermal activity.

Te Rau-o-Te Huia Stream part:

The mixed fernland recorded on the walls of the geothermal crater (NZTM E1867136 N5721902) in 2006 (Wildland Consultants 2006) is no longer present and this area now comprises predominantly geothermally-influenced bare ground with geothermal kānuka, mānuka, mingimingi, blackberry, broom, *Lycopodiella cernua*, and bracken scattered around the margins.

The most significant change since 2014 has been the increased cover of blackberry on the margins of geothermal areas in the eastern parts of the site that were retired from grazing.

Upper Wairākei Stream (Geyser Valley) part:

The fire in 2012 temporarily reduced the area of intact geothermal vegetation and resulted in avenues for weed invasion. However, since then geothermal vegetation has regenerated considerably and some weed control (including control of wilding pines and pampas) has been undertaken. Chinese privet, blackberry, and grape have continued to increase in cover at the site since the previous field surveys in 2004 and 2014. The main change since 2014 is the growth of vegetation in parts of the site, possibly related to a decline in geothermal activity in some areas.

Historical:¹

Burns *et al.* (1996) assessed vegetation change between 1945 and 1993 at this site using aerial photographs.

Te Rau-o-Te Huia part:

Burns *et al.* (1996) estimated that approximately one-quarter of the geothermal vegetation in this part of the site declined since the early 1960s. This conclusion is supported by our analysis of aerial photographs taken in 1961² and 2007 (2007 WRAPS). However, it is likely that the habitat had already undergone degradation prior to the 1960s. The area to the southwest labelled as A on the site map in Wildland Consultants (2012) appears considerably larger in 1961 aerial photographs than it does in the 2007 images. While it is difficult to determine the boundaries of the extent of geothermal and non-geothermal scrub on black and white aerial photographs, the site could have been at least twice the 2007 size. In the 1961 photographs, there is an unvegetated area to the south that is no longer present; this may have either been geothermal loamfield or unvegetated as a result of farming activities. The areas labelled as B on the site map in Wildland Consultants (2012) are in shadow in the historic photographs, so it is hard to determine boundaries. However, these areas are probably similar in size as today. The area labelled as C on the site map in Wildland Consultants (2012) appears very similar in extent in 1961 and 2007 photographs, with pines having a very similar distribution on margins. Stock may have had access to this area in the early 1960s.

Te Rau-o-Te Huia Stream part:

Based on Burns *et al.* (1996), in an area that includes Te Rau-o-Te Huia (site WKV01), geothermal vegetation decreased by at least 23% between 1945 and 1993. This estimate seems reasonable when viewing historical photographs for this site from 1961³. The area labelled as A on the site map in Wildland Consultants (2012) has been converted to pasture since 1961. Also, this part of the site extended further to the south in 1961. It was more difficult to assess site change in other areas. In 2011 the area labelled as B on the site map in Wildland Consultants (2012) had fewer pines than in 1961, but there is no overall evidence of change in the area of the site since 1961. Area C on the site map in Wildland Consultants (2012) was likely in a better condition in 1961 as it was surrounded by pine plantation and may not have been heavily browsed. The exact location of Area D on the site map in Wildland Consultants (2012) is difficult to determine within the nongeothermal and geothermal scrub as these occurred amongst scattered emergent pines. There were more areas of raw-soilfield alongside the stream to the north of the site in 1961. This may indicate that there were greater levels of geothermal surface activity alongside stream margins in the past.

Upper Wairākei Stream (Geyser Valley) part:

Burns *et al.* (1996) found that the extent of geothermal vegetation at this site decreased by at least 74% between 1945 and 1993.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photos: SN 1394 Run 3187 Photos 22-23, 1961.

³ Historic Photos: SN 1394 Run 3187 Photo 23, 1961.

A 1961 aerial photograph was located for this site (Historical photo: SN 1394 Run 3187 Photos 25, 1961). The geothermal vegetation in this photo appears more extensive to the north, west, and to the east of the site. The geothermal vegetation is significantly wider in the middle of the site in 1961. Invasion of wilding pines into geothermal habitat occurred between 1961 and the present day, and the area of geothermal vegetation has become significantly more fragmented.

**Management
Requirements:**

Te Rau-o-Te Huia part and Te Rau-o-Te Huia Stream part:

Domestic livestock should be removed from all geothermal areas. Geothermal features (particularly fumaroles) and vegetation in open pasture should be fenced to exclude stock. Wilding pines should be controlled within geothermal areas. Blackberry and other pest plants should be controlled before they out-compete indigenous geothermal vegetation. A management plan to address weed issues in this part of the site is needed. Further tracks should not be established to prevent loss of geothermal vegetation.

Upper Wairākei Stream (Geyser Valley) part:

Most parts of the site require some weed control. In particular, the grape vines, wilding pines, Tasmanian blackwood, Chinese privet, pampas, blackberry, and tradescantia need to be controlled. Education on ecological values and issues could be undertaken through the placement of signs explaining geothermal features, vegetation, and the changes which occurred as an impact of energy drawdown. A management plan should be prepared to provide guidelines for the manager(s) of this part of the site to address pest plant issues, and to enhance the ecological values that are present.

Significance Level:

R: Regional (Criteria 3, 5, 9).

L: Local (Criterion 5)

**Significance
Justification:**

R: Parts of this site are mapped as being of regional significance because they are a relatively large example of geothermal habitat, which includes ecosystems that were nationally uncommon prior to human settlement (heated ground (dry), geothermal streamsides, and fumaroles; Williams *et al.* 2007, Holdaway *et al.* 2012, Wiser *et al.* 2013). These areas also contain populations of two Threatened (*Dicranopteris linearis* and geothermal kānuka) and one At Risk plant species (*Nephrolepis flexuosa*).

L : The remainder of the site is locally significant because these areas contain small lower quality and isolated areas of geothermal vegetation and habitat amongst farmland and plantation forest.

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and classed the Upper Wairākei Stream (Geyser Valley) part of this site as Category B - the second highest category.

The Te Rau-o-Te Huia and the Te Rau-o-Te Huia Stream parts of this site have previously been considered part of the same site in some studies (e.g. Burns *et al.* 1996).

References:

Burns *et al.* 1996; Bycroft and Beadel 2007; Department of Conservation 1997; Given 1976, 1989a & 1996; Merrett and Burns 1998a & 1998b; Wildland Consultants 2000, 2004b, 2006, 2012, 2014a, 2021a, 2021b.



Geothermal kānuka shrubland amongst farmland in the Te Rau-o-Te Huia Stream part of the Te Rau-o-Te Huia-Wairākei site. NZTM N1867386 N5721776. 30 September 2020.



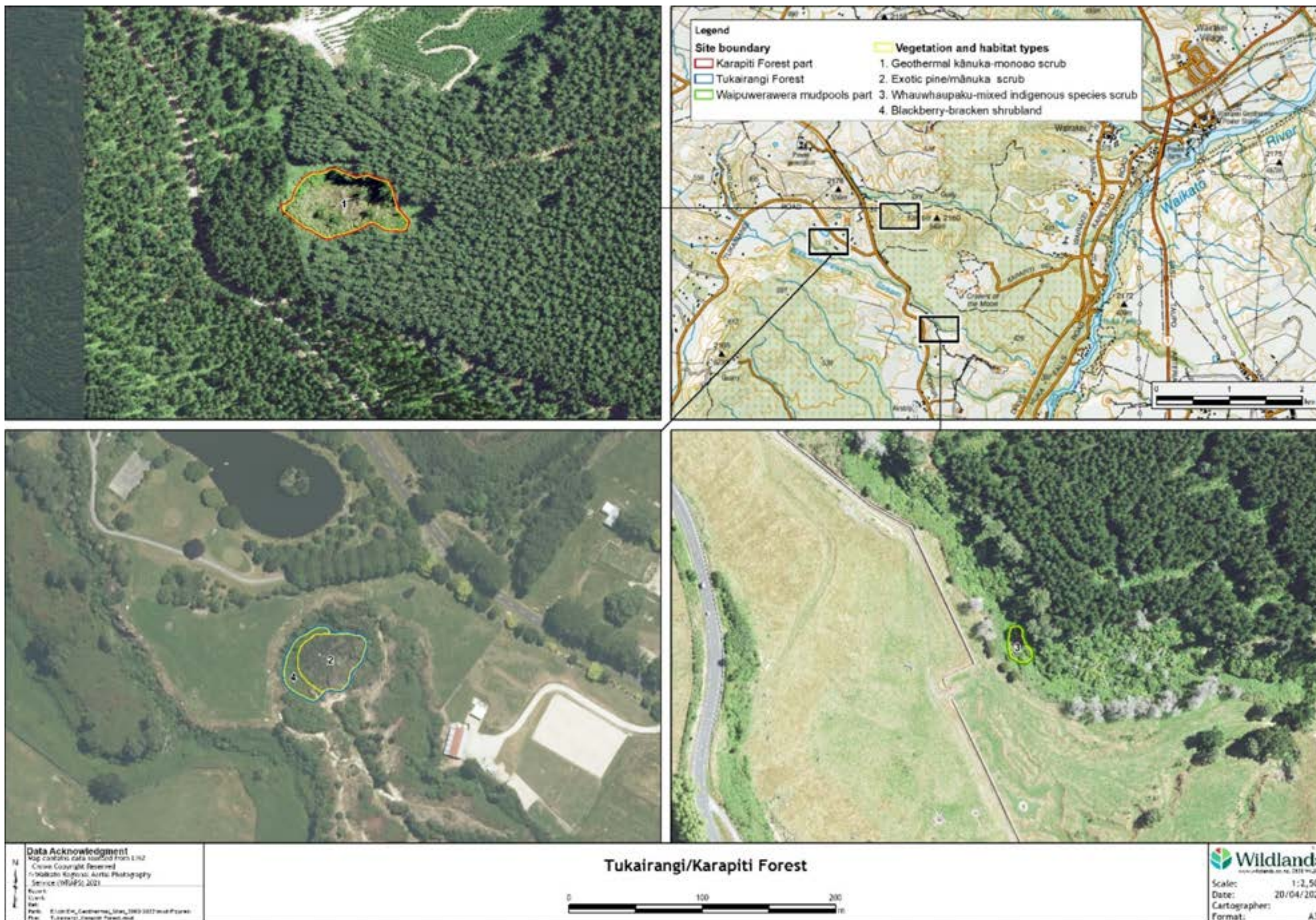
Northwest view over the main valley at the Upper Wairākei Stream part of the Te Rau-o-Te Huia-Wairākei site. Recent pampas control is evident in the foreground. NZTM E1868485 N5721398. 11 September 2020.



Geothermal kānuka shrubland in the Te Rau-o-Te Huia part of the Te Rau-o-Te Huia-Wairākei site. NZTM E1866231 N5722483. 25 June 2021.



Large fumarole in the southern part of the Te Rau-o-Te Huia part of the Te Rau-o-Te Huia-Wairākei site. NZTM E1866041 N5722126. 25 June 2021.



TUKAIRANGI/KARAPITI FOREST¹

Ecological District: Atiamuri **GPS Reference:** NZTM E1865128 N5718488
 NZTM E1866117 N5718870
 NZTM E1866669 N5717306

Geothermal System: Wairākei-Tauhara **Altitude:** c.420-480 m
Geothermal System: Wairākei
Bioclimatic Zone: Submontane **Local Authority:** Taupō
Extent of Geothermal Habitat: c.0.6 ha
Extent of Geothermal Vegetation: c.0.6 ha
Date of Most Recent Field Survey: 10 September 2020 and 25 June 2021

CODE	TYPE	LANDFORM	EXTENT
1.	Geothermal kānuka scrub (04.01) Geothermal kānuka-monoao scrub (04.01.06) Scattered radiata pine and lodgepole pine are emergent over a canopy dominated by geothermal kānuka and monoao up to c.1 metre tall, with occasional mingimingi and tūrutu. The groundcover comprises patches of the mosses <i>Campylopus</i> sp. and <i>Racomitrium</i> sp., with occasional kiokio and <i>Lycopodiella cernua</i>. Mingimingi-bracken scrub is present on the margins, with abundant Himalayan honeysuckle and blackberry, scattered prickly mingimingi, and a few whauwhaupaku saplings. Occasional broom, karamū, and Spanish heath are present. This area was previously mapped in Wildland Consultants (2014a) as the Karapiti Forest site.	Crater, gully	c.0.3 ha
2.	Mānuka scrub (04.04) Exotic pine/mānuka-geothermal kānuka scrub (04.04.03) This vegetation type covers most of the crater floor and side walls of the explosion crater. Scattered maritime pine (c.5-8 metres tall), and a few radiata pine and silver birch (to c.6 metres tall) are emergent over a mixed shrubland of mānuka and geothermal kānuka, with scattered broom also present. Blackberry is sparsely scattered throughout, becoming more common on the margins. There are occasional patches of kiokio, and a few very local monoao on the eastern side of the crater. Mingimingi, tāwiniwini, tūrutu, and small patches of <i>Gleichenia microphylla</i> are scattered throughout. Seedlings of koromiko and whauwhaupaku are also present. A few very small patches of geothermally-influenced bare ground occur on the crater floor. No elevated temperatures were observed in 2020.	Crater floor, crater walls	c.0.2 ha

¹ The site Tukairangi/Karapiti Forest merges two sites (Waipuerawera Stream/Tukairangi and Karapiti Forest) from the 2014 study (Wildland Consultants 2014a), and also includes an additional example of geothermal vegetation that was found alongside Waipuerawera Stream in 2021. The spelling Waipuerawera is used for the stream based on cultural reports prepared by Ngāti Tūwharetoa.

	On the cooler crater rim, whauwhaupaku is emergent over mānuka, and broom. This area was mapped in Wildland Consultants (2014a) as part of the Waipuwera Stream/Tukairangi site.		
3.	Whauwhaupaku dominant scrub (04.05) Whauwhaupaku-mixed indigenous species scrub (04.05.01) A series of springs occur alongside a length of at least 25 metres of Waipuwera Stream. There is also a series of mudpools. Some patches of <i>Lycopodiella cernua</i> are present beside one of the mudpools. The canopy is dominated by whauwhaupaku to c.10 metres tall, with scattered whekī and kōhūhū. There is abundant kiokio, bracken, and blackberry around geothermal features and open areas. It was difficult to view all of the area in the valley floor safely. Geothermal habitat may be more extensive than the area mapped in the 2021 field survey.	Gully	<0.1 ha
4.	Exotic species dominant shrubland (05.08) Blackberry-bracken shrubland (05.08.07) Dense scrub dominated by blackberry occurs on the crater walls and margins, particularly on the western side of the crater. There are scattered patches of bracken, occasional Himalayan honeysuckle and a few scattered silver birch (c.5 metres tall), mānuka, and occasional emergent maritime pine, whauwhaupaku, and whekī. This area was mapped in Wildland Consultants (2014a) within the Waipuwera Stream/Tukairangi site.	Crater, crater walls	<0.1 ha

Indigenous Flora: Geothermal kānuka (Threatened-Nationally Endangered) is present. Other species typical of geothermal habitat that are present include mānuka, and monoao.

Dicranopteris linearis was recorded in the Karapiti part of this site in 2004, but was not observed at the site during two subsequent surveys in 2014 or 2020/21.

Dicranopteris linearis (Threatened-Nationally Endangered) and *Lycopodiella cernua* have been recorded at the Tukairangi part of this site in the past (Given 1989a), but were not seen in 2003, 2011, or 2020/21, and are unlikely to remain present.

Fauna: Bird species recorded at this site in 2020 and 2021 include pōpokotea/whitehead, toutouwai/North Island robin (At Risk-Declining), kāhu/swamp harrier, spur-winged plover, tūi, korimako/bellbird, pīwakawaka/North Island fantail, riroriro/grey warbler, and tauhou/silvereye. Introduced species include mallard (flying over), eastern rosella, dunnock, Eurasian blackbird, chaffinch and Australian magpie.

Geothermal Ecosystems: Hydrothermally altered ground (now cool), geothermal streamsides.

Current Condition: The extent of geothermal vegetation and habitat appears to be declining throughout this site. Geothermal kānuka has increased in stature, but decreased in cover within the site, while monoao and prickly mingimingi

have increased in extent, indicating reduced geothermal activity within the areas. No obvious steaming ground was observed within the areas, which also supports the assessment of reduced geothermal activity. Pest plants have become more prominent within the site and on the margins. Of the three areas the mudpools alongside Waipuwera Stream (Vegetation Type 3), are in the best condition while the sites previously mapped as Karapiti Forest and Waipuwera Stream/Tukairangi have lost much of their geothermal character over the last 20 years, although evidence of past activity remains.

At the Tukairangi part of this site, no evidence of the fumaroles or hot ground that were recorded in 1989 (Given 1989a) were observed during the 2003, 2011, or 2020 field surveys.

Threats/Modification/ Vulnerability:

Invasive pest plants:

Karapiti Forest part: This part of the site is surrounded by plantation pine forest. As the geothermal activity within the site has decreased since 2004, the cover of wilding pines has increased from c.5% to c.10% cover. The cover of other pest plants has also slightly increased. In 2021, the following pest plants were present, particularly on the margins: Himalayan honeysuckle and blackberry (both c.5% cover), and broom, Spanish heath, and pampas, (each c.1% cover).

Tukairangi part: Wilding pines (maritime pines (15% cover) and radiata pines (5% cover)), blackberry (25% cover), broom (10% cover), silver birch (1% cover), Montpellier broom (1% cover), Spanish heath (1% cover), and Himalayan honeysuckle (1% cover), occur within the crater and on the surrounding margins.

Human impacts:

All three areas have shown a reduction in geothermal activity since 2004. Whilst geothermal activity fluctuates naturally, the power station draw-off may be exacerbating this natural fluctuation. In the Tukairangi part of this site, a bulldozer track has recently been formed which leads to the southern margin of the crater. Some pest plant control has recently been undertaken near the mudpools and springs alongside the Waipuwera Stream.

Grazing:

Livestock are not a threat to these geothermal areas.

Adjoining land use:

Karapiti Forest and Waipuwera mudpools: Harvesting and ongoing management of the surrounding pine plantation forest could result in ongoing damage to the geothermal vegetation. The mountain-biking tracks that have been established within the adjoining pine plantation are unlikely to affect the geothermal vegetation within this site.

Tukairangi: This part of the site is mainly surrounded by mixed exotic and indigenous species scrub, and farmland. This area is fenced and domestic stock are excluded.

Site Change:

Recent change:

Geothermal activity at the two larger parts of this site appears to have declined between each survey, in 2004, 2011/2014 and 2020/21. This is evidenced by the reduced dominance of geothermal species, particularly geothermal kānuka; the absence of obvious steaming ground; and the colonisation and growth of bracken and blackberry on areas of previously bare ground. The extent of geothermal vegetation and habitat at the site is getting smaller, but this is not evident on aerial photographs.

It is unknown what the condition of the vegetation around the mudpools alongside Waipuerawera Stream was prior to the current survey.

*Historical:*¹

Karapiti Forest part: 1961 aerial photographs² and 2007 aerial photographs were compared. There was a more extensive area of scrub around the site in 1961, although most of this was unlikely to be geothermal. There was also more bare ground around the site however it is difficult to assess whether some of the bare ground was geothermal or human-induced disturbance. There has probably been a small reduction of size of this site since 1961, with the establishment of pine plantation around the immediate margin of the site. It is estimated that the geothermal habitat has been reduced by c.10-20% since 1961 up until 2007.

Tukairangi part: A greater extent of bare ground was present in 1961 compared with the area visible in the 2007 photographs (i.e. there is an increase in the extent of vegetation in the 2007 aerals). Increased extent of vegetation (including non-geothermal vegetation) could be due to a number of factors including reduced heat from geothermal systems (see description of current condition above).

Management Requirements:

A buffer zone around the geothermal areas should be created to avoid damage to the site being caused during harvesting and ongoing management of the surrounding pine plantation forest. No buffer was created in previous plantings around the Karapiti Forest part of this site. Wilding pines should be controlled at this site on a regular basis (i.e. every 3-5 years).

Significance Level:

Local (Criteria 3, 5)

Significance Justification:

This site is of local significance because it contains small examples of ecosystems that were nationally uncommon prior to human settlement (geothermal streamsides, hydrothermally altered ground (now cool); Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013), and a small population of a Threatened species (geothermal kānuka).

Notes:

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and the Tukairangi part of this site was classed as Category B - the second highest category.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.
² Historical photos: SN 1394 Run 3188 Photos 22-23, 1961.

Macroinvertebrate taxa found in geothermally influenced streams here was in general typical of those recorded in non-geothermal streams, but which can tolerate high temperatures or unusual pH (Duggan and Boothroyd 2002).

References:

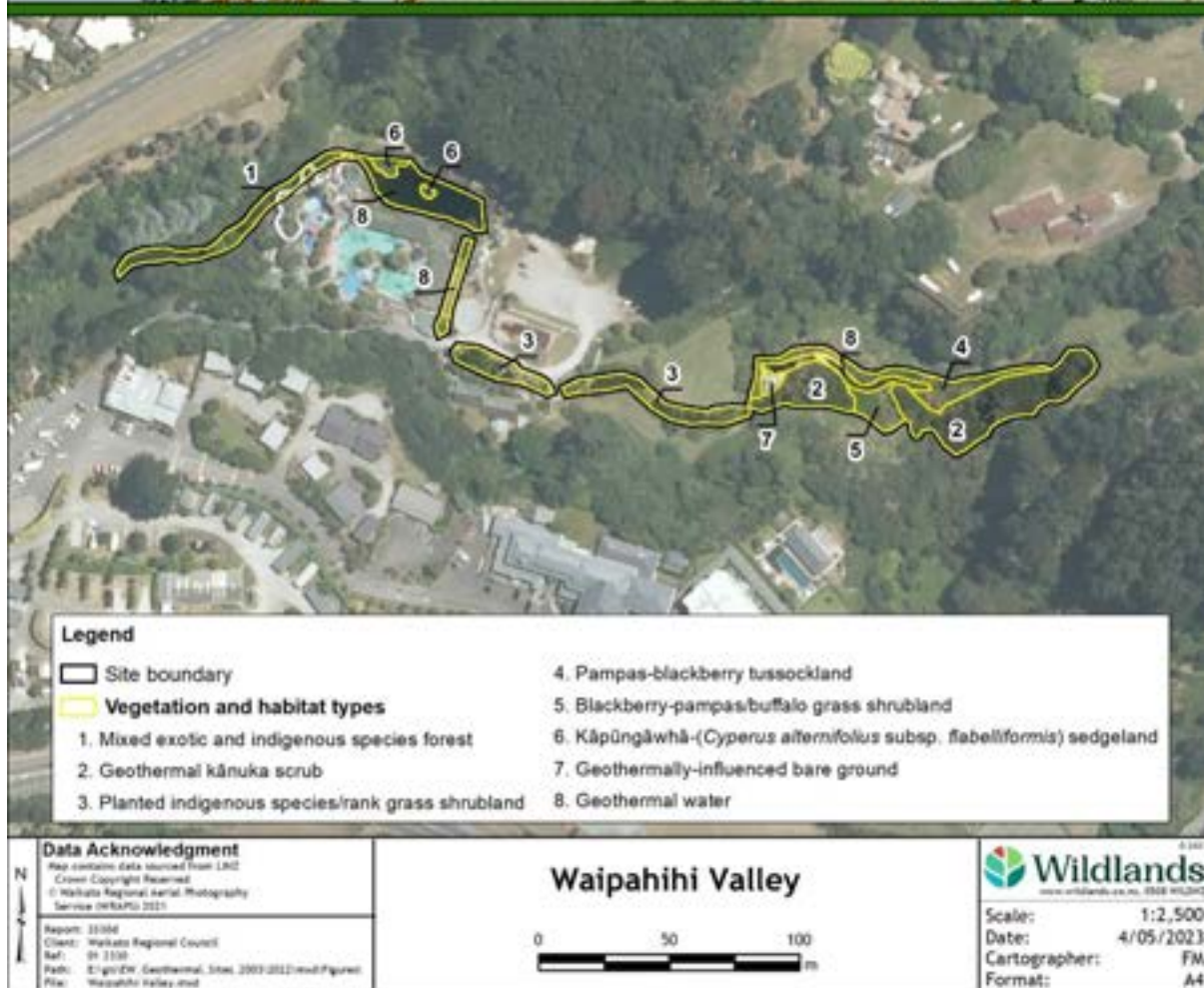
Burns *et al.* 1996; Department of Conservation 1997, 1998; Duggan and Boothroyd 2002; Given 1989a & 1996; Merrett and Burns 1998a, 1998b; Wildland Consultants 2000, 2004b, 2012, 2014a, 2021a, 2021b.



Geothermal kānuka-monoao scrub with scattered wilding pines at the Karapiti Forest part of the Tukairangi/Karapiti Forest site. NZTM E1866133 N5718882. 25 June 2021.



Tukairangi/Karapiti Forest - Tukairangi part. The crater walls are becoming increasingly dominated by pest plants such as blackberry. A vehicle access track has recently been formed which leads to the southern margin of the crater. NZTM E1865096 N5718500. 10 September 2020.



WAIPAHIHI VALLEY

Ecological District:	Taupō	GPS Reference:	NZTM E1869718 N5711647
Geothermal System:	Wairākei-Tauhara	Altitude:	420 m
Geothermal System:	Tauhara		
Bioclimatic Zone:	Submontane	Local Authority:	Taupō
Extent of Geothermal Habitat:	c.0.4 ha		
Extent of Geothermal Vegetation:	c.0.4 ha		
Date of Most Recent Field Survey:	29 March 2022		

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Mixed exotic and indigenous species forest (01.03) Mixed exotic and indigenous species forest (01.03.01) Forest canopy species present include ornamental cherry, kōhūhū, houhere, tree lucerne, olive, and whekī. Groundcover is locally dominated by tradescantia and blackberry. Other groundcover and understorey species present include Himalayan honeysuckle, montbretia, Cretan brake, and ivy. Occasional <i>Carex secta</i> are also present.	Riparian margins	<0.1 ha
2.	Geothermal kānuka scrub (04.01) Geothermal kānuka scrub (04.01.01) Geothermal kānuka (to c.5 metres tall) is present over exotic grasses and <i>Cyperus ustulatus</i> with patches of blackberry. Planted eucalyptus, olives, and ornamental cherries are present within exotic grassland at the eastern end of this type. Exotic grass species present include tall fescue, Yorkshire fog, browntop, and buffalo grass, with buffalo grass dominating in the downstream part of this vegetation type. At least one geothermal spring is present in the eastern part of this type.	Riparian margin	c.0.2 ha
3.	Mixed indigenous species shrubland (05.07) Planted indigenous species/rank grass shrubland (05.07.02) Planted indigenous, and pest plant woody species over rank grass. The surface temperature of the stream in this vegetation type was 39 °C in 2014. The eastern part of this type comprises scattered patches of geothermal kānuka (1.5-5 metres tall) along the margins of the stream. There are local areas of grassland dominated by buffalo grass, browntop, and creeping bent. Also located within this type is an area of <i>Cyperus ustulatus</i> and buffalo grass sedge-grassland. The grass is mown to within half a metre of the stream margin.	Drain, stream channel	<0.1 ha
3.	Exotic species-dominant shrubland (05.09) Blackberry-pampas/buffalo grass shrubland (05.09.09) Dense blackberry shrubland with locally common pampas, <i>Cyperus ustulatus</i> , and locally abundant buffalo grass dominates the true right stream margins below a geothermal spring. <i>Cyclosorus interruptus</i> is locally scattered along the stream margins amongst buffalo grass. Local patches of bracken are	Riparian margin	<0.1 ha

CODE	VEGETATION TYPE	LANDFORM	EXTENT
	present amongst the blackberry, with occasional patches of kāpūngāwhā are present on the stream margins.		
4.	Pampas tussockland (06.01) Pampas-blackberry tussockland (06.01.01) Pampas to 3 m tall with abundant areas of blackberry and pōhoe.	Riparian margins	<0.1 ha
5.	Exotic species-dominant grassland (08.01) Buffalo grass-pampas-blackberry grassland (08.01.17) Buffalo grass with scattered pampas and blackberry and occasional geothermal kānuka. <i>Cyclosorus interruptus</i> is abundant on the stream margins and within the grassland habitats.	Riparian margin	<0.1 ha
6.	Indigenous sedgeland (09.01) Kāpūngāwhā-(<i>Cyperus alternifolius</i> subsp. <i>flabelliformis</i>) sedgeland (09.01.07) Sedgeland, dominated by kāpūngāwhā with local <i>Cyperus alternifolius</i> subsp. <i>flabelliformis</i> ¹ and occasional <i>Carex secta</i> , is located near the outflow of the pond and on an island in a pond surrounded by warm geothermal water.	Lake margin	<0.1 ha
7.	Loamfield (20.01) Geothermally-influenced bare ground (20.01.01) Sinter, bare soil.	Flat	<0.1 ha
8.	Water (22.01) Geothermal water (22.01.01) West of Vegetation Type 4, Waipahihi Stream is channelised by earthworks and stone walls. The rocky stream margins within this area are planted with ornamental garden plants including <i>Choysia ternata</i> , rose, rhododendron, variegated harakeke, and ornamental cherry. Scattered kānuka and whekī are also present. Some <i>Cyperus ustulatus</i> has established near the water's edge. At the northwestern end of the diverted stream, a large pond is present. Patches of raupō and kāpūngāwhā are present where the stream flows into the pond. Raupō extends around the southern margin of the pond. <i>Cyperus alternifolius</i> subsp. <i>flabelliformis</i> becomes dominant on the northern margin. The northern margin of the pond is lined with boulders, upon which ornamental garden species have been planted. Below the pond, the stream is bordered by mown grassland.	Stream, pond	<0.1 ha

Indigenous Flora:

A small population of *Cyclosorus interruptus* (At Risk-Declining) is present near the spring on the stream margins in the eastern part of the site. Fewer plants were observed in 2014 compared with 2009, possibly as a result of competition from buffalo grass. The size of this population was not assessed in 2022 but was probably similar to that recorded in 2014. Geothermal kānuka (Threatened-Nationally Endangered) is also present.

¹ This species was referred to as *Cyperus involucratus* in Wildland Consultants 2014a and is considered a synonym of this species.

Hypolepis dicksonioides (At Risk-Naturally Uncommon) was previously recorded near the large pond (Beadel 1988).

Fauna: Common indigenous and introduced species, typical of the habitat, are present and include: tūi, pīwakawaka/North Island fantail, chaffinch, mallard, and Eurasian blackbird.

Geothermal Ecosystems: Geothermal streamsides, geothermal wetland, hydrothermally altered ground (now cool).

Current Condition: The spring and all geothermal vegetation is fenced to exclude domestic stock, and is surrounded by exotic grasses and planted exotic trees including olive, eucalyptus, and ornamental cherry. In places, dense blackberry and buffalo grass are present near the stream margins. Although some hand control of blackberry has been undertaken, blackberry appears to have expanded recently (between 2014 and 2022). Waipahihi Stream has been diverted and partially channelised within the De Bretts outdoor pool area. Planted exotic ornamental species are common along the margins of the stream throughout the site and in some cases have naturalised (for example *Cyperus alternifolius* subsp. *flabelliformis*). The extent of pampas has increased at the site in recent years.

**Threats/Modification/
Vulnerability:**

Invasive pest plants: Exotic plant species are prevalent throughout the site. Blackberry (10% cover), pampas (10% cover), and buffalo grass (10% cover) are locally common along the stream margins. These three species pose a serious risk to the *Cyclosorus interruptus* population at the site and need to be monitored and controlled. Any control requires care to not damage the *Cyclosorus* and will require ecological oversight. Other pest plant species present include pampas (c.5% cover), tradescantia (c.2% cover), *Cyperus alternifolius* subsp. *flabelliformis* (c.1% cover), radiata pine (<1% cover), black pine (<1% cover), ivy (c.2% cover), ornamental cherry (<1% cover), Spanish heath (<1% cover), Himalayan honeysuckle (<1% cover), Montpellier broom (<1% cover), Cretan brake (<1% cover), *Cotoneaster franchetii* (<1% cover), Japanese honeysuckle (<1% cover), agapanthus (<1% cover), and periwinkle (<1% cover). Since 2014, the most notable change is the increased extent and cover of pampas on sinter and geothermal margins. Assessment of changes in the extent of pest plants have only been made for part of the site.

Human impacts: Vegetation clearance and other site modifications (surface water draw off, pool complex development) have altered natural geothermal expressions and vegetation composition. Lawn mowing may reduce the likelihood of natural regeneration of geothermal kānuka and *Cyclosorus interruptus* populations. In 2011, the adjoining landowner damaged geothermal sinter and surrounding geothermal and non-geothermal vegetation by undertaking earthworks downstream of the geothermal spring.

Grazing: Grazing occurs in a fenced area above the geothermal spring, but stock are excluded from the areas of the site that contain geothermal features and habitat.

Adjoining land use: Parking, recreational areas, and the spa pool complex occur in the western part of the site. A mosaic of indigenous and exotic forest and restoration plantings occur on the gully sides. Residential dwellings, subdivision, and accommodation occur on the surrounding valley terraces.

Site Change:

Recent change: Blackberry and pampas have increased in cover since 2014 to become abundant in part of the site. Tracks have been cut through the blackberry in places. The cover of buffalo grass has expanded into parts of the site and, in places, now forms a dense grassland on the margins of the stream. Of particular note, the cover of buffalo grass has increased markedly within the areas of highest natural geothermal quality since 2010. This may be a threat to *Cyclosorus interruptus* populations at this site. The population of *Cyclosorus interruptus* appears to have decreased in size slightly since 2010, although no population census was carried out in 2014 or 2022 because access to the stream margins was unsafe (c.f. 2010 survey). A marked increase in the extent and cover of pampas was noted around the upper geothermal pool in 2017 (c.f. 2014 survey).

A full review of changes at this site has not been undertaken since 2014 as access has not been granted for this type of survey.

*Historical:*¹ Comparison of the extent and character of geothermal vegetation in 1946 and 2007 was undertaken. In 1946 there was substantially less urban and commercial development surrounding this site than exists presently, and the cliffs surrounding the site were less densely covered with vegetation. There appeared to be a more extensive area of wetland and open water at the site in 2007 when compared to 2014, although in places the composition of the vegetation in the gully floor could not be discerned. The site was probably at least five to ten times larger in the 1940s than it is today. The stream below the site is likely to have been more geothermal in character in 1941 than it is currently. These changes to the site are believed to have occurred as a result of the 1931 Napier earthquake.

The first recorded history of the physical geothermal features of Waipahihi Valley reported a temperature of up to *c.*31 °C in the stream as it flowed towards Lake Taupō (Hochstetter 1864 in Cody 1993). Heated pools near the spring head, as large as *c.*50 × 30 metres, and a stream 1-2 metres across, were present in the 1870s (Fox 1874, Skey 1878, and Harris 1878 in Cody 1993). The pools were described as having raupō and rushes on the margins (Cody 1993). The Terraces Hotel was built in 1889 above the upper reaches of the stream at the top of ‘a black sinter slope’, and utilised the heated water in the valley below as swimming baths for their guests. These pools were renowned as the ‘finest natural hot swimming baths in the Thermal District’, ranging in temperature from 36.7 to 76.7 °C (Cody 1993).

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

Management Requirements:

Blackberry, pampas, and buffalo grass should be controlled around the stream margins in the east of the site to maintain the *Cyclosorus interruptus* population. However, a conservative approach to the management of these species should be undertaken to protect the *C. interruptus* from the extreme temperatures of summer or winter frost (i.e. no more than 25% of the total area of the site should be cleared of blackberry or other pest plants at one time).

The site should be monitored to identify any potential changes in vegetation cover associated with draw-off from the geothermal system. The owner of the De Bretts outdoor pools intends to restore the stream margins and the site of the old bathing pools. Development and implementation of an ecological management plan for this area would ensure sustainable management of geothermal features and vegetation.

Significance Level:

Regional (Criteria 3, 5, 6)

Significance Justification:

Waipahihi Valley is of regional significance because it contains ecosystems that were nationally uncommon prior to human settlement (geothermal streamsides) (Williams *et al.* 2007; Holdaway *et al.* 2012; Wiser *et al.* 2013). It contains the southern-most population of *Cyclosorus interruptus* in New Zealand.

Notes:

Waipahihi Valley was classed as being of regional significance in 2014 (Wildland Consultants 2014a).

Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in that study this site was classed as Category C - the third highest category for protection.

References:

Beadel 1988; Cody 1993; Given 1996; Wildland Consultants 2000, 2004b, 2012, 2014a, 2017a, 2021a, 2021b.



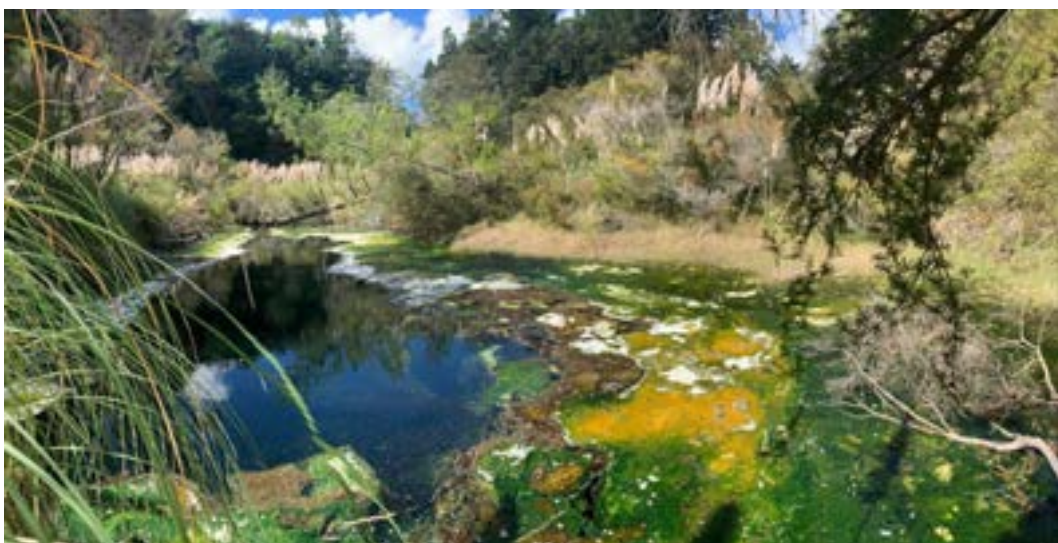
Cyclosorus interruptus in the upper Waipahihi Valley. 29 March 2022. NZTM E1869745 N5711662.



The location of the spring at the eastern end of Waipahihi Valley. NZTM E1869807 N5711688. 29 March 2022.



The geothermal stream at Waipahihi Valley. Note the abundant exotic plants such as blackberry, pampas and the exotic grassland in the middle background is mostly buffalo grass. NZTM E1869732 N5711651. 29 March 2022.



A geothermal pool with sinter and algae at Waipahihi Valley. Note the abundant pampas that has increased surrounding the site in the last ten years. NZTM E1869680 N5711666. 29 March 2022.

VASCULAR PLANT SPECIES IN RECORDED AT SURFACE GEOTHERMAL SITES IN THE WAIRĀKEI-TAUHARA GEOTHERMAL SYSTEM

1. WAIRĀKEI GEOTHERMAL SYSTEM

Scientific Name	Common Name	Te Rau-o-Te Huia-Wairākei	Te Kiri o Hinekai	Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	Tukairangi/Karapiti Forest	Carters of the Moon	Hall of Fame Stream	Additional Species recorded by Merrett and Burns (1998a) in Wairākei Geothermal System
INDIGENOUS VASCULAR PLANT SPECIES								
Monocot. trees and shrubs								
<i>Cordyline australis</i>	Ti kōuka, cabbage tree	✓						
Dicot. trees and shrubs								
<i>Aristotelia serrata</i>	Makomako, wineberry			✓			✓	
<i>Brachyglottis repanda</i>	Rangiora	✓		✓			✓	
<i>Coprosma lucida</i>	Karamū, kāramuramu, glossy karamū	✓	✓					
<i>Coprosma robusta</i>	Karamū, kāramuramu	✓	✓	✓	✓	✓	✓	
<i>Coriaria arborea</i> var. <i>arborea</i>	Tutu		✓	✓				
<i>Dracophyllum strictum</i>	Tōtorowhiti		✓					
<i>Dracophyllum subulatum</i>	Monoao	✓	✓		✓	✓		
<i>Fuchsia excorticata</i>	Kōtukutuku, kōnini			✓			✓	
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taipuku		✓		✓			
<i>Geniostoma ligustrifolium</i> var. <i>ligustrifolium</i>	Hangehange			✓				
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	✓	✓	✓	✓		
<i>Leptecophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi	✓	✓		✓	✓		
<i>Leptospermum scoparium</i> agg.	Mānuka	✓	✓		✓			
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	✓	✓	✓	✓		
<i>Leucopogon fraseri</i>	Pātōtara		✓					
<i>Melicytus ramiflorus</i> subsp. <i>ramiflorus</i>	Māhoe	✓				✓	✓	
<i>Myrsine australis</i>	Māpou, matipou, māpau	✓						
<i>Pittosporum colensoi</i>	Rautāwhiri, rautāhiri			✓				
<i>Pittosporum eugenioides</i>	Tarata, lemonwood			✓				
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓	✓		✓			
<i>Pomaderris amoena</i>	Tauhinu							✓
<i>Pseudopanax arboreus</i>	Whauwhaupaku, puahou, five finger	✓	✓	✓	✓	✓		
<i>Pterophylla racemosa</i>	Kāmahi	✓	✓					
<i>Schefflera digitata</i>	Patē	✓		✓				
<i>Sophora tetraptera</i>	Kōwhai			✓				
<i>Veronica stricta</i> var. <i>stricta</i>	Koromiko, kōkōmuka	✓		✓	✓	✓		
Dicot. lianes								
<i>Calystegia sepium</i> subsp. <i>roseata</i>	Pōhue	✓						
<i>Muehlenbeckia australis</i>	Puka	✓		✓				
<i>Rubus cissoides</i> agg.	Tātarāmoa, tātarakeke, bush lawyer							✓
Lycopods and psilopsids								
<i>Huperzia varia</i>	Whiri-o-Raukatauri		✓					
<i>Lycopodiella cernua</i>	Mātukutuku	✓	✓		✓	✓		
<i>Lycopodium volubile</i>	Waewaekoukou		✓			✓		
<i>Psilotum nudum</i>						✓		
Ferns								
<i>Adiantum cunninghamii</i>	Huruhuru tapairu, maidenhair fern	✓		✓			✓	
<i>Anogramma leptophylla</i>	Annual fern; Jersey fern			✓				
<i>Asplenium bulbiferum</i>	Mouku, hen and chicken fern							✓
<i>Asplenium flabellifolium</i>	Necklace fern					✓		
<i>Asplenium flaccidum</i>	Makawe, ngā makawe o Raukatauri	✓		✓				
<i>Asplenium oblongifolium</i>	Huruhuru whenua	✓		✓				
<i>Asplenium polyodon</i>	Petako	✓		✓		✓		
<i>Blechnum chambersii</i>	Rereti, nini	✓						
<i>Blechnum deltoides</i>	Korokio						✓	
<i>Blechnum discolor</i>	Piupiu, crown fern	✓		✓				
<i>Blechnum filiforme</i>	Pānako	✓						
<i>Blechnum fluviatile</i>	Kiwikiwi, kiwakiwa		✓					
<i>Blechnum novae-zelandiae</i>	Kiokio	✓	✓	✓	✓	✓	✓	
<i>Blechnum parrisiae</i>		✓	✓					
<i>Cheilanthes sieberi</i>			✓			✓		
<i>Christella</i> aff. <i>dentata</i> (b) (AK 126902 "thermal")				✓			✓	
<i>Cyathea dealbata</i>	Ponga, silver fern	✓	✓					
<i>Cyathea medullaris</i>	Mamaku, black treen fern			✓				
<i>Deparia petersenii</i> subsp. <i>congrua</i>		✓		✓			✓	
<i>Dicksonia fibrosa</i>	Whekī-ponga, kurīpākā	✓		✓				
<i>Dicksonia squarrosa</i>	Whekī	✓	✓	✓	✓	✓	✓	
<i>Dicranopteris linearis</i>		✓	✓		✓	✓		
<i>Diplazium australe</i>		✓		✓				
<i>Gleichenia microphylla</i>	Waewaekākā,	✓	✓		✓			
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	✓	✓				
<i>Hiya distans</i>		✓						
<i>Hymenophyllum flabellatum</i>	Mauku, filmy fern							✓
<i>Hypolepis ambigua</i>		✓	✓	✓	✓	✓		
<i>Hypolepis dicksonioides</i>			✓	✓				
<i>Hypolepis lactea</i>								✓
<i>Lastreopsis microsora</i> subsp. <i>pentangularis</i>			✓					
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pāraharaha, hound's tongue fern	✓		✓				
<i>Leptopteris hymenophylloides</i>	Heruheru		✓					
<i>Nephrolepis flexuosa</i>	Native ladder fern	✓	✓			✓		
<i>Paesia scaberula</i>	Mātātā	✓	✓	✓		✓		
<i>Pakau pennigera</i>	Piupiu, pākaurōharoha, feather fern, gully fern			✓				
<i>Pneumatopteris pennigera</i>	Pākau	✓		✓			✓	
<i>Polystichum vestitum</i>	Pūniu, prickly shield fern							✓

Scientific Name	Common Name	Te Rau-o-Te Huia-Wairākei	Te Kiri o Hinekai	Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	Tukairangi/Karapiti Forest	Carters of the Moon	Hall of Fame Stream	Additional Species recorded by Merrett and Burns (1998a) in Wairākei Geothermal System
<i>Pteridium esculentum</i>	Rārahu, bracken	✓	✓	✓	✓	✓	✓	
<i>Pteris tremula</i>	Turawera, shaking brake	✓		✓				
<i>Pyrrosia elaeagnifolia</i>	Leather-leaf fern	✓	✓	✓		✓		
<i>Rumohra adiantiformis</i>	Karuwhai							✓
<i>Thelypteris</i> sp.			✓					
Orchids								
<i>Microtis parviflora</i>								✓
<i>Microtis unifolia</i> agg.				✓				
<i>Thelymitra</i> sp. indet.		✓		✓				
Grasses								
<i>Austroderia fulvida</i> ²	Toetoe		✓					
<i>Microlaena stipoides</i>	Pātiti, meadow rice grass	✓						
<i>Poa anceps</i> agg.								✓
<i>Rytidosperma gracile</i>		✓						
Sedges								
<i>Carex geminata</i> agg.	Rautahi						✓	
<i>Carex maorica</i>								✓
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio	✓	✓	✓				
<i>Cyperus ustulatus</i> f. <i>ustulatus</i>	Toetoe upoko-tangata	✓		✓				
<i>Eleocharis acuta</i>	Spike sedge							✓
<i>Fimbristylis velata</i>						✓*Given 1989a		
Rushes								
<i>Juncus edgariae</i>	Wi, wīwī							✓
Monocot. herbs (other than orchids, grasses, sedges, and rushes)								
<i>Astelia fragrans</i>	Kakaha							✓
<i>Dianella nigra</i>	Tūrutu	✓	✓	✓	✓	✓		
<i>Lemna disperma</i>	Karearea		✓	✓				
<i>Phormium cookianum</i> subsp. <i>hookeri</i>	Wharariki, mountain flax	✓						
<i>Phormium tenax</i>	Harakeke, flax		✓	✓				
<i>Typha orientalis</i>	Raupō		✓					
Composite herbs								
<i>Euchiton audax</i>		✓						
<i>Euchiton involucratus</i>				✓				
<i>Euchiton sphaericus</i>								✓
<i>Pseudognaphalium luteoalbum</i> agg.	Pukatea			✓				
<i>Senecio bipinnatisectus</i>	Australian fireweed	✓		✓				
Dicot. herbs (other than composites)								
<i>Epilobium nerteroides</i>		✓						
<i>Geranium homeanum</i>	Pinakitere			✓				
<i>Glossostigma elatinoides</i>							✓	
<i>Hydrocotyle heteromeria</i>				✓				
<i>Hydrocotyle moschata</i> var. <i>moschata</i>				✓				
<i>Oxalis exilis</i>				✓				
<i>Persicaria decipiens</i>	Tutunawai							✓
<i>Urtica sykesii</i>							✓	
NATURALISED AND EXOTIC VASCULAR PLANT SPECIES								
Gymnosperms								
<i>Chamaecyparis lawsoniana</i>	Lawson's cypress			✓				
<i>Cryptomeria japonica</i>	Japanese cedar	✓						
<i>Pinus contorta</i>	Lodgepole pine	✓			✓	✓		
<i>Pinus pinaster</i>	Maritime pine	✓	✓	✓	✓	✓		
<i>Pinus radiata</i>	Radiata pine	✓	✓	✓	✓	✓	✓	
<i>Pseudotsuga menziesii</i>	Douglas fir	✓		✓				
Dicot. trees and shrubs								
<i>Acacia mearnsii</i>	Black wattle					✓		
<i>Acacia melanoxylon</i>	Tasmanian blackwood	✓		✓				
<i>Acacia pravissima</i>	Ovens wattle	✓						
<i>Alnus glutinosa</i>	common alder			✓				
<i>Betula pendula</i>	Silver birch			✓	✓			
<i>Buddleja davidii</i>	Buddleia	✓	✓	✓		✓		
<i>Calluna vulgaris</i>	Heather	✓						
<i>Chamaecytisus palmensis</i>	Tree lucerne			✓				
<i>Cotoneaster franchetii</i>		✓				✓		
<i>Cotoneaster glaucophyllus</i>	Cotoneaster			✓		✓		
<i>Cytisus scoparius</i>	Broom	✓	✓	✓	✓	✓	✓	
<i>Dendrobenthamia capitata</i>	Strawberry dogwood			✓				
<i>Erica lusitanica</i>	Spanish heath	✓	✓	✓	✓	✓		
<i>Eucalyptus</i> sp.	Eucalyptus			✓		✓		
<i>Leycesteria formosa</i>	Himalayan honeysuckle	✓	✓	✓	✓	✓	✓	
<i>Ligustrum lucidum</i>	Tree privet			✓				
<i>Ligustrum sinense</i>	Chinese privet	✓		✓		✓	✓	
<i>Lupinus arboreus</i>	Lupin		✓	✓		✓		
<i>Prunus laurocerasus</i>	Cherry laurel			✓				
<i>Prunus</i> sp.	Ornamental cherry			✓		✓		
<i>Rhododendron</i> sp. (unidentified)	Rhododendron			✓				
<i>Robinia pseudoacacia</i>	False acacia, black locust, robinia		✓					
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓	✓	✓	✓	✓	
<i>Salix cinerea</i>	Grey willow			✓		✓		
<i>Teline monspessulana</i>	Montpellier broom	✓	✓	✓	✓	✓		
<i>Ulex europaeus</i>	Gorse		✓	✓				
Dicot. lianes								
<i>Calystegia silvatica</i>	Greater bindweed	✓		✓				
<i>Hedera helix</i>	Ivy			✓				
<i>Jasminum humile</i>	Italian jasmine, yellow jasmine	✓						
<i>Jasminum polyanthum</i>	Jasmine			✓				
<i>Lonicera japonica</i>	Japanese honeysuckle	✓		✓				

Scientific Name	Common Name	Te Rau-o-Te Huia-Wairākei	Te Kiri o Hinekai	Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	Tukairangi/Karapiti Forest	Carters of the Moon	Hall of Fame Stream	Additional Species recorded by Merrett and Burns (1998a) in Wairākei Geothermal System
<i>Parthenocissus inserta</i>				✓				
<i>Vinca major</i>	Periwinkle			✓				
<i>Vitis vinifera</i>	Grape	✓						
Ferns								
<i>Dryopteris affinis</i>	Golden Shield fern			✓				
<i>Pteris cretica</i>	Cretan Brake			✓				
Grasses								
<i>Agrostis capillaris</i>	Browntop	✓						
<i>Agrostis stolonifera</i>	Creeping bent		✓	✓				
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓	✓	✓				
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass	✓	✓			✓		
<i>Bromus diandrus</i>	Ripgut brome			✓				
<i>Cenchrus clandestinus</i>	Kikuyu grass			✓				
<i>Cortaderia jubata</i>	Purple pampas	✓						
<i>Cortaderia selloana</i>	Pampas	✓	✓	✓	✓	✓		
<i>Cynodon dactylon</i>	Indian doab		✓	✓				
<i>Dactylis glomerata</i>	Cocksfoot	✓		✓				
<i>Digitaria ciliaris</i>	Summer grass		✓	✓				
<i>Eragrostis brownii</i>	Bay grass	✓	✓			✓		
<i>Holcus lanatus</i>	Yorkshire fog	✓	✓	✓				
<i>Leersia oryzoides</i>				✓				
<i>Lolium perenne</i>	Rye grass	✓		✓				
<i>Paspalum dilatatum</i>	Paspalum	✓		✓		✓		
<i>Paspalum urvillei</i>	Vasey grass		✓					
<i>Poa annua</i>	Annual poa	✓		✓				
<i>Poa pratensis</i>	Kentucky bluegrass							✓
<i>Sporobolus africanus</i>	Ratstail	✓						
Sedges								
<i>Cyperus eragrosis</i>	Umbrella sedge			✓				
Rushes								
<i>Juncus articulatus</i>	Jointed rush	✓						
<i>Juncus bufonius</i> var. <i>bufonius</i>	Toad rush			✓				
<i>Juncus bulbosus</i>	Bulbous rush	✓		✓				
<i>Juncus tenuis</i> var. <i>tenuis</i>	Track rush	✓						
Monocot. herbs (other than orchids, grasses, sedges, and rushes)								
<i>Agapanthus praecox</i>	Agapanthus			✓				
<i>Aloe</i> sp.	Aloe		✓					
<i>Crocasmia ×crocosmiiflora</i>	Montbretia			✓				
<i>Lomandra filiformis</i>				✓				
<i>Tradescantia fluminensis</i>	Tradescantia	✓		✓				
Composite herbs								
<i>Achillea millefolium</i>	Yarrow	✓		✓				
<i>Bellis perennis</i>	Lawn daisy			✓				
<i>Cirsium vulgare</i>	Scotch thistle			✓				
<i>Crepis capillaris</i>	Hawksbeard	✓		✓				
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane	✓	✓	✓				
<i>Gamochaeta coarctata</i>	Purple cudweed	✓		✓				
<i>Hypochaeris radicata</i>	Catsear	✓		✓				
<i>Jacobaea vulgaris</i>	Ragwort	✓						
<i>Mycelis muralis</i>	Wall lettuce	✓		✓				
<i>Senecio sylvaticus</i>	Wood groundsel			✓				
<i>Sonchus oleraceus</i>	Puha, sow thistle	✓		✓				
<i>Taraxacum officinale</i>	Dandelion	✓		✓				
Dicot. herbs (other than composites)								
<i>Aphanes inexpectata</i>	Piert parsley			✓				
<i>Apium nodiflorum</i>	Water celery	✓						
<i>Capsella bursa-pastoris</i>	Shepherd's purse			✓				
<i>Cardamine</i> sp.		✓						
<i>Centaurium erythraea</i>	Centaury			✓				
<i>Cerastium fontanum</i> subsp. <i>vulgare</i>	Mouse-ear chickweed	✓		✓				
<i>Daucus carota</i>	Wild carrot			✓				
<i>Digitalis purpurea</i>	Foxglove	✓	✓	✓				
<i>Euphorbia peplus</i>	Milkpest plant			✓				
<i>Foeniculum vulgare</i>	Fennel			✓				
<i>Fumaria muralis</i>	Scrambling fumitory			✓				
<i>Galium aparine</i>	Cleavers	✓		✓				
<i>Geranium mole</i>	Dovesfoot cranesbill			✓				
<i>Linaria purpurea</i>	Purple linaria			✓				
<i>Lotus pedunculatus</i>	Lotus	✓		✓				
<i>Lotus suaveolens</i>	Hairy birdsfoot trefoil			✓				✓
<i>Ludwigia palustris</i>	Water purslane							✓
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	Scarlet pimpernel	✓		✓				
<i>Lythrum hyssopifolia</i>	Hyssop loosestrife			✓				
<i>Malva</i> sp.	Mallow			✓				
<i>Modiola caroliniana</i>	Creeping mallow			✓				
<i>Nasturtium officinale</i>	Watercress	✓		✓				
<i>Ornithopus perpusillus</i>	Wild serradella	✓	✓	✓				
<i>Oxalis</i> sp.		✓						
<i>Parentucellia viscosa</i>	Tarweed			✓				
<i>Phytolacca octandra</i>	Inkweed	✓		✓				
<i>Plantago australis</i>	Swamp plantain							✓
<i>Plantago lanceolata</i>	Narrow-leaved plantain	✓		✓				
<i>Plantago major</i>	Broad-leaved plantain	✓		✓				
<i>Portulaca oleracea</i>	Wild portulaca		✓	✓		✓		
<i>Prunella vulgaris</i>	Selfheal	✓		✓				
<i>Ranunculus repens</i>	Creeping buttercup	✓						
<i>Reynoutria japonica</i>	Asiatic knotweed			✓				

Scientific Name	Common Name	Te Rau-o-Te Huia-Wairākei	Te Kiri o Hinekai	Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	Tukairangi/Karapiti Forest	Carters of the Moon	Hall of Fame Stream	Additional Species recorded by Merrett and Burns (1998a) in Wairākei Geothermal System
<i>Rumex acetosella</i>	Sheep's sorrel	✓		✓				
<i>Rumex obtusifolius</i>	Broad-leaved dock	✓		✓				
<i>Solanum nigrum</i>	Black nightshade	✓		✓				
<i>Stellaria media</i>	Chickpest plant			✓				
<i>Trifolium pratense</i>	Red clover			✓				
<i>Trifolium repens</i>	White clover			✓				
<i>Urtica dioica</i> subsp. <i>gracilis</i>	Stinging nettle	✓						
<i>Verbascum thapsus</i>	Woolly mullein			✓				
<i>Verbena bonariensis</i>	Purple-top	✓						
<i>Veronica arvensis</i>	Field speedwell	✓						
<i>Veronica plebeian</i>	Australian speedwell			✓				

2. TAUHARA GEOTHERMAL SYSTEM

(P) Planted.

Scientific Name	Common Name	Otumuheke	East Taupō	Waipahihi Valley	Taupō Shoreline	Tauhara South
INDIGENOUS SPECIES						
Gymnosperms						
<i>Dacrycarpus dacrydioides</i>	Kahikatea	✓ (P)	✓ (P)			
<i>Dacrydium cupressinum</i>	Rimu	✓ (P)		✓ (P)		
<i>Phyllocladus trichomanoides</i>	Tānekaha	✓ (P)				
<i>Podocarpus totara</i> var. <i>totara</i>	Tōtara	✓ (P)				
Monocot. trees and shrubs						
<i>Cordyline australis</i>	Ti kōuka, cabbage tree	✓				
<i>Cordyline banksii</i>	Ti ngahere, forest cabbage tree		✓			
Dicot. trees and shrubs						
<i>Brachyglottis repanda</i>	Rangiora	✓				
<i>Coprosma dumosa</i>		✓ (P)(2013)				
<i>Coprosma lucida</i>	Karamū, kāramuramu, glossy karamū	✓	✓			
<i>Coprosma robusta</i>	Karamū, kāramuramu	✓	✓	✓		
<i>Dodonaea viscosa</i>	Akeake	✓ (P)				
<i>Dracophyllum subulatum</i>	Monoao	✓	✓			
<i>Gaultheria antipoda</i>	Tāwiniwini, koropuka, takapo, taupuku		✓			
<i>Geniostoma ligustrifolium</i> var. <i>ligustrifolium</i>	Hangehange	✓				
<i>Hoheria sexstylosa</i>	Houhere, lacebark	✓		✓		
<i>Knightia excelsa</i>	Rewarewa			✓		
<i>Kunzea robusta</i>	Kānuka	✓	✓	✓		
<i>Kunzea tenuicaulis</i>	Geothermal kānuka	✓	✓	✓		✓
<i>Leptocophylla juniperina</i> var. <i>juniperina</i>	Prickly mingimingi	✓				
<i>Leptospermum scoparium</i>	Mānuka	✓	✓	✓		
<i>Leucopogon fasciculatus</i>	Mingimingi	✓	✓			
<i>Lophomyrtus bullata</i>	Ramarama			✓		
<i>Lophozonia menziesii</i>	Silver beech, tawhai	✓		✓		
<i>Melicytus ramiflorus</i> subsp. <i>ramiflorus</i>	Māhoe	✓ (P)	✓ (P)	✓ (P)		
<i>Metrosideros robusta</i>	Northern rātā				✓	
<i>Myrsine australis</i>	Māpou, matipou, māpau		✓			
<i>Pittosporum cornifolium</i>	Tāwhiri karo, warewhareatua	✓ (P)				
<i>Pittosporum crassifolium</i>	Karo		✓ (P)			
<i>Pittosporum eugenoides</i>	Tarata; lemonwood	✓ (P)	✓ (P)			
<i>Pittosporum tenuifolium</i>	Kōhūhū, rautāhiri, rautāwhiri	✓ (P)				
<i>Plagianthus regius</i> subsp. <i>regius</i>	Ribbonwood, mānatu	✓ (P)				
<i>Planchonella costata</i>	Tawāpou	✓	✓	✓		
<i>Pseudopanax crassifolius</i> × <i>P. lessonii</i>				✓ (P)		
<i>Pseudopanax laetus</i> (5)				✓ (P)		
<i>Sophora microphylla</i>	Kōwhai	✓ (P)				
<i>Sophora tetraptera</i>	Kōwhai		✓ (P)	✓ (P)		
<i>Veronica stricta</i> var. <i>stricta</i>	Koromiko, kōkōmuka	✓	✓	✓		
Dicot. lianes						
<i>Calystegia sepium</i> subsp. <i>roseata</i>	Pōhue	✓				
<i>Metrosideros diffusa</i>	Rātā			✓		
<i>Muehlenbeckia australis</i>	Puka	✓		✓		
Lycopods and psilopsids						
<i>Lycopodiella cernua</i>	Mātukutuku	✓	✓			✓
<i>Lycopodium volubile</i>	Waewaekoukou, climbing clubmoss		✓			
Ferns						
<i>Asplenium bulbiferum</i>	Mouku, mouki, mauku, hen and chicken fern			✓		
<i>Asplenium flabellifolium</i>	Necklace fern, butterfly fern		✓		✓	
<i>Asplenium flaccidum</i> subsp. <i>flaccidum</i>	Makawe, ngā makawe o raukatauri, drooping spleenwort	✓	✓			
<i>Asplenium oblongifolium</i>	Huruhuru whenua, shining spleenwort		✓			
<i>Asplenium polyodon</i>	Petako, paratao, sickle spleenwort	✓		✓		
<i>Blechnum chambersii</i>	Rereti, nini, lance fern			✓		
<i>Blechnum discolor</i>	Piupiu, petipeti, crown fern	✓				
<i>Blechnum minus</i>	Swamp kiokio	✓				
<i>Blechnum novae-zelandiae</i>	Kiokio, horokio	✓	✓	✓	✓	
<i>Blechnum parrisiae</i>	Pukupuku	✓	✓		✓	
<i>Blechnum penna-marina</i> subsp. <i>alpina</i>	Little hard fern		✓			
<i>Christella</i> aff. <i>dentata</i> (b) (AK 126902 "thermal")		✓			✓ *2014	
<i>Cyathea dealbata</i>	Ponga, silver fern	✓	✓	✓		
<i>Cyathea medullaris</i>	Mamaku, black tree fern	✓	✓			
<i>Cyclosorus interruptus</i>		✓		✓		
<i>Deparia petersenii</i> subsp. <i>congrua</i>		✓		✓		
<i>Dicksonia fibrosa</i>	Whekī-ponga, kurīpākā	✓		✓		
<i>Dicksonia squarrosa</i>	Whekī	✓	✓	✓		
<i>Diplazium australe</i>		✓	✓			
<i>Gleichenia microphylla</i>	Waewaekākā, carrier tangle fern		✓			
<i>Histiopteris incisa</i>	Mātātā, water fern	✓	✓	✓		

Scientific Name	Common Name	Otumuheke	East Taupō	Waipahihi Valley	Taupō Shoreline	Tauhara South
<i>Hiya distans</i>		✓				
<i>Hymenophyllum sanguinolentum</i>	Piripiri, filmy fern		✓			
<i>Hypolepis ambigua</i>		✓	✓	✓		
<i>Hypolepis dicksonioides</i>	Giant hypolepis	✓		✓		
<i>Lecanopteris pustulata</i> subsp. <i>pustulata</i>	Kōwaowao, pāharahara, hound's tongue fern	✓	✓	✓		
<i>Nephrolepis flexuosa</i>	Indigenous ladder fern	✓ ¹				
<i>Paesia scaberula</i>	Mātātā, hard fern	✓	✓	✓		
<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	Rārahu, bracken	✓	✓	✓		
<i>Pteris tremula</i>	Turawera, shaking brake	✓	✓	✓		
<i>Pyrosia elaeagnifolia</i>	Leather-leaf fern	✓	✓	✓		
Orchids						
<i>Microtis unifolia</i> agg.				✓		
<i>Thelymitra</i> sp.		✓				
Grasses						
<i>Austroderia fulvida</i>	Toetoe	✓	✓			
<i>Chionochloa flavicans</i> f. <i>flavicans</i>		✓ (P)		✓ (P)		
<i>Microlaena stipoides</i>	Pātiti, meadow rice grass	✓	✓			
<i>Pentapogon avenoides</i>		✓	✓			
<i>Pentapogon crinitus</i>	Plume grass			✓		
<i>Rytidosperma gracile</i>			✓			
<i>Carex secta</i>	Pūrei, makura, pūreirei, pūrekireki, pūkio	✓		✓		
<i>Carex virgata</i>	Pūrei	✓	✓			
<i>Cyperus ustulatus</i>	Toetoe upoko-tangata	✓		✓	✓	
<i>Isolepis prolifera</i>			✓			
<i>Machaerina rubiginosa</i>		✓	✓			
<i>Schoenoplectus tabernaemontani</i>	Kāpūngāwhā	✓		✓		
Rushes						
<i>Juncus edgariae</i>	Wi, wiwi			✓		
<i>Juncus planifolius</i>				✓		
Monocot. herbs (other than orchids, grasses, sedges, and rushes)						
<i>Astelia fragrans</i>	Kakaha	✓ (P)				
<i>Dianella nigra</i>	Tūrutu	✓	✓	✓		
<i>Phormium cookianum</i> subsp. <i>hookeri</i>	Wharariki, mountain flax		✓ (P)			
<i>Phormium tenax</i>	Harakeke, flax	✓		✓ ²		
<i>Triglochin striata</i>	Arrow grass			✓		
<i>Typha orientalis</i>	Raupō	✓				
Composite herbs						
<i>Pseudognaphalium luteoalbum</i> agg.	Pukatea	✓		✓		
<i>Senecio bipinnatisectus</i>	Australian fireweed	✓		✓		
<i>Senecio minimus</i>				✓		
Dicot. herbs (other than composites)						
<i>Cardamine</i> sp.				✓		
<i>Dichondra repens</i>	Mercury Bay weed			✓		
<i>Epilobium cinereum</i>	Papakoura			✓		
<i>Glossostigma elatinoides</i>					✓	
<i>Hydrocotyle heteromeria</i>				✓		
<i>Hypericum pusillum</i>					✓	
<i>Limosella lineata</i>	Mudwort		✓			
<i>Pelargonium inodorum</i>	Kopata	✓				
<i>Persicaria decipiens</i>	Tutunawai	✓				
<i>Stellaria parviflora</i>	Kohukohu		✓			
NATURALISED AND EXOTIC SPECIES						
Gymnosperms						
<i>Chamaecyparis lawsoniana</i>	Lawson's cypress	✓				
<i>Pinus nigra</i>	Black pine			✓		
<i>Pinus pinaster</i>	Maritime pine	✓	✓	✓		
<i>Pinus radiata</i>	Radiata pine	✓	✓	✓		
<i>Pseudotsuga menziesii</i>	Douglas fir	✓	✓	✓		
Monocot. trees and shrubs						
<i>Phoenix canariensis</i>	Phoenix palm			✓ (P)		
<i>Yucca gloriosa</i>	Yucca			✓ (P)		
Dicot. trees and shrubs						
<i>Acacia melanoxylon</i>	Tasmanian blackwood	✓	✓	✓		
<i>Acacia pravissima</i>	Ovens wattle			✓		
<i>Arbutus unedo</i>	Strawberry tree	✓	✓	✓		
<i>Banksia intermedia</i>			✓			
<i>Banksia integrifolia</i>	Banksia		✓			
<i>Betula pendula</i>	Silver birch	✓	✓	✓		
<i>Buddleja davidii</i>	Buddleia	✓	✓	✓		
<i>Callistemon</i> sp.	Bottlebrush			✓ (P)		
<i>Chamaecytisus palmensis</i>	Tree lucerne	✓	✓	✓		
<i>Choisya ternata</i>	Mexican orange			✓		
<i>Dendrobenthamia capitata</i>	Strawberry dogwood	✓		✓	✓	
<i>Cotoneaster franchetii</i>		✓	✓	✓		
<i>Cotoneaster glaucophyllus</i>	Cotoneaster	✓	✓	✓	✓	
<i>Cytisus scoparius</i>	Broom	✓	✓	✓		✓
<i>Erica lusitanica</i>	Spanish heath	✓	✓	✓		
<i>Eucalyptus</i> sp.	Eucalyptus		✓	✓		
<i>Feijoa sellowiana</i>	Feijoa	✓ (P)				
<i>Ilex aquifolium</i>	Holly	✓				
<i>Leycesteria formosa</i>	Himalayan honeysuckle	✓	✓			
<i>Lupinus arboreus</i>	Lupin	✓	✓	✓		
<i>Paulownia tomentosa</i>	Paulownia	✓				
<i>Populus</i> sp.			✓	✓		
<i>Prunus xdomestica</i>	Plum	✓				
<i>Rhododendron</i> sp. (unidentified)	Rhododendron	✓		✓		
<i>Robinia pseudoacacia</i>	False acacia, black locust, robinia	✓		✓		
<i>Rosa</i> sp.	Climbing rose	✓		✓		
<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)	Blackberry	✓	✓	✓	✓	✓
<i>Salix babylonica</i>	Weeping willow			✓		
<i>Salix cinerea</i>	Grey willow	✓	✓			
<i>Salix xfragilis</i>	Crack willow	✓				
<i>Teline monspessulana</i>	Montpellier broom	✓	✓	✓		
<i>Ulex europaeus</i>	Gorse	✓	✓			
Dicot. lianes						
<i>Calystegia silvatica</i>	Greater bindweed	✓		✓		
<i>Delairea odorata</i>	German ivy	✓	✓			
<i>Hedera helix</i>	Ivy	✓	✓	✓		
<i>Jasminum polyanthum</i>	Jasmine	✓	✓	✓		

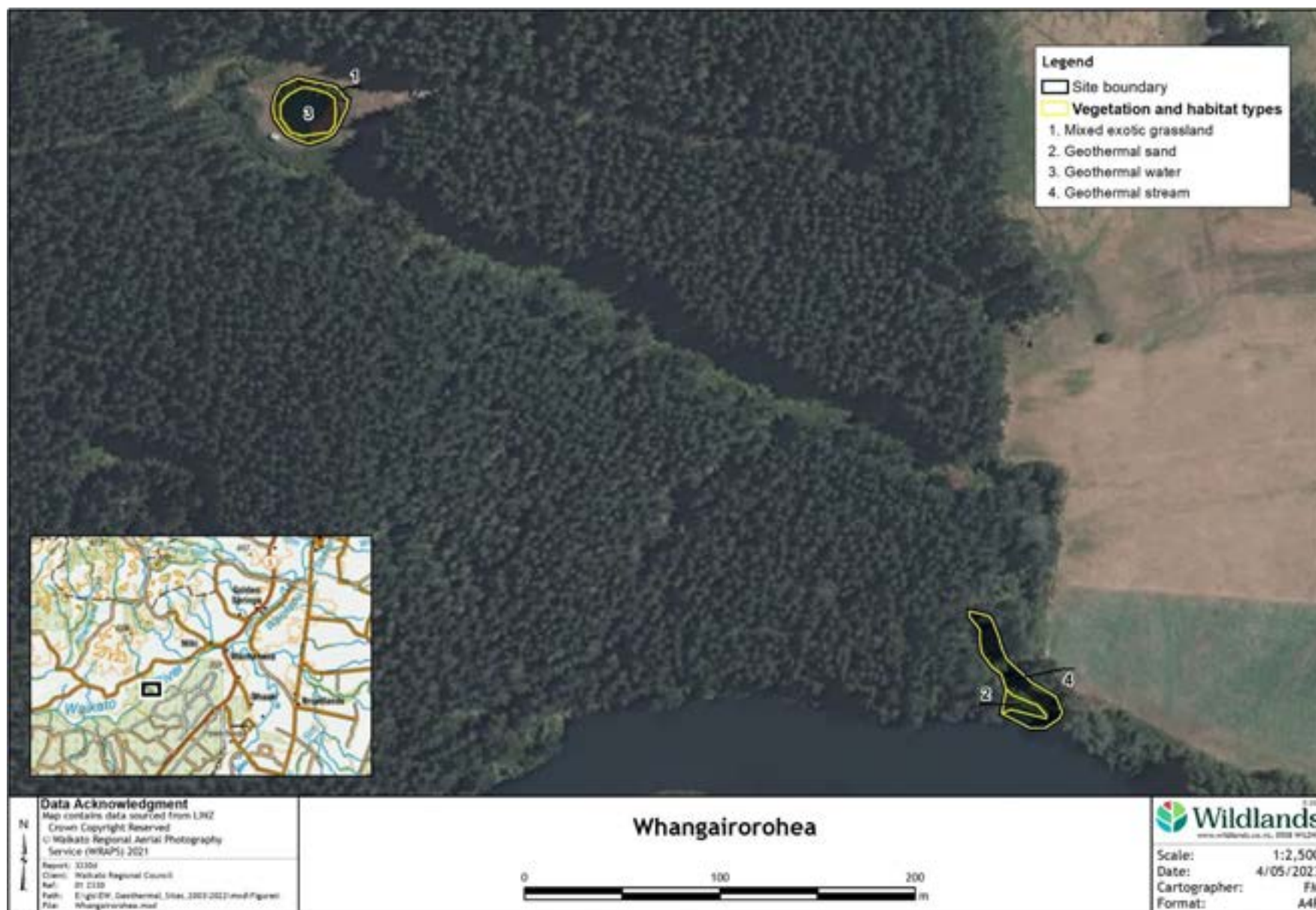
¹ Probably extinct at site – not recorded since 2014

² A cultivated variety of harakeke.

Scientific Name	Common Name	Otumuheke	East Taupō	Waipahihi Valley	Taupō Shoreline	Tauhara South
<i>Lonicera japonica</i>	Japanese honeysuckle	✓	✓	✓	✓	
<i>Vinca major</i>	Periwinkle	✓		✓		
Ferns						
<i>Dryopteris affinis</i>	Golden shield fern	✓	✓			
<i>Dryopteris filix-mas</i>	Male fern	✓	✓			
<i>Pteris cretica</i>	Cretan brake	✓	✓	✓	✓	
Grasses						
<i>Agrostis capillaris</i>	Browntop	✓	✓	✓		✓
<i>Agrostis stolonifera</i>	Creeping bent			✓		
<i>Aira caryophyllea</i> subsp. <i>caryophyllea</i>	Silver hairy grass	✓		✓		
<i>Anthoxanthum odoratum</i>	Sweet vernal	✓	✓	✓		✓
<i>Axonopus fissifolius</i>	Narrow-leaved carpet grass	✓	✓	✓		✓
<i>Briza minor</i>	Shivery grass			✓		
<i>Bromus diandrus</i>	Ripgut brome	✓				
<i>Bromus willdenowii</i>	Prairie grass			✓		
<i>Cortaderia selloana</i>	Pampas	✓	✓	✓	✓	
<i>Cynodon dactylon</i>	Indian doab	✓	✓	✓		
<i>Cynosurus cristatus</i>	Crested dogstail			✓		
<i>Dactylis glomerata</i>	Cocksfoot	✓	✓			
<i>Digitaria sanguinalis</i>	Summer grass		✓			
<i>Ehrharta erecta</i>	Veldt grass	✓	✓	✓		
<i>Festuca rubra</i> subsp. <i>rubra</i>	Red fescue		✓			
<i>Holcus lanatus</i>	Yorkshire fog	✓	✓	✓		
<i>Lolium arundinaceum</i> subsp. <i>arundinaceum</i>	Tall fescue	✓	✓	✓		
<i>Lolium perenne</i>	Rye grass	✓	✓			
<i>Paspalum dilatatum</i>	Paspalum	✓	✓	✓		✓
<i>Paspalum urvillei</i>	Vasey grass	✓				
<i>Poa annua</i>	Annual poa	✓	✓	✓	✓	
<i>Setaria gracilis</i>	Knot-root bristle grass		✓			
<i>Sporobolus africanus</i>	Ratstail			✓	✓	
<i>Stenotaphrum secundatum</i>	Buffalo grass		✓	✓		
Sedges						
<i>Cyperus congestus</i>	Purple umbrella sedge			✓		
<i>Cyperus eragrostis</i>	Umbrella sedge			✓		
Rushes						
<i>Juncus acuminatus</i>	Sharp-fruited rush	✓		✓	✓	
<i>Juncus effusus</i> var. <i>effusus</i>	Soft rush, leafless rush	✓		✓		
<i>Juncus tenuis</i> var. <i>tenuis</i>	Track rush	✓				
Monocot. herbs (other than orchids, grasses, sedges, and rushes)						
<i>Agapanthus praecox</i>	Agapanthus	✓	✓	✓		
<i>Crocasmia ×crocosmiiflora</i>	Montbretia	✓		✓		
<i>Kniphofia praecox</i>	Red hot poker			✓ (P)		
<i>Sisyrinchium iridifolium</i>	Purple-eyed grass			✓		
<i>Tradescantia fluminensis</i>	Tradescantia	✓	✓	✓		
Composite herbs						
<i>Achillea millefolium</i>	Yarrow	✓				
<i>Cirsium vulgare</i>	Scotch thistle	✓	✓	✓		
<i>Crepis capillaris</i>	Hawksbeard		✓	✓		
<i>Erechtites hieraciifolia</i>	American fireweed	✓				
<i>Erigeron karvinskianus</i>	Mexican daisy			✓	✓	
<i>Erigeron sumatrensis</i>	Broad-leaved fleabane	✓	✓	✓	✓	
<i>Gamochaeta calviceps</i>	Silky cudweed	✓				
<i>Gamochaeta coarctata</i>	Purple cudweed	✓				
<i>Hypochaeris radicata</i>	Catsear	✓	✓	✓		✓
<i>Jacobaea vulgaris</i>	Ragwort	✓	✓	✓		
<i>Lactuca serriola</i>	Prickly lettuce	✓	✓	✓		
<i>Lapsana communis</i>	Nipplewort			✓		
<i>Leontodon taraxacoides</i>	Hawkbit			✓		
<i>Mycelis muralis</i>	Wall lettuce	✓	✓	✓		
<i>Sonchus asper</i>	Prickly puha	✓	✓	✓		
<i>Sonchus oleraceus</i>	Puha, sow thistle	✓	✓	✓		
<i>Taraxacum officinale</i>	Dandelion	✓	✓	✓		
Dicot. herbs (other than composites)						
<i>Acanthus mollis</i>	Bear's breeches			✓		
<i>Angelica pachycarpa</i>	Angelica			✓		
<i>Brassica rapa</i> subsp. <i>sylvestris</i>	Wild turnip	✓				
<i>Cardamine</i> sp.		✓	✓			
<i>Carpobrotus edulis</i>	Ice plant			✓		
<i>Cerastium fontanum</i> subsp. <i>vulgare</i>	Mouse-ear chickweed	✓				
<i>Cotyledon orbiculata</i>	Pig's ear			✓		
<i>Digitalis purpurea</i>	Foxglove	✓	✓	✓		
<i>Epilobium ciliatum</i>	Tall willow herb	✓		✓		
<i>Euphorbia peplus</i>	Milkweed		✓	✓		
<i>Fumaria muralis</i>	Scrambling fumitory	✓				
<i>Galium aparine</i>	Cleavers	✓	✓	✓		
<i>Geranium molle</i>	Dovesfoot cranesbill		✓	✓		
<i>Lotus pedunculatus</i>	Lotus	✓	✓	✓		
<i>Ludwigia palustris</i>	Water purslane	✓		✓		
<i>Lysimachia arvensis</i> subsp. <i>arvensis</i>	Scarlet pimpernel	✓				
<i>Modiola caroliniana</i>	Creeping mallow			✓		
<i>Nasturtium officinale</i>	Watercress	✓	✓			
<i>Oenothera</i> sp.	Primrose	✓				
<i>Ornithopus perpusillus</i>	Wild seradella		✓			
<i>Parentucellia viscosa</i>	Tarweed			✓		
<i>Persicaria hydropiper</i>	Water pepper			✓		
<i>Persicaria maculosa</i>	Willow weed	✓	✓			
<i>Phytolacca octandra</i>	Inkweed	✓				
<i>Plantago lanceolata</i>	Narrow-leaved plantain	✓	✓	✓		
<i>Polycarpon tetraphyllum</i>	Allseed			✓		
<i>Prunella vulgaris</i>	Selfheal			✓		
<i>Rumex acetosella</i>	Sheep's sorrel	✓	✓	✓		
<i>Rumex obtusifolius</i>	Broad-leaved dock	✓	✓	✓		
<i>Sagina procumbens</i>	Pearlwort			✓		
<i>Sisymbrium orientale</i>	Hedge mustard	✓		✓		
<i>Solanum chenopodioides</i>	Velvety nightshade			✓		
<i>Solanum nigrum</i>	Black nightshade	✓	✓	✓		
<i>Stellaria alsine</i>	Bog stitchwort			✓		
<i>Stellaria media</i>	Chickweed			✓		
<i>Trifolium arvense</i>	Haresfoot trefoil		✓			
<i>Trifolium dubium</i>	Suckling clover		✓	✓		
<i>Trifolium pratense</i>	Red clover	✓	✓	✓		
<i>Trifolium repens</i>	White clover	✓	✓	✓		
<i>Tropaeolum majus</i>	Garden nasturtium			✓		
<i>Verbascum thapsus</i>	Woolly mullein	✓	✓	✓		

Scientific Name	Common Name	Otumuheke	East Taupō	Waipahihi Valley	Taupō Shoreline	Tauhara South
<i>Verbena bonariensis</i>	Purple-top		✓			
<i>Vicia sativa</i>	Vetch	✓				
<i>Viola odorata</i>	Violet		✓			

27. WHANGAIROROHEA GEOTHERMAL SYSTEM



WHANGAIROROHEA

Ecological District: Atiamuri **GPS Reference:** NZTM E1882987 N5733149
Geothermal System: Whangairorohea **Altitude:** 300 m
Bioclimatic Zone: Lowland **Local Authority:** Rotorua
Extent of Geothermal Habitat: c.0.2 ha
Extent of Geothermal Vegetation: c. 0.1 ha
Date of Most Recent Field Survey: 13 February 2014 and 15 November 2022 (Waikato River Springs part)

CODE	VEGETATION TYPE	LANDFORM	EXTENT
1.	Exotic grassland (08.01) Mixed exotic grassland (08.01.15) (Spanish heath)-(buddleia)-(blackberry)/Yorkshire fog-browntop-lotus grassland Mixed exotic species grassland present on the dry terrace around the geothermal pool is dominated by Yorkshire fog, browntop, and lotus with locally common cocksfoot. Also around the margins of the pool are local patches of exotic woody species including Spanish heath, buddleia, blackberry, and occasional whekī and whekī-ponga. Bracken and creeping buttercup are common. Harakeke has been planted into the grassland around most of the margin. <i>Blechnum penna-marina</i> subsp. <i>alpina</i> is present at the northern side of the pool. There was no evidence of heated geothermal soils surrounding the pool.	Flat	<0.1 ha
2.	Sandfield (19.01) Geothermal sand (19.01.01)	Delta	<0.1 ha
3.	Water (22.01) Geothermal water (22.01.01) A pool measuring c.10 × 15 m within a shallow depression. The water within this pool was clear and c.36 °C in 2014. Immediately on the margins of the pool patches of Mercer grass, <i>Carex secta</i> , and a small patch of lake clubrush are present.	Crater, open water, stream	<0.1 ha
4.	Geothermal Stream (22.01.03) A small area on the Whangairorohea Stream near the outlet where there are numerous warm springs in the Waikato River. Spring temperatures were in the range of 33.4-35.6 °C. The water contains scattered plants of floating sweetgrass and creeping bent with occasional <i>Carex virgata</i> on the water margins. The pool is surrounded by poplars and radiata pine plantation with local small areas of mixed indigenous broadleaved species (kōhūhū, <i>Kunzea robusta</i> , karamū, occasional whekī) and dense blackberry.	Open water, stream	<0.1 ha

Indigenous Flora: *Blechnum penna-marina* subsp. *alpina* is present amongst the exotic grassland on the northern side of the pool. *Pimelea prostrata* subsp. *prostrata* was present in 2010 but was not observed in 2014.

Fauna:	Whangairorohea Pool. In 2014 common bird species typical of the habitats at the site were present. Indigenous species recorded were tūi, tauhou/silvereye, riroriro/grey warbler and introduced species recorded were eastern rosella, Australian magpie, Eurasian blackbird and European goldfinch. Springs at the outlet of Whangairorohea Stream: riroriro/grey warbler and chaffinch were recorded during the 2022 site visit. The Waikato River is known to support a wide range of indigenous water bird species including kaikānau/black swan, pūtangitangi/paradise shelduck, pāpango/New Zealand scaup, kuruwhegi/Australasian shoveler, tētē-moroiti/grey teal, māpunga/black shag (At Risk-Relict), kawaupaka/little shag (At Risk-Relict), and kawau tūi/little black shag (At Risk-Naturally Uncommon) (Wildland Consultants 2020d).
Geothermal Ecosystems:	Geothermal streamsides.
Current Condition:	One area in the site comprises a geothermal pool located in a radiata pine plantation. There is a 20-50 m buffer zone around the spring which is not planted in pines. The vegetation in the buffer zone comprises mainly exotic grassland with a small gully dominated by blackberry and Himalayan honeysuckle. The pool is used for bathing, with a constructed jetty built towards the centre for easy access. The terrestrial vegetation alongside the springs on the Waikato River is dominated by introduced species.
Threats/Modification/Vulnerability:	<i>Invasive pest plants:</i> Spanish heath (c.5% cover), Mercer grass (c.2% cover), buddleia (c.1% cover), and blackberry (c.1% cover) are present. The springs on the Waikato River have a 10% cover of reed sweetgrass. <i>Human impacts:</i> There are no impacts from adjacent forestry operations because there is a 20-50 m buffer between the geothermal pool and the plantation forest. A bund was created on the southern side of the pool in about 2009. The earthworks associated with this bund may have slightly reduced the size of the pool (Evelyn Forrest pers. comm.) and some vegetation clearance was undertaken during the creation of the bund. There is a permanent wooden structure that provides access into the pool for bathers. A small shed has been built within 5 metres of the pool. A vehicle track leads to the river edge near the springs on the Waikato River margins. <i>Grazing:</i> Stock do not have access to this site. <i>Adjoining land use:</i> Radiata pine plantation, Waikato River.

Site Change:

Recent change: Whangairorohea pool: Vegetation has been cleared from part of the site since 2010 and the area of lake clubrush has reduced in size. In 2014, the remainder of the site appeared to be of a similar extent to that described in 2010.

The river springs on the Waikato River had not been surveyed previously.

*Historical:*¹ The geothermal pool is visible on the 1941 aerial photograph² and appears to be of a similar size to that observed in the 2011 survey. In 1941, plantation forestry did not completely surround the pool.

Management Requirements: Control of pest plants near the springs and pool is recommended.

Significance Level: Local (Criterion 5)

Significance Justification: This site is locally significant because it comprises two small examples of a nationally uncommon habitat type (geothermal habitat).

Notes: Youngman (1996) references geothermal springs on the Waikato River near the Whangairorohea site, and this reference was used to inform the site visit to the Waikato River part. The area mapped as Whangairorohea in 2014 (Wildland Consultants 2014a) was not visited in 2022.

The stream to the south of the site is eroding and undercutting the steep stream bank to the south of the pool. This could eventually result in the pool disappearing, although bank stabilisation works have been undertaken in an attempt to reduce the risk of undercutting the stream banks. These works are likely to be successful in delaying erosion of the stream bank in the short term.

A sign identifies this site as 'Taahunaa tapu Waiariki o Toa'.

There are almost certainly other geothermal seepages and springs along the Waikato River near this site, although this is very difficult to determine alongside the deep fast moving Waikato River.

References: Wildland Consultants 2012, 2014a, 2020d; Youngman 1996.

¹ This was an assessment undertaken in 2014 that compared 2011/12 aerial photographs with historical photographs where available. The assessment was not updated as part of the current work.

² Historical photo: SN 172 Run 1167 Photo 2, 1941.



Geothermal spring at Whangairorohea. 13 February 2014.



Geothermal springs where Whangairorohea Stream flows into the Waikato River. 15 November 2022. NZTM E1883350 N5732864.

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AMALGAMATED GEOTHERMAL SITES IN THE WAIKATO REGION

This table allows cross-referencing of sites between Wildland Consultants (2014a, 2016a, and 2020a). The relevant geothermal system is also listed.

¹ Geothermal site name in Wildland Consultants (2020a), as discussed and agreed with Waikato Regional Council on 25 September 2018.

² These areas were included in the “Orakeikorako” site in the 2016 Indicator Report (Wildland Consultants 2016a). The 2022 field survey identified areas of geothermal vegetation between the two Orakeikorako sites that has it made it difficult to determine where each site should start and finish. On this basis, the area has been mapped as one larger site, showing the areas originally identified as the Orakeikorako part, Red Hills part, and new areas identified.

³ These two areas were treated as one site “Ohaaki” in the 2016 Indicator Report (Wildland Consultants 2016a).

⁴ Small springs on the shoreline of Lake Taupō were included as part of the Waipahihi Valley site in Wildland Consultants (2014a). These springs have now been mapped as part of the Taupō Shoreline site.

⁵ A new area of geothermal habitat that was identified alongside Waipuwera Stream in 2021 has been added to this site. This area was not known to the authors prior to the current survey.

⁶ Due to a relatively large area of geothermal habitat that was identified alongside the lower section of Te Kiri O Hinekai Stream for the first time during the current survey, the small area of geothermal habitat on the margins of the Lower Wairākei Stream has been included within the Lower Sections: Te Kiri O Hinekai Stream and Wairākei Stream site.

Geothermal System	Current Survey	Wildland Consultants 2021b	Geothermal Site (2020a) ¹	Geothermal Site (2016a)	Geothermal Site Name (2014a)
Atiamuri	Matapan Road	Matapan Road	Matapan Road	Matapan Road	Matapan Road
Atiamuri	Whangapoa Springs	Whangapoa Springs	Whangapoa Springs	Whangapoa Springs	Whangapoa Springs Upper Atiamuri
Horohoro	Horohoro	Horohoro	Horohoro	Horohoro	Horohoro
Mokai	Paerata Road	Paerata Road	Paerata Road	Paerata Road	Paerata Road
Mokai	Tirohanga Road	Tirohanga Road	Tirohanga Road	Tirohanga Road	Tirohanga Road
Mokai	Waipapa Stream	Waipapa Stream	Waipapa Stream	Waipapa Stream	Waipapa Stream
Ngā Tamariki	Orakonui	Orakonui	Orakonui	Orakonui	Orakonui
Ngā Tamariki	Waikato River Springs/ Mangamingi Stream	Waikato River Springs/ Mangamingi Stream	Waikato River Springs	Waikato River Springs	Waikato River Springs
Ohaaki	Ohaaki Steamfield East	Ohaaki Steamfield East	Ohaaki Steamfield East	Ohaaki	Ohaaki Steamfield East ³
Ohaaki	Ohaaki Steamfield West	Ohaaki Steamfield West	Ohaaki Steamfield West	Ohaaki	Ohaaki Steamfield West ³
Orākei Kōrako	Akatarewa East	Akatarewa	Akatarewa	Orakeikorako	Akatarewa East ²
Orākei Kōrako	Akatarewa Stream	Akatarewa	Akatarewa	Orakeikorako	Akatarewa Stream ²
Orākei Kōrako	Orākei Kōrako and Red Hills	Orakeikorako and Red Hills	Orakeikorako	Orakeikorako	Orakeikorako ²
Orākei Kōrako			Red Hills	Orakeikorako	Red Hills ²
Orākei Kōrako	Waihunuhunu	Waihunuhunu	Waihunuhunu	Waihunuhunu	Waihunuhunu
Reporoa	Golden Springs	Golden Springs	Golden Springs	Golden Springs	Golden Springs
Reporoa	Longview Road	Longview Road	Longview Road	Longview Road	Longview Road
Reporoa	Wharepapa Road	Wharepapa Road	Wharepapa Road	Wharepapa Road	Wharepapa Road
Rotokawa	Rotokawa	Rotokawa	Rotokawa	Rotokawa	Lake Rotokawa Rotokawa North
Te Kopia	Murphy's Springs	Murphy's Springs	Murphy's Springs	Murphy's Springs	Murphy's Springs
Te Kopia	Te Kopia	Te Kopia	Te Kopia	Te Kopia	Te Kopia Western Te Kopia Mangamingi Station
Tokaanu-Waihi-Hipaua	Hipaua	Hipaua	Hipaua	Hipaua	Hipaua
Tokaanu-Waihi-Hipaua	Maunganamu	Maunganamu	Maunganamu	Maunganamu	Maunganamu West Maunganamu East Maunganamu North Wetland Tokaanu Tailrace Canal
Tokaanu-Waihi-Hipaua	Tokaanu	Tokaanu	Tokaanu	Tokaanu	Tokaanu Thermal Park Tokaanu Urupa Mud Pools
Tokaanu-Waihi-Hipaua	Tokaanu Lakeshore Wetland	Tokaanu Lakeshore Wetland	Tokaanu Lakeshore Wetland	Tokaanu Lakeshore Wetland	Tokaanu Lakeshore Wetland
Tongariro	Ketetahi	Ketetahi	Ketetahi	Ketetahi	Ketetahi
Tongariro	Ngarotopounamu/Red Crater	Emerald Lakes/Red Crater	Emerald Lakes/Red Crater	Emerald Lakes/Red Crater	Emerald Lake Red Crater
Tongariro	Rotopaunga	Rotopaunga	Rotopaunga	Not surveyed	Not surveyed
Tongariro	Te Maari Craters	Te Maari Craters	Te Maari Craters	Te Maari Craters	Te Maari Craters
Waikite-Waiotapu-Waimangu	Northern Paeroa Range	Northern Paeroa Range	Northern Paeroa Range	Northern Paeroa Range	Northern Paeroa Range
Waikite-Waiotapu-Waimangu	Waikite Valley	Waikite Valley	Waikite Valley	Waikite Valley	Waikite Valley
Waikite-Waiotapu-Waimangu	Maunga Kākaramea (Rainbow Mountain)	Maunga Kākaramea (Rainbow Mountain)	Maunga Kākaramea (Rainbow Mountain)	Maunga Kākaramea (Rainbow Mountain)	Maunga Kākaramea(Rainbow Mountain)
Waikite-Waiotapu-Waimangu	Maungaongaonga	Maungaongaonga	Maungaongaonga	Maungaongaonga	Maungaongaonga
Waikite-Waiotapu-Waimangu	Waiotapu	Waiotapu	Waiotapu	Waiotapu	Ngapouri Waiotapu North Waiotapu South
Wairākei-Tauhara	East Taupō	East Taupō	East Taupō	East Taupō	Broadlands Road Crown Road Crown Park
Wairākei-Tauhara	Otumuheke	Otumuheke	Otumuheke	Otumuheke	Otumuheke Spa Thermal Park Kathleen Springs
Wairākei-Tauhara	Tauhara South	Tauhara South	Mountain Road	Mountain Road	Mountain Road
Wairākei-Tauhara	Taupō Shoreline ⁴	Taupō Shoreline ⁴	Part of Waipahihi Valley	Part of Waipahihi Valley	Part of Waipahihi Valley
Wairākei-Tauhara	Waipahihi Valley	Waipahihi Valley	Waipahihi Valley	Waipahihi Valley	Waipahihi Valley
Wairākei-Tauhara	Craters of the Moon	Craters of the Moon	Craters of the Moon	Karapiti	Craters of the Moon ⁵
Wairākei-Tauhara	Hall of Fame Stream	Hall of Fame Stream	Hall of Fame Stream	Karapiti	Hall of Fame Stream ⁵
Wairākei-Tauhara	Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream ⁶	Lower Sections: Te Kiri O Hinekai Stream and Wairākei Stream ⁶	- Te Kiri O Hinekai Stream part, not identified. - Lower Wairākei Stream part, included in Te Rau-o- Te Huia-Wairākei.	- Te Kiri O Hinekai Stream part, not identified. - Lower Wairākei Stream part, included in Wairākei Valley.	Lower Wairākei Stream
Wairākei-Tauhara	Te Kiri o Hinekai	Te Kiri O Hinekai	Te Kiri O Hinekai	Te Kiri O Hinekai	Wairākei Borefield Te Kiri O Hinekai Stream Catchment/Wairoa Hill
Wairākei-Tauhara	Te Rau-o-Te Huia-Wairākei	Te Rau-o-Te Huia-Wairākei	Te Rau-o-Te Huia-Wairākei	Wairākei Valley	Te Rau-o-Te Huia Te Rau-o-Te Huia Stream Upper Wairākei Stream (Geyser Valley)
Wairākei-Tauhara	Tukairangi/Karapiti Forest ⁵	Tukairangi/Karapiti Forest ⁵	Tukairangi/Karapiti Forest	Karapiti	Karapiti Forest Waipuwera Stream/Tukairangi
Whakamaru	Whakamaru	Whakamaru	Whakamaru	Whakamaru	Whakamaru
Whangairorohea	Whangairorohea	Whangairorohea	Whangairorohea	Whangairorohea	Whangairorohea

APPENDIX 2

YEAR OF MOST RECENT FIELD INSPECTION FOR EACH SITE

Site Name	Year of Most Recent Site Survey	Comments
Atiamuri Geothermal System		
Matapan Road	2011	
Whangapoa Springs	2022	
Horohoro Geothermal System		
Horohoro	2023	
Mokai Geothermal System		
Paerata Road	2011	Landowner permission not given.
Tirohanga Road	2011	Landowner permission not given.
Waipapa Stream	2020	
Ngatamariki Geothermal System		
Orakonui	2022	
Waikato River Springs/Mangamingi Stream	2022	
Ohaaki Geothermal System		
Ohaaki Steamfield East	2022	
Ohaaki Steamfield West	2023	
Orākei Kōrako Geothermal System		
Akatārewa East	2023	
Akatārewa Stream	2022	
Orākei Kōrako and Red Hills	2022	
Waihunuhunu	2022	
Reporoa Geothermal System		
Golden Springs	2023	
Longview Road	2022	
Wharepapa Road	2017	Landowner permission not given.
Reporoa Geothermal System		
Rotokawa	2023	
Te Kopia Geothermal System		
Te Kopia	2023	
Murphy's Springs	2023	
Tokaanu-Waihi-Hipaua Geothermal System		
Tokaanu Geothermal System		
Hipaua	-	Landowner permission not given.
Maunganamu	2007	Landowner permission not given.
Tokaanu	2007	Landowner permission not given.
Tokaanu Lakeshore Wetland	2007	Landowner permission not given.
Tongariro Geothermal System		
Ketetahi	-	Landowner permission not given.
Ngarotopounamu/Red Crater	2018	
Rotopaunga	2018	
Te Maari Craters	2018	
Waikite-Waiotapu Geothermal System		
Waikite Geothermal System		
Northern Paeroa Range	2022	
Waikite Valley	2022	
Waiotapu Geothermal System		
Maunga Kākaramea (Rainbow Mountain)	2022	
Maungaongaonga	2022	
Waiotapu	2023	Landowner permission not given for one property.
Wairākei-Tauhara Geothermal System		
Tauhara Geothermal System		
East Taupō	2022	
Otumuheke	2020	
Tauhara South	2020	

Site Name	Year of Most Recent Site Survey	Comments
Taupō Shoreline	2020	
Waipahihi Valley	2022	
Wairākei Geothermal System		
Craters of the Moon	2022	
Hall of Fame Stream	2022	
Lower Sections: Te Kiri o Hinekai Stream and Wairākei Stream	2022	
Te Kiri o Hinekai	2020	
Te Rau-o-Te Huia-Wairākei	2021	
Tukairangi/Karapiti Forest	2021	
Whakamaru Geothermal System		
Whakamaru	2008	
Whangaiorohea Geothermal System		
Whangaiorohea	2022	

GEOTHERMAL AREAS NOT FIELD SURVEYED

No field inspection was carried out for geothermal areas in the Waikato Region listed below because the area was either extremely small, and/or has little to no geothermal vegetation present. Note that there are some small geothermal areas in the Tongariro geothermal system which are located outside the Waikato Region (in Horizons Region: Lake Otamangakau, Ngauruhoe Crater, and the Te Wai-ā-Moe /Crater Lake on Mt Ruapehu) and thus these areas are not considered in this report.

Site Name	Bathing Pool
Location	Tirohanga Road
Grid Reference (NZTM)	E1853183 N5734523
Geothermal System	Mokai
Ecological District	Atiamuri
Vegetation	No geothermal vegetation. Pool enclosed by dirt, concrete and wooden railings although these may have been removed.
Notes	A small bathing pool securely fenced off. Wooden shed beside fence.
References	Waikato Regional Council (undated).

Site Name	Atiamuri School Spring
Location	Corner SH30 and Ōhakuri Road
Grid Reference (NZTM)	E1867993 N5752733
Geothermal System	Atiamuri
Ecological District	Atiamuri
Vegetation and Site Description	Highly modified spring surrounded by blackberry, that looks more like a culvert than a natural spring.
References	Waikato Regional Council (undated).

Site Name	Mangatete Stream
Location	Waikite Valley
Grid Reference (NZTM)	E1880300 N5746800
Geothermal System	Te Kopia
Ecological District	Atiamuri
Vegetation	No geothermal vegetation present.
Notes	Site inspected on 7 May 2004. No geothermal vegetation or activity found within a kilometre upstream or downstream of the grid reference. The general area was also inspected from a vantage point hill on true left of Mangatete Stream. The landowner did not know of any geothermal vegetation in this area.
References	Spring-Rice (unpublished).

Site Name	Butcher's Pool
Location	Broadlands Road, Reporoa
Grid Reference (NZTM)	E1891750 N5738690 (estimate only)
Geothermal System	Reporoa
Ecological District	Atiamuri
Vegetation	No geothermal vegetation.
Notes	A small spring enclosed by man-made, wooden edges. Recreational use.

Site Name	Mihi
Location	Mangamingi
Grid Reference (NZTM)	Near: E1887950 N5734030
Geothermal System	Ohaaki
Ecological District	Atiamuri
Vegetation	Tepid spring in pasture behind haybarn.
References	Waikato Regional Council (undated).

Site Name	Waihi Geothermal Site
Location	Waihi Village, Lake Taupō
Grid Reference (NZTM)	E1837824 N5685065 (estimate only)
Geothermal System	Tokaanu-Waihi-Hipaua
Ecological District	Taupō
Vegetation	Presence, extent and composition of geothermal vegetation is not known.
Notes	More than a dozen small springs discharging hot water along a c.0.7 km stretch of the Waihi foreshore following the main fracture zone of the Waihi Fault. Some areas of geothermal vegetation are mapped in this report in the Hipaua site (Bromley and Mongillo 1991). Geothermal manifestations also extend well into Lake Taupō (Risk <i>et al.</i> 1998). It is likely that there are additional areas of geothermal vegetation that are not mapped in the Hipaua site, however permission to access this site was not granted in 2000, 2011, 2014, or 2022/23 surveys.
References	Bromley and Mongillo (1991), Hochstein (2005), Risk <i>et al.</i> (1998).

Site Name	Southern Stream
Location	Turangi
Grid Reference (NZTM)	E1839428 N5682165 (estimate only)
Geothermal System	Tokaanu-Waihi-Hipaua
Ecological District	Tongariro
Vegetation	Presence, extent and composition of geothermal vegetation is not known.
References	Bromley and Mongillo (1991), Hochstein (2005).

Site Name	Toputomatua Stream
Location	Turangi
Grid Reference (NZTM)	E1838631 N5677862 (estimate only)
Geothermal System	Tokaanu-Waihi-Hipaua
Ecological District	Tongariro
Vegetation	Presence, extent and composition of geothermal vegetation is not known.
References	Bromley and Mongillo (1991), Hochstein (2005).

Site Name	Mokena Geyser
Location	Te Aroha
Grid Reference (NZTM)	Near E1839920 N5841305
Geothermal System	Te Aroha
Ecological District	Hinuera
Vegetation	Surrounded by concrete. No vegetation present, geothermal or otherwise.
Notes	An artificial geyser located within the grounds of the Mokena private spa baths. Water temperature c.90 °C.
References	Waikato Regional Council (undated).

Site Name	Waitoa Spring
Location	Waitoa
Grid Reference (NZTM)	E1828164 N5845856
Geothermal System	Waitoa
Ecological District	Hinuera
Vegetation	Spring in pasture. No geothermal vegetation present.
Notes	Located beside a farm drain. Water <i>c.</i> 50°C.
References	Waikato Regional Council (undated).

Site Name	Opal Baths
Location	Okauia
Grid Reference (NZTM)	E1850008 N5841305
Geothermal System	Okauia
Ecological District	Hinuera
Vegetation	Bathing pools. No geothermal vegetation present.
Notes	Pools constructed for commercial, recreational use. Water <i>c.</i> 40°C.
References	Waikato Regional Council (undated).

Site Name	Okoroire Spring
Location	Okoroire
Grid Reference (NZTM)	E1846375 N5795776
Geothermal System	Okoroire
Ecological District	Hinuera
Vegetation	Bathing pools. No geothermal vegetation present.
Notes	Natural spring around/beside which concrete pools have been constructed for commercial, recreational use (two pools).
References	Waikato Regional Council (undated).

Site Name	Miranda Hot Pools
Location	Waitakaruru
Grid Reference (NZTM)	E1806963 N5879559
Geothermal System	Miranda
Ecological District	Hauraki
Vegetation	No geothermal vegetation present.
Notes	A spring contained by a metal shaft on a lawn behind the camping ground shop/office. Water <i>c.</i> 50°C.
References	Waikato Regional Council (undated).

Site Name	Kerepehi Spring
Location	Kerepehi
Grid Reference (NZTM)	E1823825 N5873435 (estimate only)
Geothermal System	Kerepehi
Ecological District	Hauraki
Vegetation	Spring in pasture. No geothermal vegetation present.
Notes	Water is <i>c.</i> 40°C and escapes from pipe with variable pressure. Located on the far side of Paddock 76 from the race (on the boundary with the neighbouring farm).
References	Waikato Regional Council (undated).

Site Name	Waingaro Hot Pools
Location	Waingaro
Grid Reference (NZTM)	E1776332 N5826606
Geothermal System	Waingaro
Ecological District	Raglan
Vegetation	Bathing pools. No geothermal vegetation present.
Notes	Pools constructed for commercial, recreational use. Fed by a bore opposite the entrance to the hot pools. Water c.50°C.
References	Waikato Regional Council (undated).

Site Name	Naike (Te Maire) Spring
Location	Naike
Grid Reference (NZTM)	E1771803 N5848022
Geothermal System	Naike
Ecological District	Raglan
Vegetation	Pool in pasture. Vegetation not assessed.
Notes	Pool bank is a little unstable. Water c.45°C.
References	Waikato Regional Council (undated).

Site Name	Hot Water Beach
Location	Coromandel
Grid Reference (NZTM)	Near: E1851525 N5913975
Geothermal System	Not known
Ecological District	Tairua
Vegetation	Hot water seepage on beach. No geothermal vegetation present.
References	Waikato Regional Council (undated).

GEOPHYSICAL ASSESSMENTS OF SURFACE GEOTHERMAL MANIFESTATIONS AT 20 SITES¹ IN THE WAIKATO REGION (from Wildland Consultants 2012)

NORTHERN PAEROA RANGE²

- Area A* Viewed from other side of creek. Similar to Sites B, D and E, but no geophysical assessment undertaken.
- Area B* This is a 25 × 15 m outcrop of poorly sorted, moderately rounded, and weakly cemented gravelly pumice with weakly defined bedding. This overlies pinkish poorly sorted coarse clayey pumice sand. The entire outcrop is >50% covered by pine needles.
- Unfortunately we did not record orientation data, but estimated north is shown on the sketch. The northern end of the area is a roughly circular outcrop, with the margins showing moderate silicification; there is a strongly silicified outcrop on the western margin of this structure.
- In the southern section of this area there is a 1 m diameter vertical concrete pipe around 1.2 m high. In the ground enclosed by this pipe are two small fumaroles with delicate sulphur structures (Plates 1 and 2). Within 2.5 m east and west of this pipe are two further fumaroles with sulphur encrusted walls, and south of these is a sulphur-encrusted east-west vent (Plates 3 and 4).
- On the western margin of the area opposite the pipe is a 2 m diameter cracked and broken sinter mound (Plate 5).
- Area C* Grid Reference: E1889201 N5749763
- An area of bare ground and exposed altered rock. The area measures approximately 20 × 15 m. There is a dry gully on its southern flank with a small stream flowing past the northern boundary. A small low flowing/stagnant stream runs along the western boundary. Soil temperatures at 10 cm depth across the area were not elevated above ambient temperatures (12 °C). The exposed surface varies from altered pumiceous rock, which exhibit moderate alteration, to brittle silicified gravelly soils/clay. There is evidence of sulphur deposition however no steaming ground was observed. A moderate sulphur odour was present although a source was not found. It could be diffuse H₂S or simply related to the adjacent area (Paeroa North 2) with steaming ground. The area is surrounded by pine woodland and farmland. Photographs were not taken at this site due to fading light.
- Area D* This site measures approximately 28 × 40 m in area and comprises areas of exposed ground, clay banks, marshland, two gas discharging cold pools and

¹ Many of the sites described in this section have been amalgamated into other sites. See Appendix 1 for details.

² Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

two streams which meet at the centre of the southern end of the area. There is a slight H₂S odour at the area. The surrounding area is farmland and pine woodland.

On the western flank of this area is a clay slope or bank (Plate 6); soil temperatures were not above ambient conditions. The upper half of the slope is composed of poorly sorted gravelly clay. The gravels are coarse, angular to sub rounded, highly weathered and brittle. The clay matrix exhibits some flow banding in places. This would point towards the bank being formed as a result of a land slump or collapse. The lower half of the slope is composed of fine-grained gravelly clay. A stream flows from the northwest along the base of the slope and as such may erode and shape this bank over time.

There are two cold pools in the centre of the site which have vigorous gas discharge (Plate 7). The gas is likely to be a combination of H₂S and CO₂. The temperature of the pools was 9.5 °C and the pH was 3.5. Both pools are surrounded by a marsh/swamp area which includes various drainage channels that lead into the main stream, which originates in the northeast.

The southeastern part of this area is dominated by a silt/sand bank with abundant rock outcrops and areas of fractured or broken sinter. Many of the rocks include silicified wood and other organic matter (Plate 8). Also present are rock outcrops with weakly cemented gravelly horizontally layers and pumiceous rocks as well as occasional exposed welded ignimbrites with carbonized wood fragments. There is some minor sulphur deposition on the surface in this area (Plate 9). The main stream from the northeast flows past this area and joins the stream from the northwest at the southern end of the area. The main stream has a pH of 8. The soil temperatures at 10 cm depth across this area were not above ambient temperatures (11-12 °C).

Area E

This is an area of bare ground and exposed altered rock (Plate 10). The area measures approximately 12 × 20 m. There is a dry gully on its southern flank with a small stream flowing past the western boundary (Plate 11). Soil temperatures at 10 cm depth across the area were not elevated above ambient temperatures (range from 9 °C to 12 °C). The exposed surfaces vary from altered pumiceous rock, which exhibit moderate alteration, to brittle silicified gravelly soils/clays with dissolution features in the clay matrix. Organic material was also noted in the pumiceous rock (Plate 12). There is little or no evidence of sulphur deposition and no steaming ground was observed.

Area F

Grid Ref: E1889165 N5749531

This is an easterly facing bank of bare rock partially covered by pine needles (Plate 13). The bank is c.5 m high and 6 m wide.

The exposed rock is moderately acid altered pumiceous rock. The south and east margins of the outcrop are moderately to strongly silicified.

There is a stream running SW to NE along the base of the outcrop. The water temperature before and after it passes the outcrop is 12 °C and the pH is 6.4-6.5. There is no indication of any current thermal activity.

This site measures approximately 50 × 20 m and is an area of exposed ground on the edge of a pine woodland area. The long axis of the area runs in an east-west orientation. The area consists of three main areas of exposed lightly sulphur encrusted gravelly pumice (maximum thickness 0.5 m) over pinkish poorly sorted pumice sandstone. There is minor silicification of both clay soil and rock and some areas of intense sulphur deposition around small warm vents. A small stream/drainage channel originates from two small pools on the southern boundary of the area.

The eastern end of the site, nearest the road access point, is dominated by an area of cold bare ground (temperatures of between 11-12 °C at 10 cm depth) (foreground Plate 14).

In the centre of the site there are two small pools from which a small stream flows to the west along the southern boundary of the area (Plate 15). There is also an area of bare ground with minor sulphur deposition on top of altered/weathered clays.

In the western end of the site is a third area of exposed ground with sulphur-encrusted fissures with some small (<0.1 m diameter) vents (Plate 16). The ground temperatures increase towards the most active vent which was 85 °C at 0.25 m depth. At 2m distance the temperatures are between 18 and 27 °C.

The stream on the southern boundary originates in a small oval pool in the east, which is 0.3 × 0.4 m × 0.2 m deep (temperature 21 °C) with a very low outflow rate (estimated to be < 0.1 l/s) (Plate 15). This drains into a second pool of around 0.6 m diameter and 0.2 m depth, which has a temperature of 22 °C and an estimated outflow of 0.5 l/s. As the stream reaches the western exposed rocks it has cooled to 15 °C, and after it has passed this area of weak thermal activity the temperature is 16 °C. The pH of the stream is between 3.2 and 3.7.



Plate 1 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.



Plate 2 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.



Plate 3 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.



Plate 4 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range



Plate 5 Fumarole surrounding concrete pipe, Area B Northern Paeroa Range.

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Figure 2: Sketch map indicating main features and photo locations at manifestation B Northern Paeroa Range Geothermal Area.

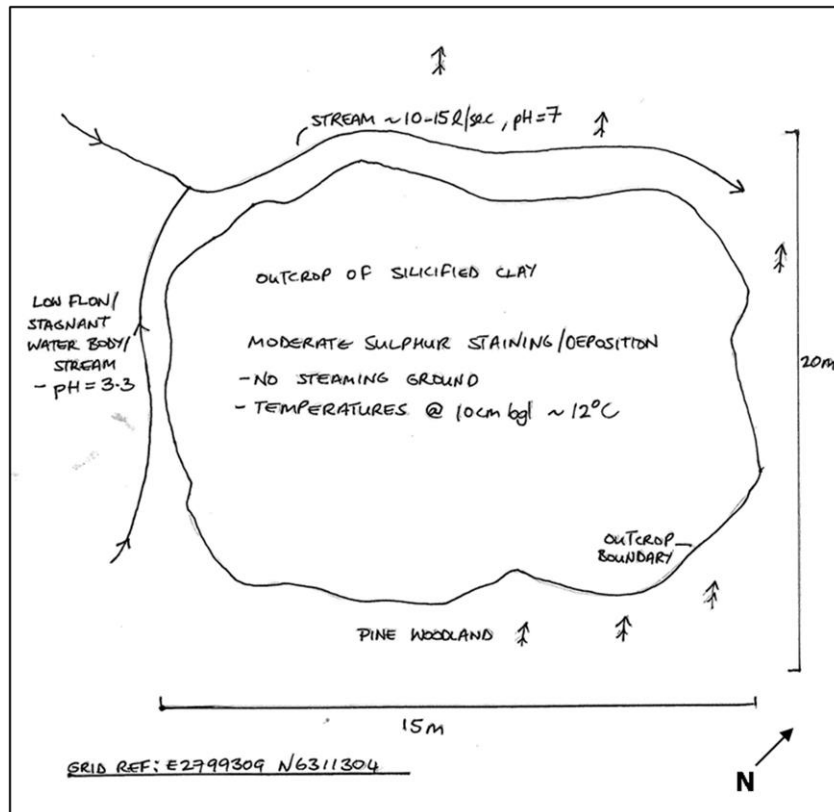
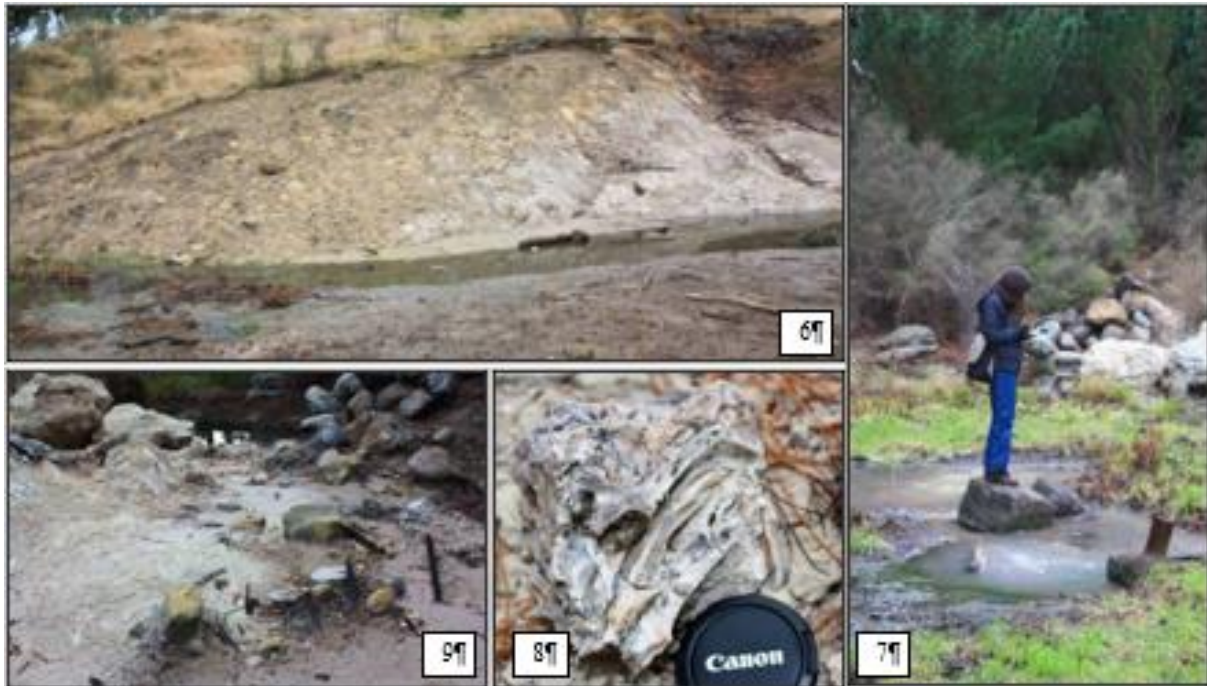


Figure 3: Field sketch map indicating main features at manifestation C, Northern Paeroa Range Geothermal Area. The grid reference labelled here is NZMG.



Figure 4: Field sketch map indicating main features and photo locations at manifestation D, Northern Paeroa Range Geothermal Area. The grid reference labelled here is NZMG.



Plates 8-9: Northern Paeroa Range Geothermal Area D. Clockwise from top left - 6. Clay Bank/Slope, southwestern orientation; 7. Cold Gas Discharging Pools northeastern orientation; 8. Silicified clay with silicified wood; 9. Exposed ground with rock outcrops, sulphur deposits and sinter, northern orientation.



Figure 5: Field Sketch Map indicating main features and photo locations at manifestation E, Northern Paeroa Range Geothermal Area. The grid reference labelled here is NZMG.



10



12



11

Plates 10-12: Northern Paeroa Range Geothermal Area E. Clockwise from top left – 10. Bare Ground and exposed altered rock; 11. Dry Gully with exposed rock on sides; 12. Pumiceous altered rock, top left, and more brittle/ weathered silicified soil/clay with organic material beneath



Figure 6: Field Sketch Map indicating main features and photo locations at manifestation F, Northern Paeroa Range Geothermal Area.
The grid reference labelled here is NZMG.



Plate 13: Northern Paeroa Range Geothermal Area F.

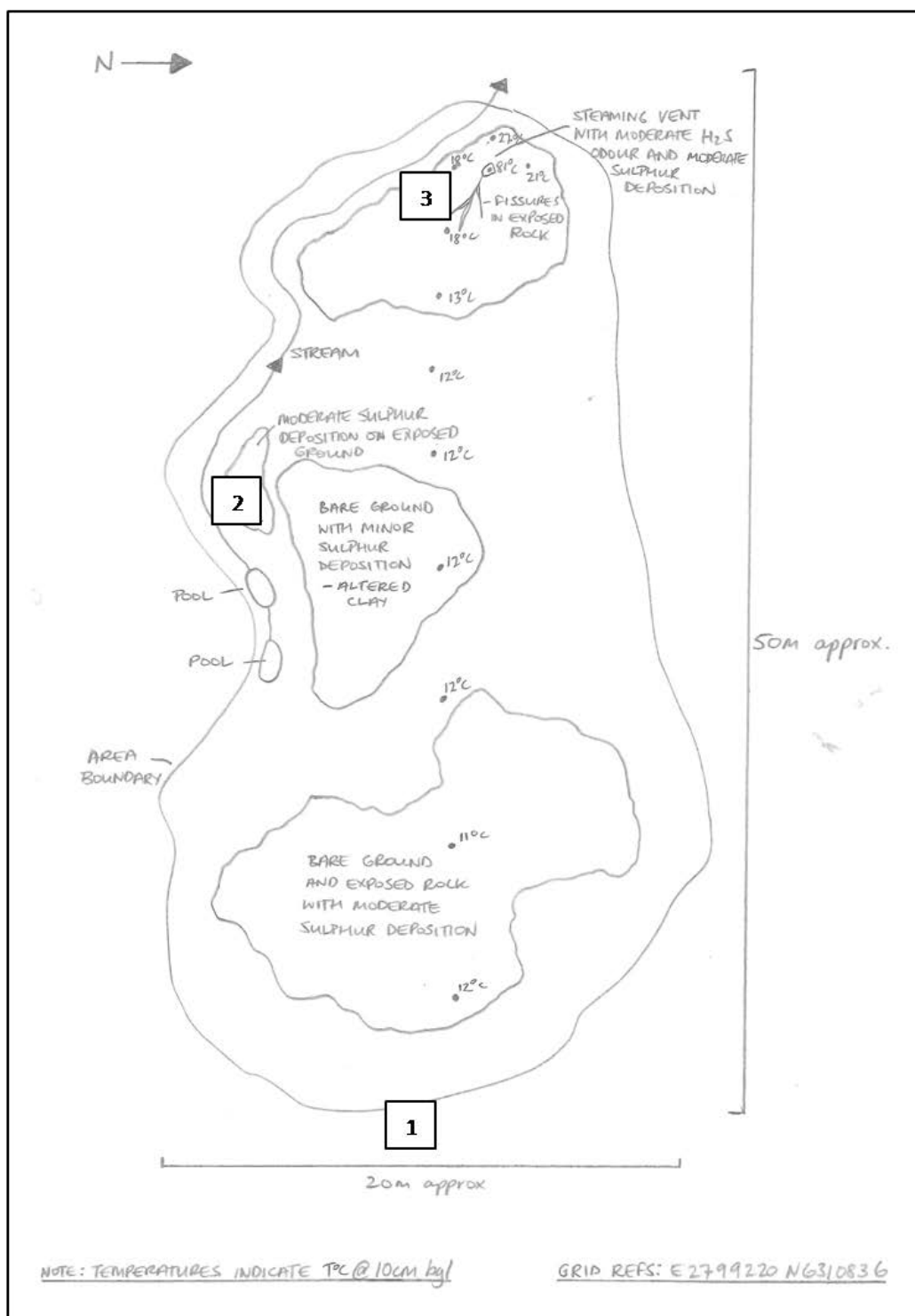


Figure 7: Field sketch map indicating main features and photo locations at manifestation G, Northern Paeroa Range Geothermal Area. The grid reference labelled here is NZMG.



Plates 14-16: Northern Paeroa Range Geothermal Area G. Clockwise from top left - 14. Full area view from eastern end; 15. Pools and stream along southern boundary; 16. Steam vent showing sulphur deposition around edge and fissure through silicified rock.

WAIOTAPU (WAIOTAPU NORTH PART)¹

Feature 1:
Geothermal lake

Grid Reference:
E1895238 N5752181

This lake is located on the southern side of the access road and measures approximately 50 × 70 m. There are steaming parts of the lake near the road. The vegetation cover did not allow an assessment of the source of the steam. As such it could be coming from the surface of the lake or separate discharges along the lake edge. The main stream enters at the northwestern edge of the lake. The temperature was measured (using an infrared (IR) thermometer) at 44 °C. There was no access to take a pH reading.



Plate 17: Steam rising from northern part of lake, Feature 1, Waiotapu North.

Feature 2:
Hot pools and sinter terrace

Grid Reference:
E1895436 N5751840

Approximately 100 m to the south of the lake and access road there are a number of hot pools discharging silica laden fluid forming a sinter terrace on the banks of the stream. Among the pools is a large mound of sinter which incorporates a large deep pool (2.5 × 1 m) of near boiling water which discharges to the south (Plate 18). The water was clear with a blue tinge, indicating colloidal silica. The flow was estimated to be approximately 1-2 l/s. There are a number of other small, clear, slightly blue pools discharging small volumes into a channel which flowed into the stream to the west (Plate 19). Minor sulphur encrustation was noted along the channel from these pools. The temperatures of the pools ranged from 85 °C to 97 °C. Both the IR thermometer and thermocouple device were used. The pH in the large pool was 8.2.

¹ Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson 2010.



Plate 18: Feature 2, Waiotapu North. A large clear blue hot (boiling) pool. Note: Discharge was to the south, towards stream in the background. Sinter terrace is also visible on left-hand side of the photo



Plate 19: Feature 2, Waiotapu North: small shallow pools discharging to the west. Note: minor sulphur deposition and sinter terrace.

Feature 3:
Hot pools and sinter
terrace

Grid Reference:
E18960085 N5751239

This feature comprises an area of sinter terrace with numerous small hot pools discharging a small volume of fluid into the adjacent stream. A sketch has been prepared indicating the main features (Figure 7). There are up to eight distinguishable hot pools with fluid temperatures ranging from 40 °C to 90 °C. In the northern end of the area there is a large shallow pool with diffuse degassing. The temperature in this pool ranges from 40 °C to 65 °C. In the northeastern corner there is a bank of steaming ground composed of silicified rock with sulphur encrustation.

The discharge from the shallow pool flows to the south and passes other hot pools and small discharge channels. One hot pool in the centre of the area had 80 °C fluid. The rim of this pool was raised and composed of dark grey sinter and could be described as geyserite (Plate 21). There was no visible discharge from this pool. Two pools nearby had a sheen on the water surface (similar to a hydrocarbon sheen) (Plate 22). Most of the area comprised a sinter terrace. The full area of this site was approximately 30 × 20 m.

The main channel draining the area had a temperature of 58 °C and flow was <1 l/s. The stream temperature upstream of the sinter terrace was 34 °C while this had risen to 36 °C two metres downstream of the discharge channel.



Plate 20: Feature 3, Waiotapu North: view from southeast of sinter terrace and shallow pool area. Note stream flow from right to left in background and main discharge channel on the left-hand side of the photo.



Plate 21: Hot pool with geyserite structure rim, Feature 3, Waiotapu North.



Plate 22: Small hot pool (90 °C) with sheen, Feature 3, Waiotapu North.



Plate 23: Discharge from sinter terrace and pools into stream, Feature 3, Waiotapu North.

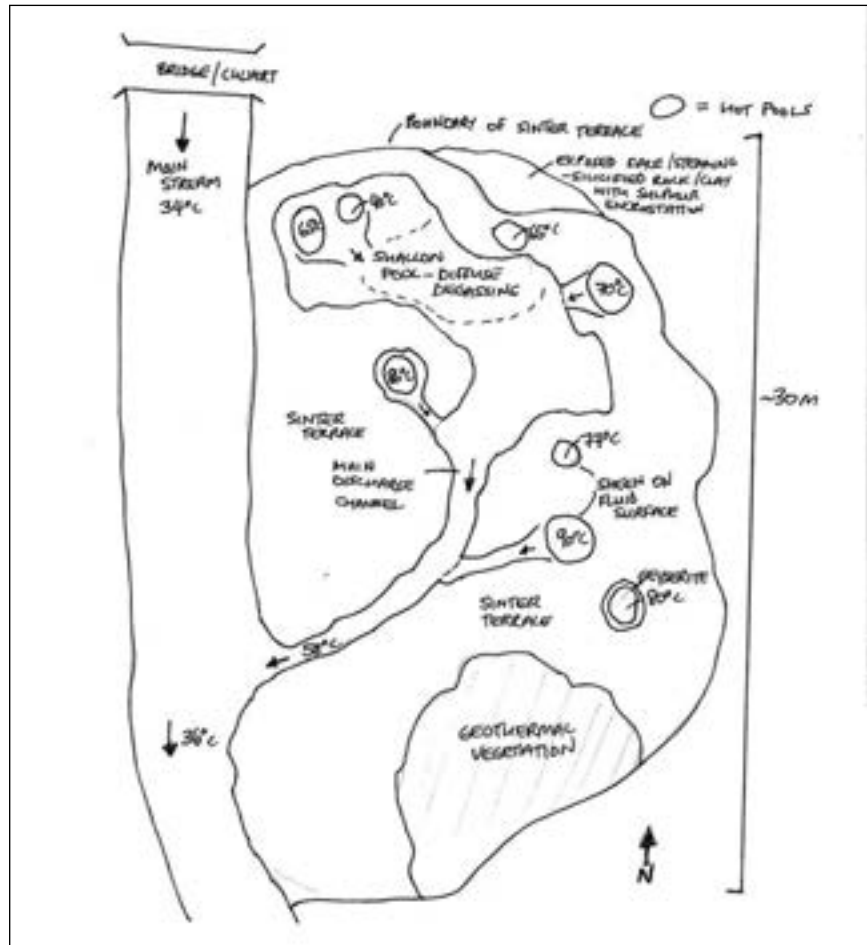


Figure A1-7: Field sketch of hot pools and sinter terrace, Feature 3, Waiotapu North.

Feature 4:
Shallow mud lake

Grid Reference:
E1894833 N5750814

This feature measures approximately 40 m² and comprises a shallow mud lake. There was no access to obtain temperature measurements. The southeast corner of the lake contained the most significant activity with significant steam and gas discharge associated with two erupting mud pools (Plate 24). The southern of the two mud pools erupted approximately every 30 seconds. Diffuse steam discharge and degassing was noted across the rest of the lake.



Plate 24: Southeast corner of shallow mud lake with two areas of erupting mud and significant steam discharge, Feature 4, Waiotapu North.

Feature 5:
Pale green, steaming
lake

The lake measures approximately 30 m² and has a minor steam discharge at its surface. It is cloudy and pale green in colour, which suggests a sulphuric input. Access was not sufficient to take a temperature measurement.

Grid Reference:
E1895025 N5750791

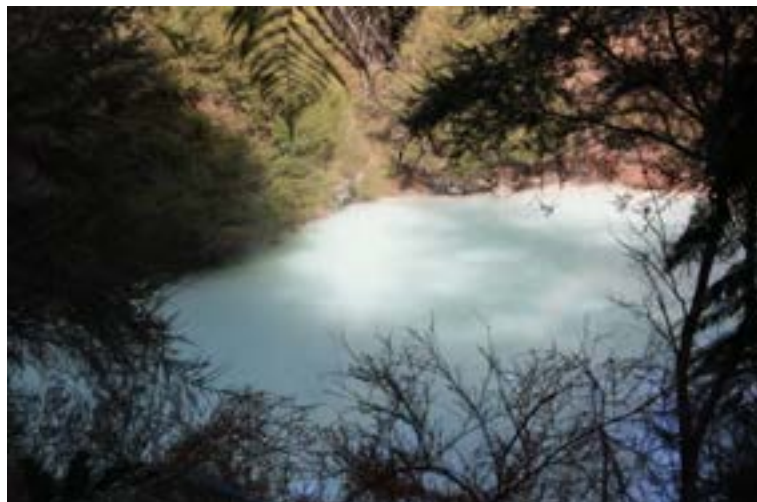


Plate 25: Pale green lake with minor steam discharge, Feature 5, Waiotapu North.

Feature 6:
Hot springs, steaming
ground

Approximately 10 m to the north of the bridge at this location there are a number of hot springs discharging into a stream from its western bank. There was also a minor amount of steam discharge. The discharges are small <0.1 l/s and had a maximum temperature of 38 °C. The bank with the springs is cream with some minor sulphur deposition. From a distance it was not clear if the colour of the bank was as a result of silica deposition or bacterial/algal growth. The stream had a temperature of 20 °C and was slightly cloudy. The flow was estimated to be in order of 200 l/s.

Grid Reference:
E1895507 N5749948



Plate 26: Steaming ground and hot springs on western bank of stream, Feature 6, Waiotapu North.

Feature 7:
Freshwater stream with
geothermal inputs

Grid Reference:
E1895977 N5753920

A freshwater stream is culverted beneath the road and flows south near the western end of Lake Rotowhero. The stream had a temperature of 14-15 °C, a pH of 5.2 and had a flow of approximately 200 l/s. There are numerous geothermal springs which contribute fluid to and heat the stream along its course which flows south. The features are discussed below:

- (a) Grid Reference: E1894920 N5752841. Area of hot pools with clear water and grey bases on the eastern bank discharging a small volume of fluid into the stream (c.1 l/s). The temperatures ranged from 33 °C to 79 °C and had pH values of approximately 6.
- (b) Grid Reference: E1894928 N5752731. A small clear pool on the eastern bank of the stream with a temperature of 95 °C discharging approximately 0.5 l/s through a 2 m long channel into the stream (Plate 28). Minor silica deposition in the channel. The temperature of the stream upstream of the pool discharge was 18 °C and 23 °C downstream. The pH of the pool was 6.6. On the western bank there were numerous areas of steaming ground which were not accessible.
- (c) Grid Reference: E1894996 N5752509. A small spring outflow at an outcrop of silicified clay discharging 95 °C fluid into the stream. Flow is approximately 0.2 l/s.



Plate 27: Area of hot pools discharging into stream (a), Feature 7, Waiotapu North.

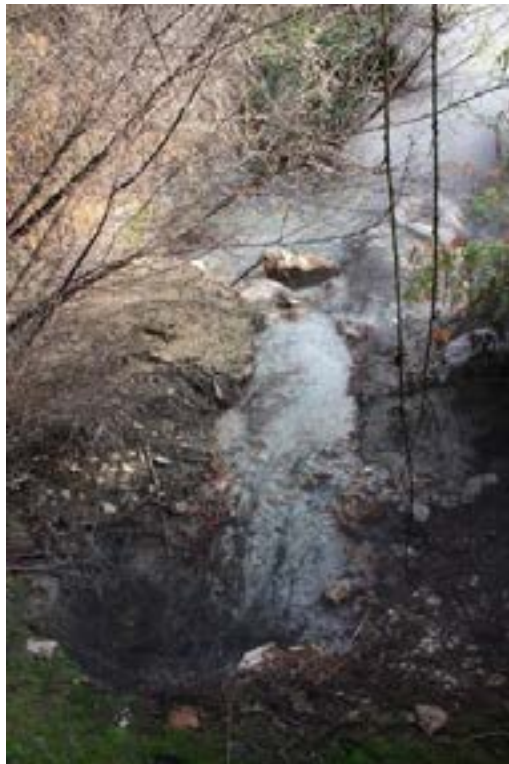


Plate 28: Small clear, near boiling pool, 0.2 l/s discharge into stream (b), Feature 7, Waiotapu North.

Feature 8:
Steaming ground

Grid Reference:
E1896462 N5751308

Approximately 30 m upstream from a bridge there is an area of steaming ground. There was no access to this area due to thick blackberry vegetation. The steaming ground is close to a stream.

Feature 9:
Steaming ground, mud pools

Grid Reference:
E1895496 N5750840

This feature comprises an area of exposed ground with silicified pumiceous soil and four mud pools. The mud pools ranged from 1 × 4 m in diameter and had temperatures ranging from 50 °C to 78 °C. The mud pools were all dark grey and had significant steam and H₂S discharges. There were also isolated areas with sulphur encrustation on the surface. The deepest and hottest of the pools was bound on three sides by steep 2 m walls, while the

other pools were shallower (Plates 28 and 29). All pools appear to be located in collapse craters formed by steam dissolution of the soil.



Plate 29: Large mud pool within collapse crater, Feature 9, Waiotapu North.



Plate 30: Steep sided collapse crater with mud pool at base, Feature 9, Waiotapu North.

WAIOTAPU SOUTH¹

Feature 1:
Steaming ground

This is an area of steaming ground surrounded by thick vegetation including blackberry (Plate 42). Access was not possible to identify the nature of the feature. From a distance of 20 m the steam discharge was considered moderate and there was no audible bubbling.



Plate 42: Steam rising from centre of densely vegetated area, Feature 1, Waiotapu South.

Feature 2:
Cool, slightly acidic lake

Grid Reference:
E1893847 N5748881

This feature is a lake which is slightly warmer than ambient temperature (water temperature of 15 °C) and had a pH of 4.1. This would indicate some geothermal input affecting both the temperature and pH, albeit rather small. Some minor degassing/bubbling was noted in one area of the lake.

¹ Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

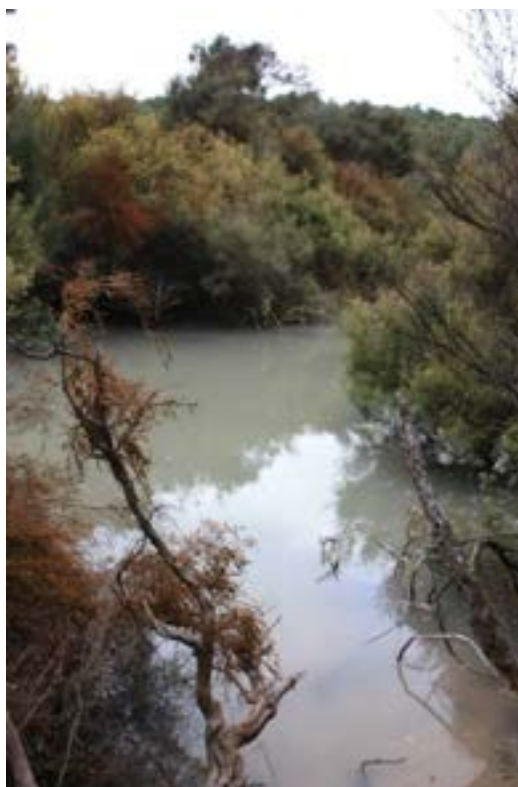


Plate 43: View from northern end of lake. Degassing was noted in middle ground of photo, Feature 2, Waiotapu South.

Feature 3:
Geothermal pools/
sinter terrace/
shallow lake

Grid Reference:
E1893775 N5748797

This feature measures 40×15 m and comprises an area of near boiling pools which are actively depositing silica. The central area of the feature is a shallow lake. The pools have clear water and a blue/green tinge, an attribute created by the presence of colloidal silica. A sketch map of the area has been prepared indicating the location of some of the mapped pools and the photographs (Figure A1-8). Not all the areas were accessible and caution was required around such unstable structures. The temperatures ranged from 80°C to 99°C ; the hottest pools were found in the western limits of the area. These pools were discharging fluid; their discharge then depositing silica forming an area of sinter terrace (Plate 47). The diffuse discharge and limited access allowed only visual estimates of the flow. This was estimated to be in the order of 1-2 l/s. The pH of the pools in this area was 7.6. There was significant steam discharging from the area and a moderate H_2S odour. Measurements were taken using an in situ thermocouple device where access was safe and using an IR thermometer where access was not considered safe.



Plate 44: View of pool from northern edge, Feature 3, Waiotapu South.



Plate 45: Hot Pools with very small discharge at northeastern edge of area, Feature 3, Waiotapu South.



Plate 46: View from northeastern limit across shallow lake area and green pool, Feature 3, Waiotapu South.



Plate 47: View from western limit of feature showing two large boiling pools which discharge fluid forming a sinter terrace, Feature 3, Waiotapu South.

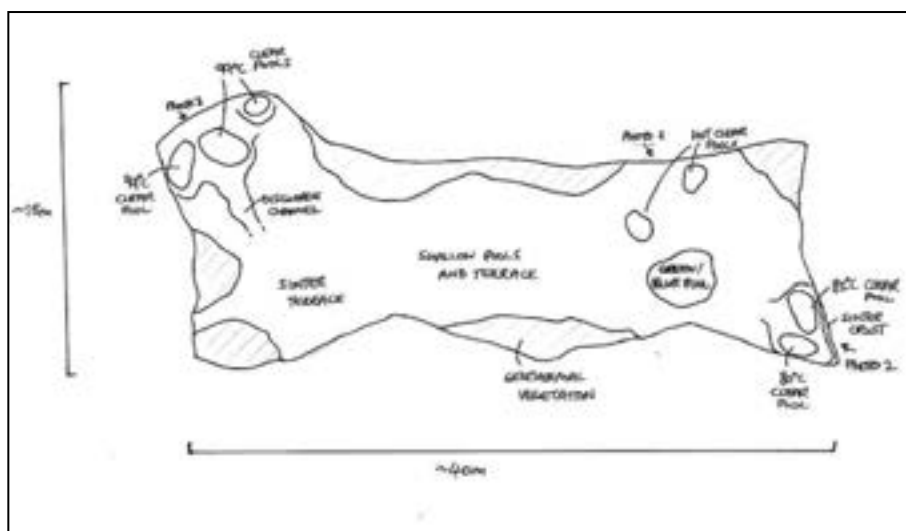


Figure A1-8: Field sketch of area of hot pools and sinter terrace, Feature 3, Waitapu South.

Feature 4:
Concealed mud pools

Grid Reference:
E1893725 N5748742

Up to three concealed mud pools were noted at this location. Access was not safe; however steam discharge and audible bubbling distinctive of mud pools were noted.

Feature 5:
Shallow lake

Grid Reference:
E1893737 N5748532

This feature is a shallow lake with grey cloudy water. The temperature at the surface of the lake was 20 °C while the soil temperature at the lake edge was 15.7 °C. No steam was observed at the lake and there was no evidence of degassing. Some steaming ground was noted approximately 10 m south of the lake.

Feature 6:
Mud pool
Grid Reference:
E1893611 N5748639

A mud pool with significant steam discharge including an almost continuous 'hissing' vent was observed. The pool measured approximately 2 × 2 m. The base of the pool was 2 m below ground level. The surface temperature was between 60 °C and 64 °C.



Plate 48: Mud pool. Note steam vent on right hand side of photo, Feature 6, Waitapu South.

Feature 7:
Cool mud pool

Grid Reference:
E1893689 N5748532

This feature comprised a cool mud pool that measured approximately 1 × 1.5 m and was approximately 1 m deep. The surface temperature was 39 °C. There was no steam discharge associated with this feature although there infrequent bubbling was noted. The surrounding vegetation was coated in a light grey mud indicating that the pool was eruptive in the past (Plate 48). On one side the vegetation was flattened.



Plate 48: Small mud pool in centre of photograph. Note mud coating on vegetation surrounding pit, Feature 7, Waiotapu South.

Feature 8:
Geothermal seepage

Grid Reference:
E1893742 N5748546

A clear very shallow seepage was noted at this location. The temperature was 43 °C. The flow was very low (<0.1 l/s).

Feature 9:
Mud pool

Grid Reference:
E1893738 N5748513

A grey mud pool was observed at this location which was approximately 3 m² in area (Plate 49). The feature had considerable gas and steam discharge. The temperature at the surface was between 70 °C and 80 °C. The soil temperature at 10 cm depth at the edge of the pool was 15.7 °C.



Plate 49: Mud pool, Feature 9, Waiotapu South.

Feature 10:
Geothermal pool

Grid Reference:
E1893728 N5748481

This feature is a large, deep, clear pool/lake 10 m² in area. The temperature at the surface was 55 °C. There was no safe access to take a pH measurement as the margins of the lake were heavily vegetated over a soft substrate. No evidence of silica deposition was noted. No outflow was noted.



Plate 50: Clear deep pool with soft margins,
Feature 10, Waiotapu South.

Feature 11:
Freshwater stream with
geothermal inputs

Grid Reference:
E1893961 N5749308

The stream that flows through the northern section of the Waiotapu tourist park had a temperature of 26 °C near the visitors centre. At the grid reference listed above the temperature was 28 °C. This location is further downstream and to the west of the main surface features. There are numerous areas of steaming ground in the vegetation on the banks of the stream and there are bathing areas where geothermal fluid inputs must raise the temperature closer to 35 °C locally (common public hot spring bathing temperature). The flow of the stream was estimated to be in the order 150-200 l/s.

Feature 12:
Mud pool

Grid Reference:
E1893477 N5748452

A mud pool with a surface temperature of 60 °C was observed at this location. It contained a light grey liquid, measured 3 m² and was degassing. There was considerable vegetative cover.

Feature 13:
Warm Lake

Grid Reference:
E1893575 N5748330

A warm lake was observed with a temperature of 18 °C and pH of 4.9 at its western margin. An area at the southern end of the lake had moderate steam discharge (Plate 51) which may be the result of an upwelling of hotter fluid. An outflow is present at the southern margin, and had a temperature of 21 °C, a pH of 4.8, and a flow of approximately 5-6 l/s. The water was clear.



Plate 51: Warm lake with area of steam discharge at southern end, Feature 13, Waiotapu South.

Feature 14:
Hot spring

Grid Reference:
E1893329 N5748493

A hot spring discharging fluid of up to 40 °C was observed on the edge of the main stream running through the northern part of the Waiotapu tourist park (Plate 52). Green and orange algae were noted on the banks at the hot spring. The surface temperature of the stream at this point was 26 °C.



Plate 52: Hot spring with orange and green algal growth on bank of stream. View from road bridge, Feature 14, Waiotapu South.

Feature 15:
Exposed warm ground

Grid Reference:
E1894865 N5748370

This feature is an area of exposed silicified soil and pumice measuring approximately 20 × 30 m (Plate 53). There was widespread minor sulphur encrustation on the surface and occasional fragments of silicified organic material. A small area of steaming ground was identified at the southern end of the site. The steam discharge was not significant and was surrounded by geothermal vegetation. The soil temperatures at 10 cm depth here and in the southeastern part of the site were around 32 °C, while most of the exposed area had soil temperatures between 15 °C and 18 °C.



Plate 53: Exposed ground with silicified soil, pumice and organic material, Feature 15, Waioatapu South.

Feature 16:
Exposed ground,
steaming ground, mud
pools

Grid Reference:
E1894979 N5748228

This feature is a series of large areas of exposed steaming ground with fumaroles depositing sulphur, mud pools/pits and numerous small, hot, grey pools (Plate 55). The main area of mud pools measures approximately 30 × 60 m and consists of two main pits with mud pools and an extensive silicified crust. Sulphur encrustation was common across the area. There was moderate steam discharge and audible bubbling of the shallow water table beneath the silicified crust. One clear, grey pool measuring 0.2 × 0.2 m had a fluid temperature of 90 °C.



Plate 54: Main area of activity with two pits comprising mud pools seen in the foreground and background respectively (arrows), Feature 16, Waioatapu South.



Plate 55: Small 90 °C clear grey pool,
Feature 16, Waiotapu South.

TIROHANGA ROAD¹

Overview of field work and background:

The thermal manifestations close to the Tirohanga Road in the Mokai Field were visited during the late morning on 5 February 2007 (refer to map Tirohanga Road – 2007 Geophysical Assessment). The sky was overcast and air and surface (ground) temperatures were between 18° and 20 °C. These manifestations comprise a number of north-south aligned, often north-south elongated craters and small canyons which occur over a distance of *c.*300 m. In the past, steam was discharged along this fracture zone segment which derived from boiling of thermal water at a few hundred meters depth. Some of the acid condensates accumulated in a few muddy pools. When the Mokai Field was developed for electric power production in 2000, the separated thermal waste water from the power house was reinjected into a few drill holes *c.*500 m to the east of the then steaming mud pools. This led most likely to some quenching of underground vapour ascending in the fracture zone and thermal steam discharges ceased during 2005. All water-filled craters had cooled and exhibited ambient temperatures (*c.*20 °C) when visited on 30 March 2006 (see Hochstein 2006).

During our visit on 5 February 2007 it was found that thermal water (not steam) is again entering most of the pools which had cooled down to quasi-ambient temperatures a year ago. The findings of the visit are listed in sequence, going from south to north along the *c.*300 m long segment of manifestations.

Manifestation 1A – Crater and Pond 1A:

This is the southern most, water-filled crater. At present, it exhibits a thin strip of black mud along its margin. The pond surface covers an area of *c.*300 m² (all areas cited in this report are order of magnitude estimates only using stepped out distances). The 2007 water level is significantly higher than that observed in 2006 when the pond area was much smaller (<30 m²) and exposed a large area covered with black mud. The surface temperatures of the pond on 5 February 2007, when measured with the IR-gun, were between 28 and 29 °C. The water exhibits a dark, muddy colour. It is likely that the elevated surface temperatures are due to some input of thermal water.

Manifestation 1B – Crater and Pond 1B:

This small crater lies *c.*20 m north of Pond 1A. The pond in the crater covers an area of <50 m². It contains muddy, grey-brownish water with surface temperatures between 22 °C and 24 °C. The pond might not be recharged by thermal water.

Manifestation 2 – Hot Lake:

The hot lake lies *c.*50 m north of Pond 1B and covers an area of *c.*500 m² with surface temperatures (IR-gun) between 53 °C and 56 °C. There appears to be a small up-flow zone near the south margin where a maximum temperature of 67.1 °C was measured at *c.*0.2 m water depth with a thermocouple device. About 10 m to the south is a deep (2 m) collapse pit with *c.*53 °C stagnant water at the base. Elevated ground temperatures of *c.*27 °C occur at 0.2 m depth on land, half way between the lake and the collapse feature. At the northwest margin of the lake there is a shallow trickle outflow of lake water (<1 l/s) which infiltrates the ground. Further downstream to the south, another shallow, small outflow emerges. There was

¹ Undertaken by Hochstein in 2007

no lake at this site in 2006 although it was occupied by bare, partly steaming ground prior to 2000; it is likely that the hot lake is fed by thermal water which derives from reinjected water now ascending in the fracture zone.

*Manifestation 3A –
Large Mud Pool 3A:*

About 50 m north of the new hot lake lies an old, large mud pool (3A), used historically as a rubbish tip but now almost cleared of rubbish. The pool area is covered by a muddy grey-brown coloured lake with an estimated surface area of *c.*500 m². The maximum surface temperature in the centre of the lake was *c.*30 °C, observed within a large discoloured water patch (up-flow?). The 2007 colour of the lake water is quite different from that observed in 2006 when it was a dark-brown stagnant water. The surface area of the lake has not changed considerably between 2006 and 2007 (although a minor increase was noticed along the western shore).

On top of the western rim of Pool 3A, a small strip of thermally altered ground is exposed. The ground temperature of the thermally altered ground at 0.2 m depth was 19 °C (i.e. non active ground).

*Manifestation 3B –
Adjacent Smaller
Muddy Pool 3B:*

Directly adjacent to the southeast margin of Pool 3A lies a smaller (*c.*150 m²), water-filled, almost circular crater (Pool 3B), exhibiting a surface temperature of 35 °C (36.0 °C when measured with a thermocouple at 0.2 m depth). The elevated temperatures point to some significant input of thermal water. The level of the smaller pond (3B) was *c.*1 m above that of the larger pool/lake (3A). Some water of the smaller pond appears to seep through a small, *c.*1 m wide dam which separates the two ponds and which could be breached at any time. The surface temperature of the larger pool/lake (3A) was *c.*34 °C just adjacent to the dam. In March 2006, the surface level of Pool 3B was below that of the larger Pool 3A (Hochstein 2006).

*A Deep Pit (Acid
Leaching?):*

About 35 m to the southwest of Pool 3A was a *c.*2.5 m deep, almost circular pit (*c.*3 m diameter), which exhibits almost vertical walls (located at E1853320 N5734250). The temperature on the dry bottom was *c.*20 °C (i.e. a non active feature). Pits with a similar wall structure occur in the Waiotapu geothermal system where they are most likely caused by slow dissolution of pumice layers involving acid (steam) condensates. It is possible that some pits and canyons of the Tirohanga Road manifestations are also caused by ‘acid leaching’.

*Manifestation 4 – Deep
Canyon:*

An almost 15 m deep and *c.*40 m elongated (in north-south direction) ‘canyon’ lies *c.*100 m north of Manifestation 3. The bottom of the gully (Feature 4) is covered by a small lake. The surface temperature of the northern part of the lake was *c.*28 °C. There is a small, up-welling, muddy pool at the south end, associated with some wafting steam. The temperature at its southern margin was between 30 °C and 50 °C when measured from the rim with the IR gun. The walls of the canyon were too steep to climb to the bottom for closer inspection. However, some thermal water is obviously entering the bottom of this canyon.

*Manifestation 5 –
Canyon at the Northern
End of the Tirohanga
Road Manifestations:*

Another *c.*50 m long, deep canyon (Feature 5) lies at the north end of the north-south aligned craters and canyons. This feature contains no pools and does not exhibit any visible thermal activity. However, at the northern end of the deep, elongated structure lies an old Māori ‘steam pit (umu)’ where the ground temperature at the bottom was *c.*38 °C (0.4 m below surface). Some residual geothermal kānuka shrubs were found along the northernmost

western rim. However, the ground temperature at 0.2 m depth beneath 1.0-1.5 m high geothermal kānuka was *c.*18 °C (i.e. non-thermal ground).

Interpretation of Findings:

It is likely that the thermal water now emerging in five manifestations (Features 1A, 2, 3A, 3B, and 4) derives from thermal waste fluids discharged by the geothermal power station (located *c.*3.5 km to the southeast of the Tirohanga Road manifestations), from where they are transmitted by surface pipes to three reinjection wells (MK 4, 8, 9) which lie *c.*400 to 500 m east of the Tirohanga Road craters and pools. Since the commissioning of the plant in 2000 until 2005, *c.*800 t/hr of separated thermal waste water was injected into two of the three reinjection wells, down to depths of about 400 m. This rate was increased to *c.*1,400 t/hr from May/June 2005 onwards when the abstraction rates from hot bores supplying hot fluids to the power station were increased. During the first period of reinjection (i.e. from 2000 to *c.*2004) the injected wastes started to accumulate at depth and around the injection wells, which led to the quenching of naturally discharging steam beneath and within the Tirohanga Road thermal manifestations, which ceased to discharge steam by 2004/2005. All manifestations then cooled down and elevated ground temperatures could no longer be observed at the beginning of 2006. When the injection rate of the plant was increased in 2005 and after the quenching of ascending steam, thermal waste water must have started to ascend to the surface, as it was noticed during our visit on 5 February 2007.

The Mokai Geothermal Power Plant managers must have been aware about the underground pressure build-up around the reinjection wells, since deeper reinjection has been considered. One of the new, deep reinjection wells is presently being drilled near one of the old injection wells. Since rapid changes in the natural discharge rate of the injected waste fluids might occur, some detailed monitoring of the Tirohanga Road manifestations should be considered.

UPPER ATIAMURI WEST¹

Overview of field work and background:

The site was inspected on 5 February 2007 in the early afternoon. Overcast conditions prevailed the whole day, it was calm, air and ground temperatures were in the range of 20 °C and 22 °C. Two smaller previously unknown manifestations had been recently reported by the farmer, Mr B. Bergs.

A circular pit exposing an active thermal spring:

A subsurface thermal spring discharges at the bottom of a c.2.5 m deep, almost circular pit (diameter c.2 m) on Bergs Farm at E1866338 N5749636. The site lies c.190 m northwest from the southern Atiamuri hot pool. Hot water with a temperature of 59.3 °C flows as a trickle across the bottom of the pit. The upper part of the almost vertical wall of the pit exposes a grey, c.0.5 m thick, old silica sinter layer. The pit lies on top of a c.2.5 m high sinter mound which points to a long deposition history of this manifestation. The trickle flow of thermal water at the bottom drains through a subsurface layer. The sinter mound is overgrown with dense scrub. The temperature of the hot spring is close to that measured at the surface of the nearby Upper Atiamuri hot pools (Site U16/6). No simple explanation can be put forward to describe the processes which might have led to the formation of a deep, vertical pit on top of an obviously old sinter mound.

A quenched fumarole:

About 350 m to the northwest from the southern Atiamuri hot pool, also on Bergs Farm at E1866297 N5749798, there is a small thermal feature which appears to be a quenched fumarole that occurs within a vertical vent of <0.3 m diameter. The vent is out of sight and occurs at the bottom of a c.2 m deep and c.5 m wide depression which is overgrown by dense exotic herbfield. Near the top of the vent, steam is condensed by liquid, black mud. The stable temperature c.0.1 m inside the mud layer was 97.5 °C. The ground around the vent is heated to c.40 °C at the surface, about 0.5 m away. Quenching of steam is associated with a hissing and bubbling noise. This feature was not described as a 'boiling mud pool' because of its small size.

¹ Undertaken by Hochstein in 2007.

WHANGAPOA SPRINGS¹

The southern hot pool: This pool had a surface area of *c.*600 m², infilling a deep crater with clear bluish coloured thermal water. The surface temperature was rather constant at 60 °C (fluke thermocouple). Minor gas discharges showed up as bubbles in the centre of the pool. At the main outflow and overflow at the southwestern rim, thermal water was discharged at a rate of *c.*1 l/s at 58 °C (pH = 7).

The northern hot pool: About 60 m north of the southern pool lies the somewhat smaller northern hot pool, which covers an area of *c.*400 m². It occurs in a deep hollow, and is surrounded by 2-3 m high cliffs. The thermal water is also of a blue colour, but slightly less clear. The surface temperature was also constant (*c.*60 °C when measured with an IR gun). In the north corner, near a dug outflow channel, there was a significant gas discharge (continuous bubbles). Here, the pool temperature at *c.*0.2 m depth was 69 °C. At the north outlet, the outflow rate was estimated to be 1-2 l/s (discharging at 53 °C).

MATAPAN ROAD²

There are two springs, one discharging *c.*3 m above the pool with a temperature of 64 °C. A cooler spring with a smaller flow discharges from the right of the rock face around 1 m above the pool. No smell of H₂S was recorded. The rocks below the spring and in the pool are covered in black algae.

¹ Undertaken by Hochstein in 2007.

² Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

MURPHY'S SPRINGS¹

Thermal Springs discharge into a stream along the edge of a pine plantation and a bank of recently felled pine. During the site visit, four thermal springs were identified, which discharge at various points along a c.200 m stretch of the gully. A small stream originates in an area of wetland on the east bank of cleared pines (Location 1 on sketch). The flow in this stream is approximately 10 l/s with a temperature of 32.8 °C and a pH of 6.3.

On the western side of the gully there are three thermal springs which discharge along the steep bank into the main stream. The access to these springs is difficult and only one of them, the furthest south, was directly measured using a pH meter and thermometer. The remaining two were obstructed by vegetation and fallen trees and were measured using the IR thermometer. The flow rates in the two obstructed springs were estimated to be in the order of 5 l/s, while the accessible spring had a flow rate of approximately 20 l/s. The temperatures in all springs ranged from 41 °C to 47 °C. The pH of the southern spring was 7.5 indicating a neutral spring. Pine forest, which has recently been felled around this site, tends to have slightly acidic soils; therefore the neutral pH of the thermal spring fluid would suggest that the source is deeper chloride water. All springs were discharging clear water.

Downstream of the thermal spring inputs the main stream has a flow of 80-100 l/s, a temperature of 26 °C, and a pH of 7.1.



Plate 56: Murphy's Springs geothermal area looking south across gully at largest spring on stream true right. Note the abundant *Christella* sp. aff. *dentata* ("thermal") alongside stream margins.

¹ Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

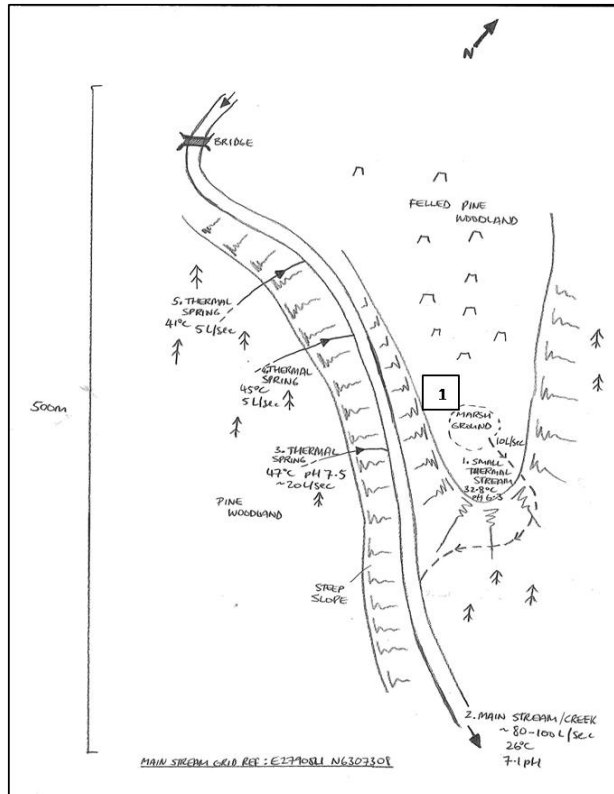


Figure A1-9: Murphy's Springs geothermal area:
Sketch map showing main features and photograph location.
The grid reference labelled here is E1880411 N5745753 (NZTM).

TE KOPIA NORTHWEST¹

This is an area of bare, steam-heated ground which lies to the west of the mud pools described in the site Te Kopia West Mudpools (TKV04). It comprises 15 × 25 m of thermal ground consisting of areas of silicified crust, steam vents/fumaroles and bubbling mud pools (Plate 57). The area has a northwest-southeast orientation and falls by approximately 0.5 m from north to south. A small stream (*c.*30 l/s) flows along the western margin of the area.

The southeastern part of the area is dominated by a thin silicified crust which lies above steam heated soil. The crust was found to be very thin and unstable limiting movement and inspection of the area to the boundaries only (Plate 58). One soil temperature measurement at 0.1 m depth showed 52 °C (see map for location). Associated with this area are steam vents or fumaroles which are actively discharging gas with moderate H₂S content. Near one steam vent in this area, bubbling from beneath the crust could be heard. There is also active sulphur deposition occurring in this area. Between this area and the stream are some small steam vents where soil temperature was 100 °C (see map for location).

The central part of the area appears to be less active. This area, while still covered by the silicified crust/sinter, is encroached by geothermal kākūka and moss cover indicating cooler temperatures (Plate 59).

The northeastern part of the area comprises a silicified crust along with two mud pools (Plate 59). At the back of this area, where the slope rises, it comprises bare ground with altered rock and soil. The lower parts of the slope have active pools. There was no safe access to these pools so it is not known if the pools are boiling or only near to boiling; however rising steam was observed from all pools. This area has noticeably more steam discharge than the southeastern area.

The stream flowing along the western boundary does not appear to be affected by the thermal ground or display evidence of heating. Temperatures ranged from 12.6 °C to 13.2 °C with pH between 5.7 and 5.9.

¹ Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

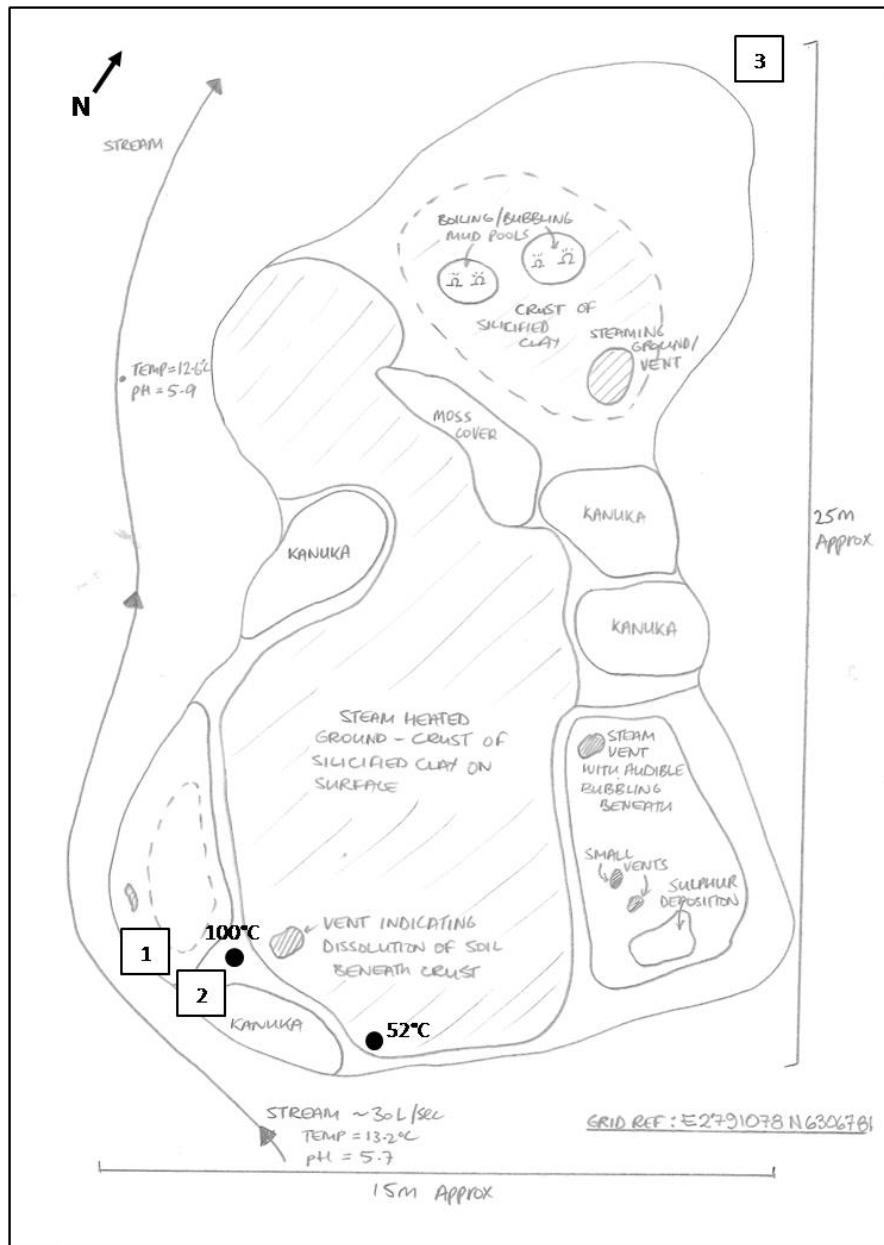


Figure A1-10: Te Kopia – Northwest. Field sketch map indicating main features and photo locations. The grid reference labelled here is NZMG.



57



59



58

Plates 57-59:

- 57. View of area from southwest corner. Note: geothermal kānuka and moss present in central area with steaming ground and mud pool in background.
- 58. View of silicified crust, steaming ground and sulphur deposition in southeastern corner.
- 59. View from elevated area in northeastern corner. Note mud pools in the foreground with adjacent central area of geothermal kānuka/*Campylopus* cover.

TE KOPIA WEST MUD POOLS¹

This is a group of three mud pools on the slopes of a small north-south ridge on the west of the Te Kopia Road. All these features must be approached from the downhill side; there is nothing to break a slip into these from the top, and sides are often undercut. The temperature in all of the mud pools is >80 °C.

On the northern end of the ridge there are two deeply cut-in mud pools approximately 8 m apart.

Eastern Pool

The most eastern of these features is 1.5-2 m wide, and >6.5 m long. The southern end of this feature has undercut at least 3 m into the hill, although the full extent cannot be seen. The downhill lip of the pool has an apron of lumpy mud ejecta that extends at least 3 m downhill (Plate 60).

The pool has brown muddy water with two hot regions (81 °C and 80 °C), separated by a cool midsection (25 °C). There is significant effervescing gas associated with the major upwelling at the back of the overhang (Plate 61). There are smaller upwellings in thicker mud near the northern end of the pool. There is no visible liquid discharge.

The water level in the pool is *c.* 2 m below the downhill lip. The near vertical walls of the pool are coated with vertically fluted mud which has recently sloughed off in patches.

¹ Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

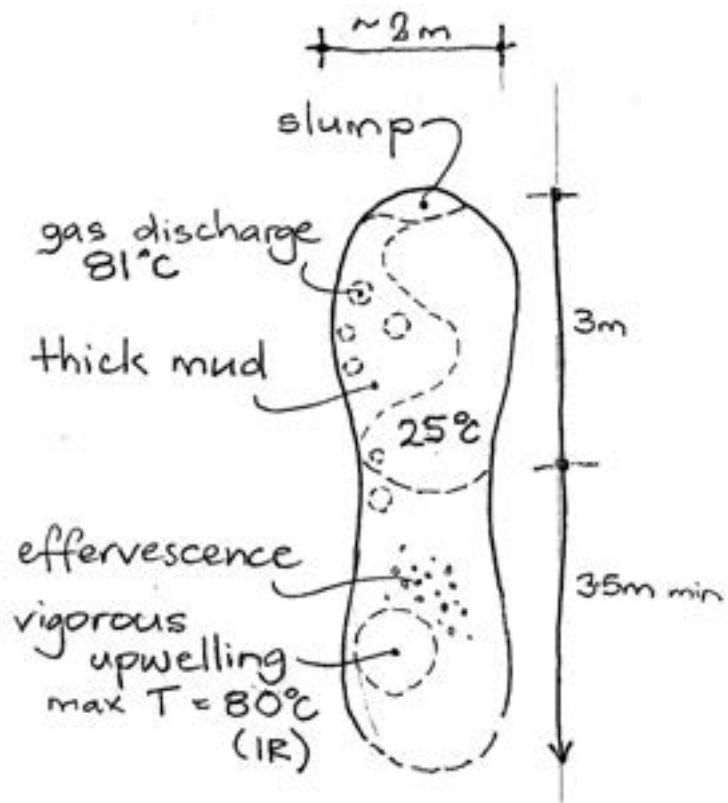


Figure A1-11: Sketch map of the eastern-most mud pool, Te Kopia West Mud Pools.



Plate 60: Apron of mud over the northern lip of the eastern mud pool, Te Kopia West Mud Pools.



Plate 61:
Looking south into the pool. The major upwelling is at the far end of the pool, Te Kopia West Mud Pools.

Middle Pool

The middle feature is located on the northern slope. This is a 5 m diameter hole at the surface which narrows to a *c.*3 m diameter at the base, which is 4 m below the downhill lip.

There is an area of vigorous activity on the north side of the pool (99 °C), accompanied by significant effervescing gas. The pool is lightly undercut in this area. There is a 0.4 m wide beach on the southern and eastern sides of the hole and a ledge, possibly indicating a past water level, *c.*0.7 m above the present water level.

There is no visible liquid discharge.

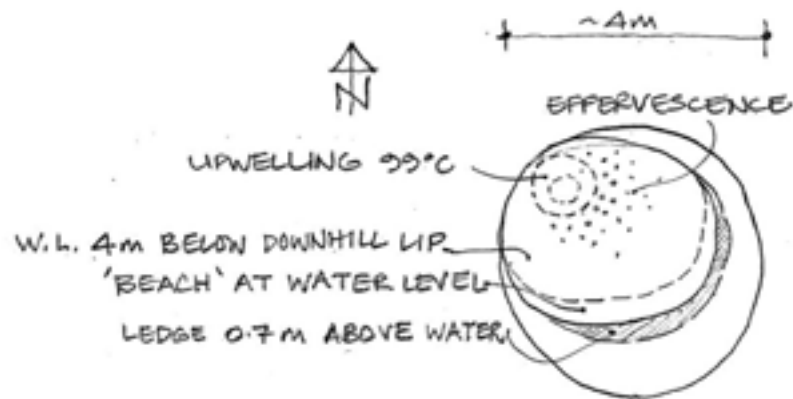


Figure A1-12: Sketch map of middle pool, Te Kopia West Mud Pools.



Plate 62: Middle pool, Te Kopia West Mud Pools.

Southern Pool

The landowner has reported that this pool has become more active recently. The pool is set into the western side of the hill. The dimensions and form are

Grid Ref (NZTM):
E1880900 N5745117

shown in the accompanying sketch map and cross-section (Figures A1-13 and A1-14). A distinctive feature is the mud dam that is confining the present mud pool to the eastern portion of the feature. In front of the dam is a dry area with a floor that is 0.5 m below the pool water level, which may have been part of an earlier pool, and which is bounded to the west by the lip of the earlier pool.

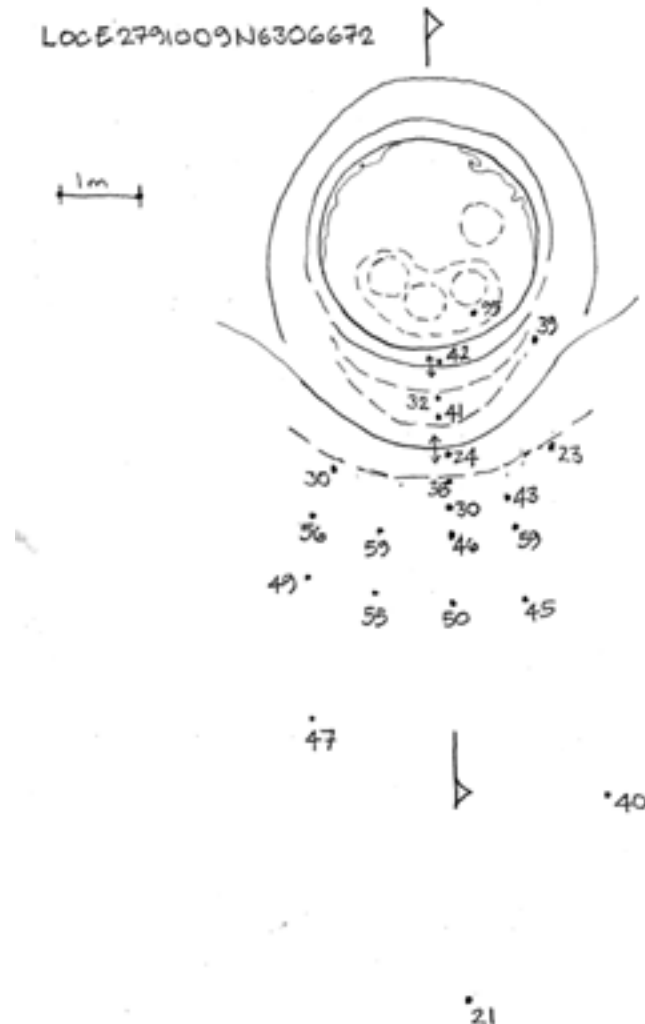


Figure A1-13: Sketch map of southern pool, indicating temperature in degr499mall499ssius. Grid reference is in New Zealand Map Grid.

The ground immediately in front of the pool has elevated temperatures (23 C-41 °C), but between 1 and 5 meters away the ground temperature is in excess of 50 °C, and the vegetation is dying. The temperature measurements were paced out, but give an indication of the temperature distribution down-slope of the pool.

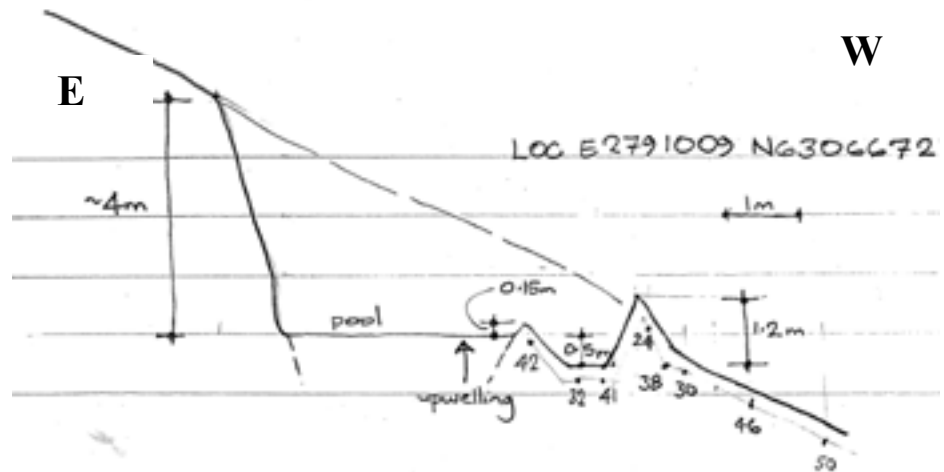


Figure A1-14: Sketch cross section E-W through the feature showing the inner dam confining the pool, and the soil temperatures at 0.1 m depth. Southern pool, Te Kopia West Mud Pools. Grid reference is in New Zealand Map Grid.

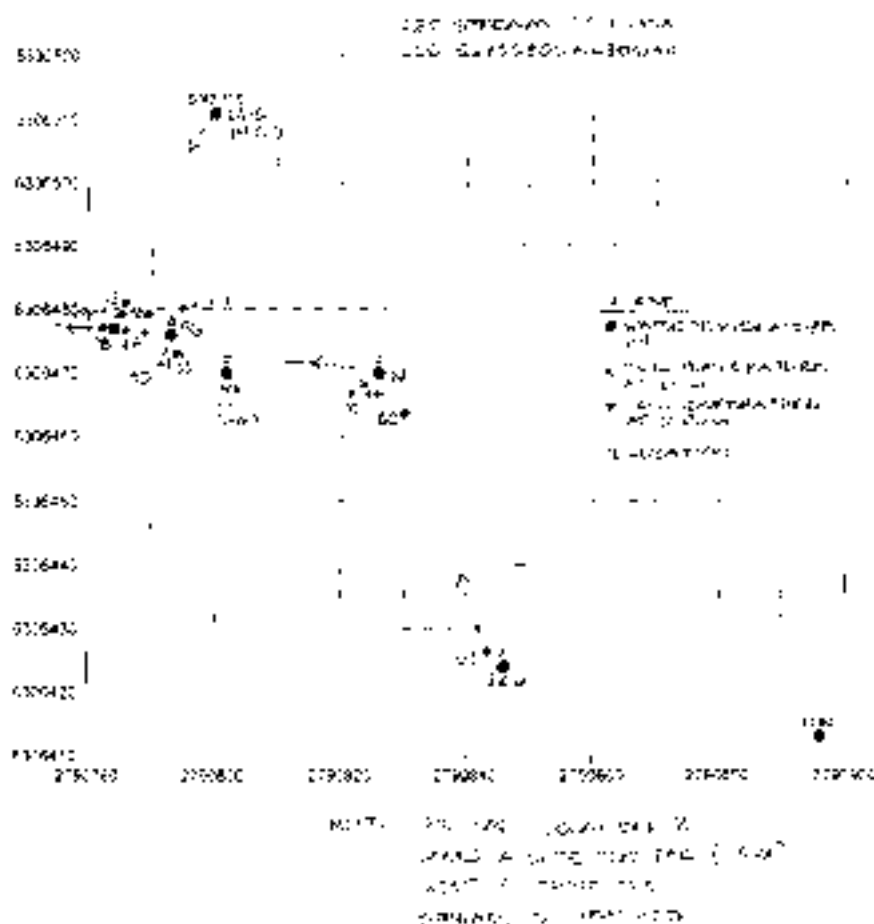


Plate 63: The southern pool showing inner dam in foreground.

TE KOPIA RED STREAM¹

This is a small stream west of Te Kopia Road. The stream runs from the road for about 70 m to join a cold stream (12-13 °C, pH 6.3) flowing south through farmland. The flow rate of the cold stream is difficult to estimate as it flows through a large swampy area; the best estimate is 15 to 20 l/s. Below the confluence the temperature of the stream is 28 °C. The thermal stream bed has a rich, dark red coating, and the flow rate is also 15 to 20 l/s. Most of the stream is in a blackberry infested gully and access is difficult, however, there are sections where access is possible. Above the confluence the water temperature is 47 °C, and as we moved upstream the temperature increased to a maximum of 61 °C. Thereafter the next temperature measurement was 53 °C (Plate 64), and another 3 m along the stream 22 °C. This indicates that there is an approximately 50 m length of stream which has significant geothermal discharge. The soil on the edge of the stream (within 1 m of the water) was also warm (42-59 °C at 1 cm depth) but there is no thermal activity >1 m from the edge of the stream.

The accompanying map (see below) shows only measured temperatures at the recorded locations.



MANGAMINGI STATION¹

Overview of field work: This is an area of geothermal ground south of Te Kopia. The area was visited on 28 June 2010, in the afternoon. We arrived at the site at 1315 hrs. The weather was cold and overcast with a light wind. It rained intermittently all afternoon.

Areas are shown on diagrams at end of site sheet. The largest area of thermal ground (Area 5, which is *c.*200 m²) is situated on a southwest facing slope, with small areas of warm ground (Areas 1 and 2, which are 4 m² and 16 m² respectively) outcropping on an adjacent southeast facing slope. There are two small pools, which are slightly above ambient temperature. Over the ridge to the southeast there is another smaller area of warm ground (Area 6, *c.*24 m²), with steam issuing from a fracture in a rock outcrop.

Locality 1: This is a small exposed face consisting of thermally altered clay, which measures approximately 4 m². The face is 1 metre high and comprises a band of altered white clay at the base (kaolin) and red/ochre stained altered clay above it. The temperatures across the face and at the base range from 24 °C to 41 °C (see Diagram 1)

Localities 2 and 3: These areas are similar to Locality 1 approximately 15 m to the southeast. They comprise a small area of exposed altered pink and white clay measuring approximately 3 m². The temperatures across the exposed face range from 28 °C to 45 °C at 10 cm depth.

Locality 3 (pool) This 0.4 m diameter pool is 17 °C and has murky brown water.

Locality 4 (pool): This oval pool is *c.*1 m long by 0.5 m wide and is 18 °C and also has murky brown water.

Locality 5: An approximately triangular area of thermal ground. Approximately 30% of the ground is exposed white (kaolin) clay or pink clay. Rocks that outcrop or lie on the ground in the area are silicified white clay.

The north of the area is a 5 m wide shallow gully stepping 18 m up the hillside in four small scarps of exposed thermally altered ground. Temperatures in this thermal ground are up to 91 °C at 10 cm depth.

In the southern half of the area there are five main areas of exposed ground (Figure A1-16). Three of these comprise altered pink and white clays and have temperatures ranging from 45 °C to 75 °C. There is minor diffuse steam discharge across all three areas. The two remaining areas have moderate steam discharge and temperatures ranging from 56 °C to 99 °C. Both of these areas are higher up, approximately halfway up the slope. The most northern of these, has smectite banding associated with the altered pink and white clays. This type of alteration is distinctive by a green staining of the clay. The southern point source of steam discharge comprises altered clays and silicified clay fragments. The small steam vent measures approximately 5

¹ Geophysical assessment undertaken by Juliet Newson and Julian McDowell, 2010.

cm in diameter. The temperature at this point was 85 °C at 10 cm depth (see Diagram 3).

Locality 6:

This is a 24 m² area of thermal ground over the ridge from Locality 5. There is an outcrop of fractured silicified fine grained white rock. The junction of the fractures hosts a steam vent which is c.0.15 m wide. Ground temperatures at 10 cm depth around the base of the rock range from 34 to 55 °C. A second outcrop of silicified rock has a steam vent at the base of the rock where the ground is 92 °C. There is an area of soft white and pink clay with no grass cover which has temperatures ranging from 48 to 57 °C (see Diagram 2).

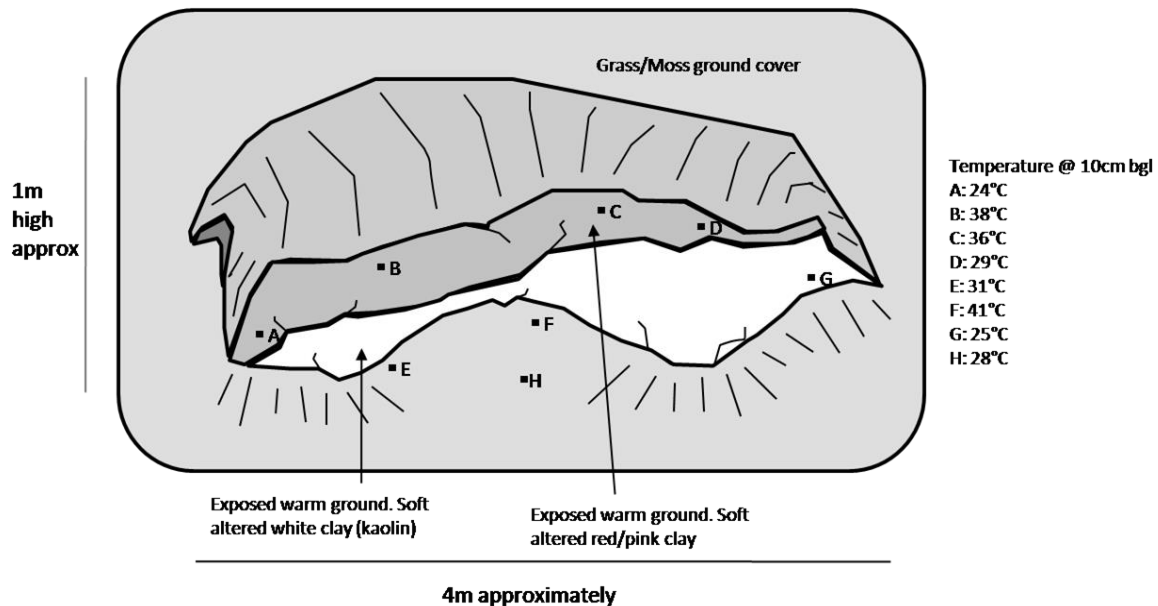


Diagram 1: Geothermal activity at Locality 1.

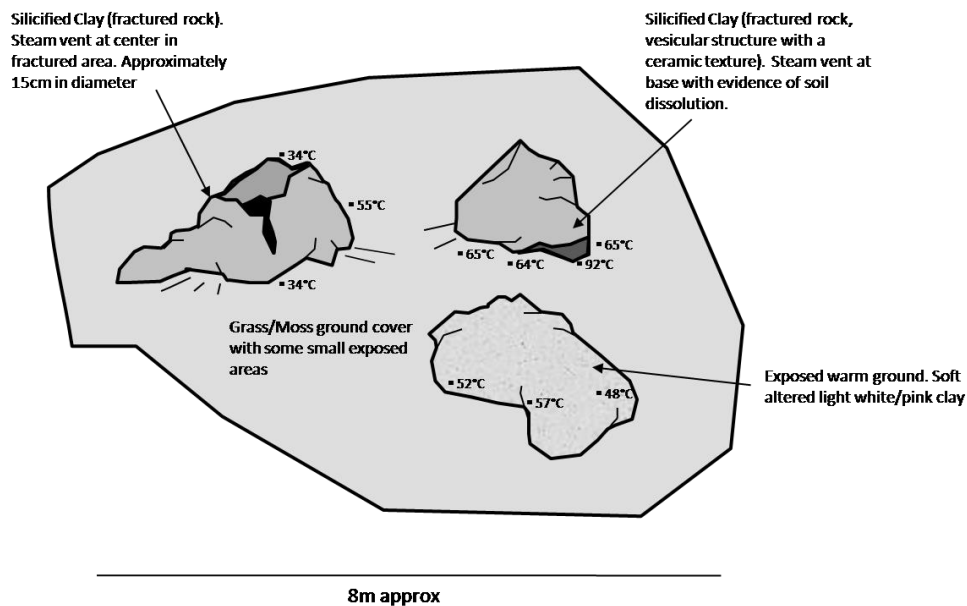
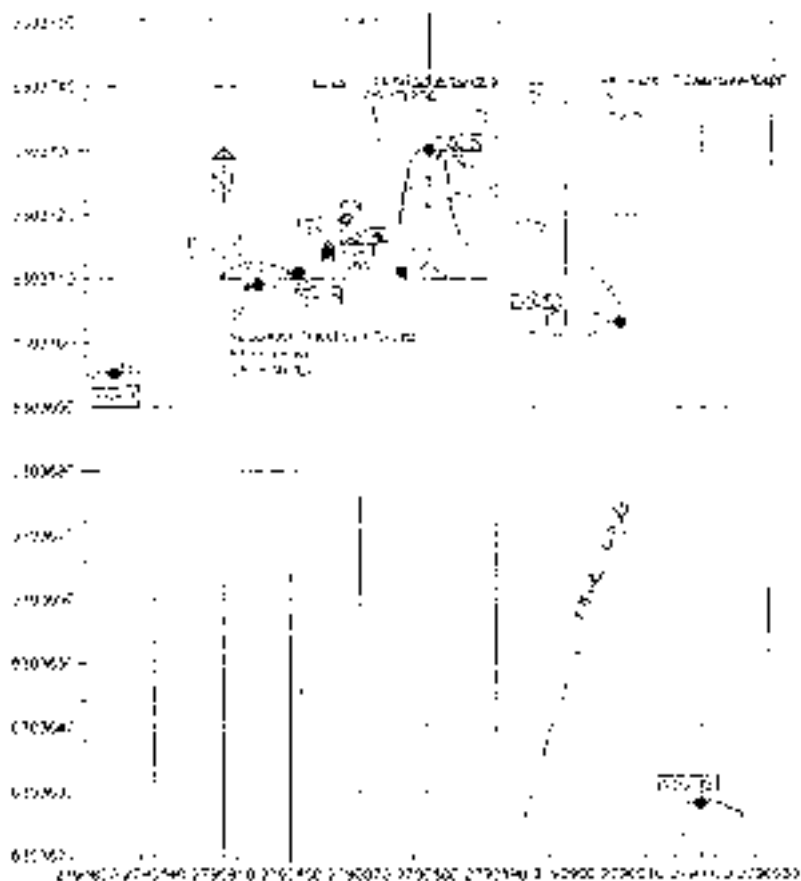


Diagram 2: Geothermal activity at Locality 6.



Sketch map of geothermal features at Mangamingi Station. Grid references are in NZMG in the sketch and NZTM in the table opposite.

1	1880729	5742138
2	1880750	5742152
4	1880760	5742157
3	1880756	5742154
5a	1880803	5742146
5b	1880771	5742154
5c	1880775	5742173
6	1880815	5742071

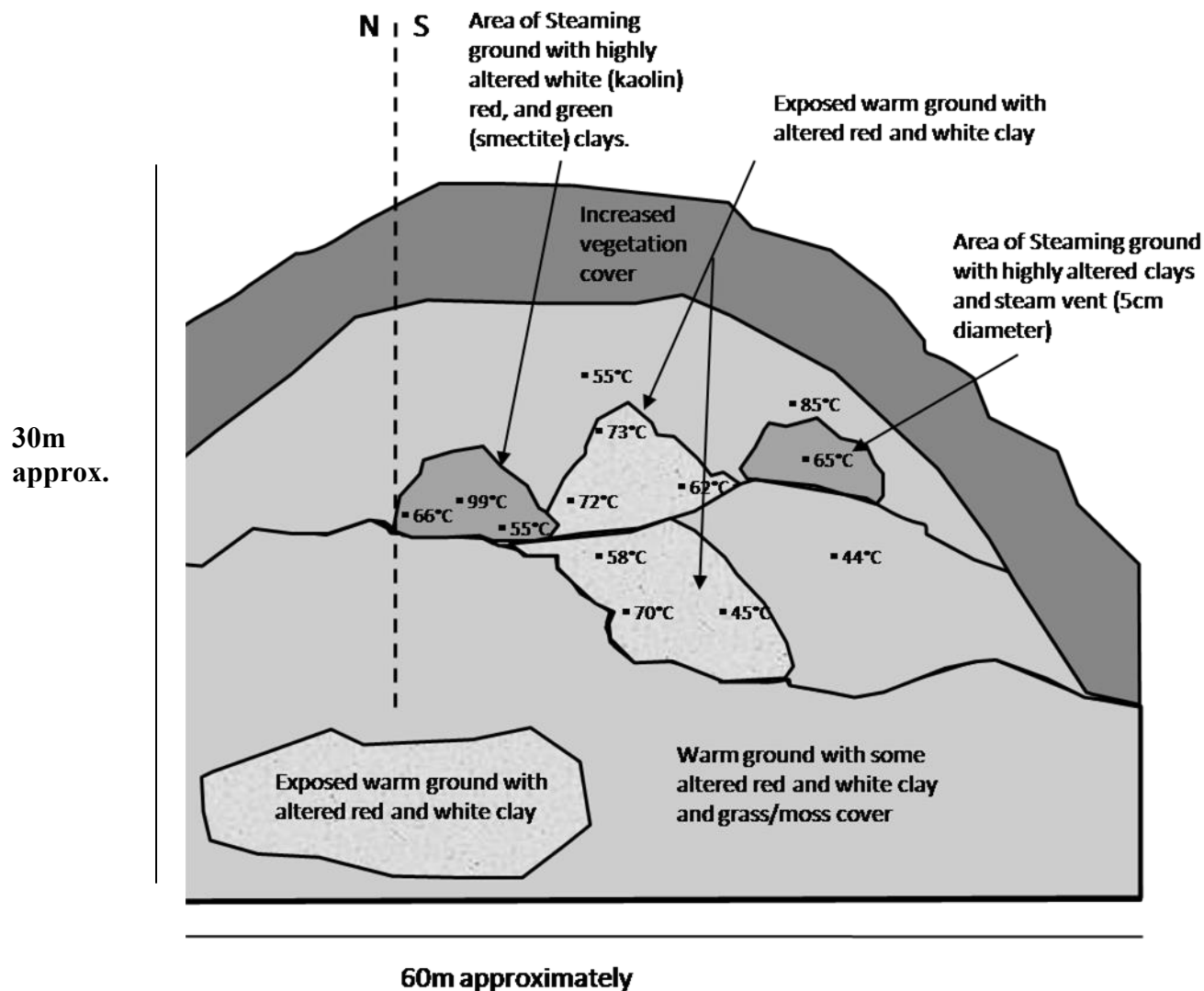


Diagram 3: Sketch map of geothermal activity at Locality 5 (see other sketch map) at Mangamingi Station.

ORĀKEI KŌRAKO¹

Feature 1:
Steaming ground, relic
geyser mound

A small area of steaming ground was identified in the centre of a relic geyser. The sinter/geyserite mound measured 0.6 m² while the aperture measured 0.3 m². The temperatures in the centre ranged from 77 °C to 87 °C. The soil temperatures surrounding the feature ranged from 48 °C to 72 °C. The steam discharge was minor.



Plate 65: Relic geyser mound with steaming ground. Feature 1, Orākei Kōrako. Note the *Dicranopteris linearis* in photo.

Feature 2:
Sinter scarp

Grid Reference:
E1874513 N5736869

Directly behind the relic geyser mound is a large expanse of sinter scarp (30 × 8 m). The scarp was heavily vegetated in places and did not appear to be undergoing active deposition of sinter (wet surfaces appear to be soil run-off as opposed to silica laden fluids). At the base of the scarp were two areas with moderate steam discharge. The soil temperatures at 10 cm depth were between 50 °C and 60 °C. At one point the thickness of the sinter was observed through a break in the crust to be about 10 cm thick.

¹ Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.



Plate 66: Heavily vegetated sinter scarp. Feature 2, Orākei Kōrako.



Plate 67: Sinter structure on scarp. Note silicified organic material. Feature 2, Orākei Kōrako.

Feature 3:
Relic discharging
pool/Geyser

Grid Reference:
E1874554 N5736837

A relic sinter depositing pool/geyser was identified above the scarp and sinter deposition channels. The sinter channel could be traced back to this feature. The feature consists of 6 × 5 m crater with audible bubbling at depth. The centre of the crater is dominated by an east-west trending fissure. The sinter apron has disintegrated considerably and the rock is stained pink-orange and grey. There was moderate steam discharge from this feature.



Plate 68: Relic discharging pool/gyser with east west fissure and sinter terrace in background, Feature 3, Orākei Kōrako.

Feature 4:
Active geyser

Grid Reference:
E1874564 N5736844

Approximately 10 m to the east of Feature 4 is an active geyser. The crater associated with the geyser is approximately 8×4 m and while the frequency of playing is not known, there are clear indications of geyser activity such as: rounded surfaces at the crater edge, a damp base (noticeable as there had not been any rainfall) with rounded pebbles, and a drainage channel which directed fluid back into the crater (Plates 69 and 70). During the monitoring round, the geyser played at 11.55 a.m. for approximately 30 seconds-1 minute. There is a main central fissure (with an east-west orientation and almost in line with Feature 4) in the crater with two identifiable vents - one seen to be discharging steam constantly, the other observed to be the fluid/steam discharge point when active. The jet of water/steam rose approximately 3 m above ground level.

Associated with the geyser is a large area of sinter and altered clay (Plate 71). There was also an area of steaming ground. The soil temperatures to the south of the geyser were not elevated (15°C) while directly to the east the temperatures ranged from 60°C to 80°C . The sinter crust was very thin and delicate.

A sketch map of Features 4 and 5 has been prepared.



Plate 69: Geyser. Looking west, note main vent, fissure alignment, and rounded surfaces, Feature 5, Orākei Kōrako.



Plate 70: Geyser. View looking northeast. Note drainage channel back into crater, Feature 5, Orākei Kōrako.

Feature 6:
Steaming ground

An area of steaming ground was identified measuring 2 m² with soil temperatures ranging from 25-35 °C. This was located between Features 5 and 7.

Grid Reference:
E1874546 N5737104

Feature 7:
Mud pool

This feature was a small mud pool with viscous mud and vigorous bubbling. Thick vegetation prevented access.

Grid Reference:
E1874593 N5737122

Feature 8:
Mud pool and volcano

This feature is a mud pool with minor steam discharge and less viscous mud. A mud volcano approximately 30 cm high lies adjacent to it. Thick vegetation prevented access for temperature measurement.

Grid Reference:
E1874607 N5737129



Plate 72: Mud volcano, Feature 8.

Feature 9:
Artist Palette
(hot, clear pool)

The main pool in the Artist Palette area was noted to have a very low water level (not visible) and was discharging steam. In July 2010 this pool was actively discharging chloride water with extensive algal growth along the discharge channels.



Plate 73: Pool at Artist Palette - July 2010 on left,
July 2009 on right.

WHAREPAPA ROAD¹

Feature 1:
Hot clear pool, sinter
terrace
(labelled as F1 on
feature map).

This feature is a hot, clear pool with a slight blue colouration. The temperature of the water was 90 °C and the pH was 8.6. The pool measures approximately 4 m² and has two central fissures/chambers at least 1 m deep and approximately 0.5 m in diameter. The remaining area of the pool is shallow, 5-10 cm. Only one of the chambers appeared to be supplying fluid to the pool. There are at least three relic drainage channels from the pool and it is surrounded by a large, 25 m² sinter terrace. Two constructed channels now drain the outflow from the pool and as such the sinter terrace is no longer being deposited. The water level is 5-6 cm below the sinter apron. Both the sinter apron and discharge channels exhibit minor sulphur encrustation. The main man-made channel was measured to calculate the discharge. The flow from the pool was calculated to be approximately 0.9 l/s (based on a channel width of 0.15 m, depth of 0.03 m, and a velocity of 0.2 m/s). A second small up-welling of fluid was noted in one of the relic drainage channels (Plate 75). It had a temperature of 90 °C and flow of approximately 0.1 l/s.

The constructed channel directs the pool outflow to a series of baths after which the outflow meets the original sinter terrace formed by the pool which was deposited down a gentle slope to the southeast. The sinter terrace is extensive and measures 70 × 30 m, however the area of active deposition is small, near the bathing water discharge point (Plate 76). The vast majority of the terrace is deteriorating, and at its lowest point is covered by a layer of silt which makes the sinter structure barely visible (Plates 77 and 78). At this point the sinter is very brittle. A field sketch has been prepared of the pool and sinter terrace area.



Plate 74: Hot, clear pool, sinter apron, and terrace. Note two main chambers and discharge channels at Feature 1, Wharepapa Road.

¹ Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.



Plate 75: View of small upflow, sinter terrace, main pool and baths in background at Feature 1, Wharepapa Road.



Plate 76: Relic sinter terrace looking north towards baths. Active sinter deposition area out of sight in left hand corner at Feature 1, Wharepapa Road.



Plates 77 and 78: Deteriorating sinter terrace. Structure still visible but very brittle/soft underfoot at Feature 1, Wharepapa Road.

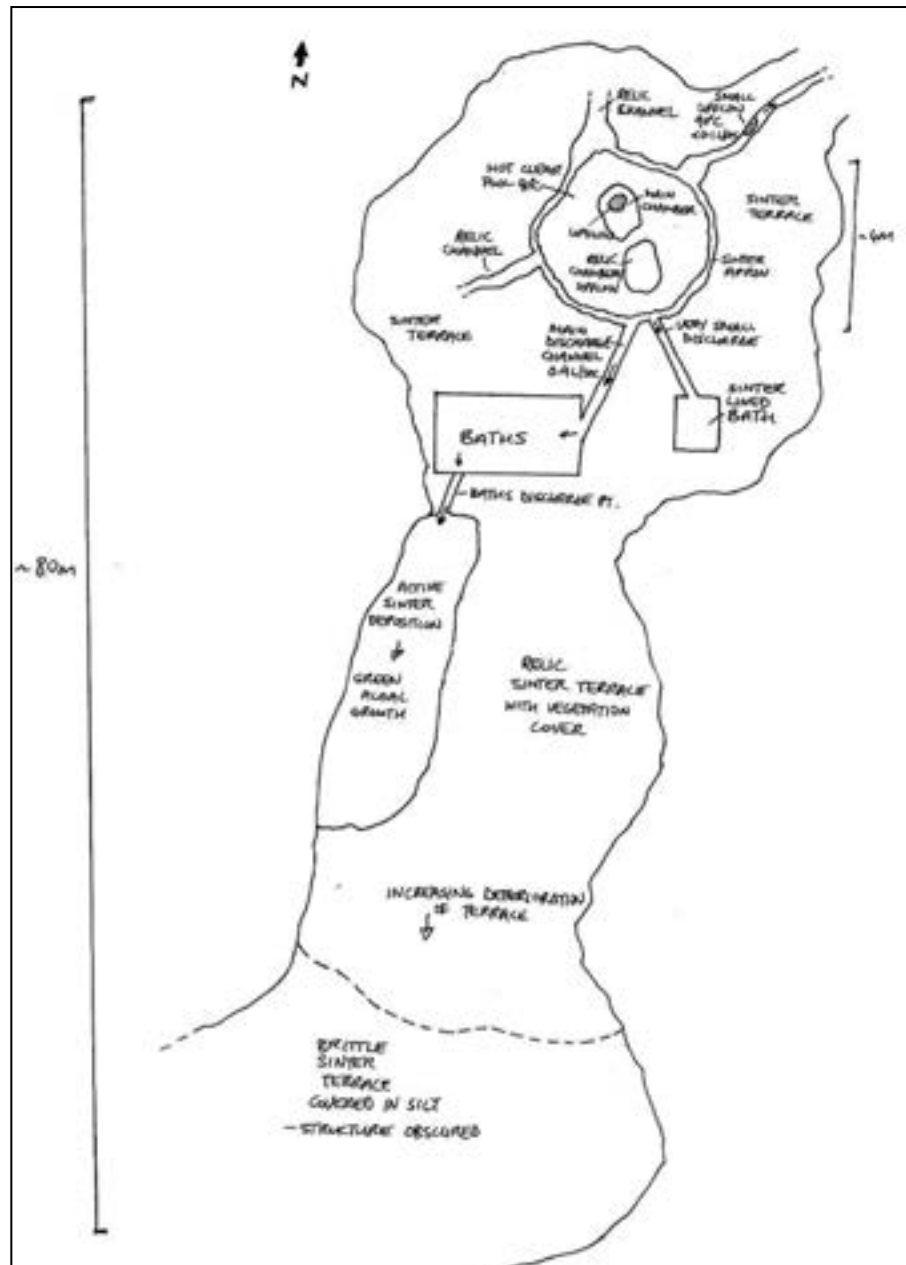


Figure A1-21: Field sketch map of hot pool, drainage and sinter terraces at Feature 1, Wharepapa Road.

Feature 2:

Hot clear pool
(labelled as F2 on site
map)

Grid Reference:
E1890775 N5742844

This feature is a hot, clear pool with a dark grey base (Plate 79). There is evidence of a sinter apron around the pool, although it is weathered and is coated in dark grey soil. The pool is approximately 3 m long and has two main chambers, one of which was bubbling. The temperature of the water was 90 °C while the pH was a neutral 7.6. There was no discharge from the pool at the time of the visit but a damp discharge channel is present to the southeast of the pool. The soil temperatures surrounding the pool ranged from 12 °C to 47 °C, the highest point being within the channel. Adjacent to the pool are two outcrops of silicified pumice rock which appeared to have some sinter structure (Plate 80). They are both weathered and fractured.



Plate 79: Hot, clear pool with damp discharge channel at Feature 2, Wharepapa Road.



Plate 80: Silicified pumice outcrop to the east of pool at Feature 2, Wharepapa Road.

Feature 3:
Steaming ground,
fumaroles
(labelled as F3 on
feature map)

Grid Reference:
E1890799 N5742775

An area of steaming ground comprising five fumaroles, four of which are roughly in alignment along a NW/SE orientation (Plate 81). The vents are too deep to see the base, however there was audible bubbling and the thermocouple device was used to measure a temperature of 95 °C in one of them. The area is approximately 10 × 3 m. The largest of the fumaroles appeared to be a discharging feature in the past (either mud or water) as a discharge area with flow patterns was identified near the opening (Plate 82). In the area surrounding the fumaroles there is relic deteriorated sinter terrace and a sinter bank. It would appear that the features at this location discharged sinter depositing fluid in the past.



Plate 81: Line of four fumaroles in NW/SE orientation with silicified bank behind and deteriorating terrace in front, Feature 3, Wharepapa Road.



Plate 82: Large fumarole with relic sinter terrace and relic flow/drainage formations at opening (arrow), Feature 3, Wharepapa Road.

Feature 4:
Thermal spring
(labelled F4 on feature
map)
Grid Reference:
E1890917 N5742571

A large pool within a ditch at the edge of a culvert had a steam discharge and temperature of 47 °C. There was no obvious upflow but the discharge from the pool was estimated to be approximately 1.5 l/s. There was abundant green and orange algal growth along the discharge channel.



Plate 83: Hot spring/pool. Note orange and green algae in discharge channel, Feature 4, Wharepapa Road.

Feature 5:
Hot, clear pool
(labelled F5 on feature
map)

Grid Reference:
E1890856 N5742786

This feature is a large 5 m² clear pool. The water has a blue colouration (colloidal silica) and is at boiling point (99 °C using thermocouple). The pH of the water is 7.8. It is at least 2 m deep and is discharging via a discharge channel (Plate 84). The pool itself has a small/narrow sinter apron with grass meeting its margins while there is active silica deposition along the discharge channel and ditch (Plate 85). Both the discharge channel and silicified ditch appear to be manmade and direct the outflow into a stream to the south. At the point where the ditch meets the stream the temperature is 78 °C and there is no further silica deposition (Plate 86). The discharge channel from the pool has a section measuring 1 m length which made the flow estimation very straightforward, approximately 4.5 l/s. The point where the channel meets the ditch could provide a good location to install a weir for future flow recording.

To the east of the pool and sinter ditch there is another minor stream draining the land (Plate 87). There are numerous hot spring inputs into this stream ranging from 45 °C to 60 °C. The temperature of the minor stream is 24 °C before it also meets the main stream to the south. A schematic of the drainage system including the pool discharge, minor stream, and main stream is presented below showing flow rates and temperatures at various points.



Plate 84: Hot, clear blue pool with discharge channel in background, Feature 5, Wharepapa Road.



Plate 85: Pool discharge channel joining ditch - both have considerable silica deposition, Feature 5, Wharepapa Road.



Plate 86: Pool discharge meeting main stream. Note minimal sinter deposition at this point (78 °C), Feature 5, Wharepapa Road.



Plate 87: Minor stream with hot spring inputs, Feature 5, Wharepapa Road.

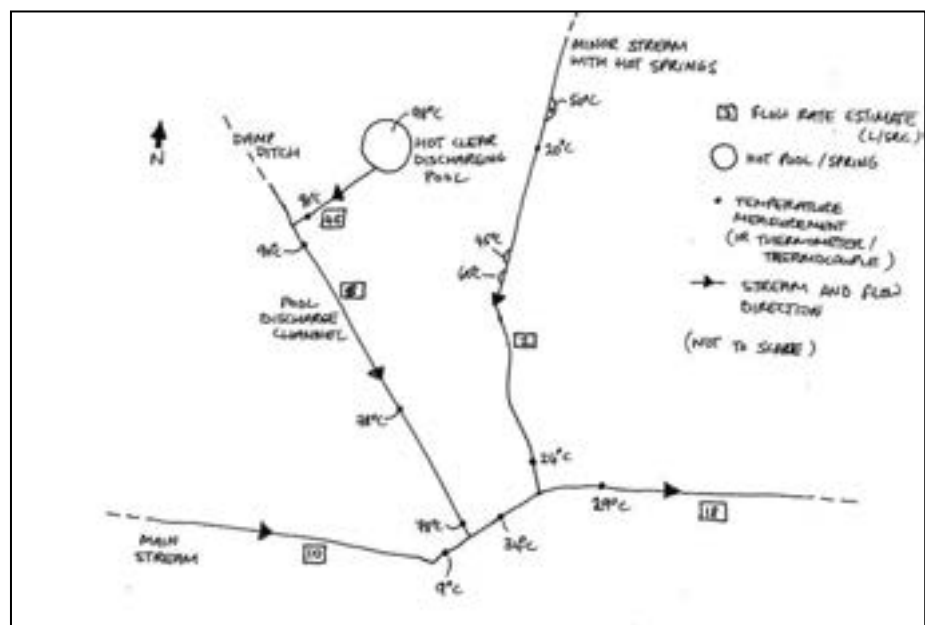


Figure A1-22: Schematic of hot pool drainage, temperature and local stream inputs, Feature 5, Wharepapa Road.

Feature 6:
Mud pool
(labelled F6 on feature
map)

Grid Reference:
E1891092 N5742911

This feature is a small boiling mud pool which measures 1.5 m² and is approximately 1 m deep. The temperature of the fluid was 99 °C. At the edge of the pool there is evidence of relic sinter deposition (Plate 89), indicating historical silica laden fluid discharge in the past. Broken timber was at the base of the pool and at its edge.



Plate 88: Mud pool, Feature 6, Wharepapa Road.



Plate 89: Sinter structure at edge of mud pool, Feature 6, Wharepapa Road.

Feature 7:
Exposed ground,
fumaroles, mud pools
(labelled as F7 on
feature map)

Grid Reference:
E1891134 N5743013

A large area of exposed ground with active fumaroles and mud pools lies 100 m to the northeast of the mud pool (Feature 34). The area measures approximately 25×50 m. Access to take *in situ* measurements was not deemed safe at this area; as such only the largest of the mud pools was measured using the IR thermometer and returned a temperature of 72°C (Plate 90). A field sketch indicating the location and type of features is shown below. The location has four other large mud pool areas as well as many small pools and a pit consisting of multiple fumaroles (Plate 91). There is an isolated area of geothermal type vegetation in the centre of the area around which soil temperatures ranged from 13°C to 53°C at 10 cm depth. There were no outflows noted from any of the features.



Plate 90: Large mud pool, 72°C at surface, Feature 7, Wharepapa Road.



Plate 91: Mud pit with multiple fumaroles discharging steam, Feature 7, Wharepapa Road.

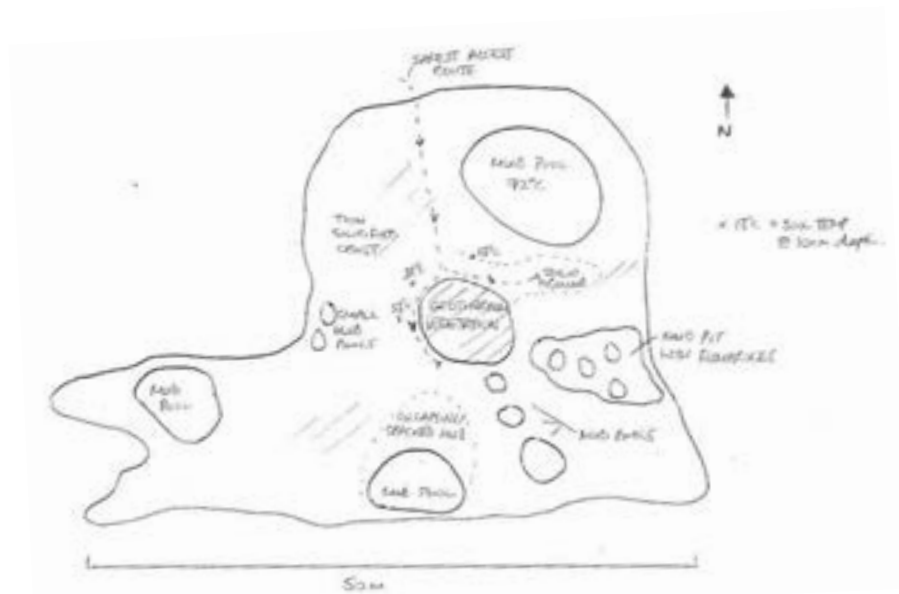


Figure A1-23: Field sketch map of location, Feature 7, Wharepapa Road.

Feature 8:
Exposed ground, mud
pools
(labelled F8 on feature
map)

Grid Reference:
E1890976 N5743135

This feature comprises a 30 m² area of exposed ground including three mud pools with temperatures ranging from 40-50 °C and two warm pools with dark green cloudy water with temperatures of approximately 30 °C. The warm pools were bubbling and discharging small amounts of gas. The area was covered in a layer of mud and pine needles, however beneath this a silicified crust was observed.



Plate 92: Two of the mud pools at this location. Note that pool to the right had more significant steam discharge (50 °C), Feature 8, Wharepapa Road.

Feature 9:
Exposed ground, hot
clear pool, mud pools

The western part of this area was mapped, while the eastern area was not accessible. The western area comprised an area of exposed ground with steaming ground, at least two mud pools, and one hot, clear green/blue pool.

(labelled F9 on feature map)

Grid Reference:
E1891114 N5743198

The clear pool was approximately 1.5×3 m and appeared to be at least 2.5 m deep. The water had a green/blue colouration (colloidal silica), a temperature of 80-85 °C and a pH of 8.7. A sinter apron was well formed at its edge and along the discharge channel. The discharge flowed to the east and was estimated to be approximately 1 l/s. A wooden palette and bird feathers nearby indicated that this pool is used by local farmers for cooking or game hunting related purposes.

Two metres to the west of the clear pool is a 2 m² mud pool with a temperature of 85 °C and two fumaroles with audible boiling/bubbling beneath the surface. It is thought that these are also mud pools.

A view through the vegetation into the eastern part of the area indicated an expanse of exposed ground and multiple mud pools and fumaroles.



Plate 93: Hot, clear green/blue pool. Note wooden palette access point to pool and sinter apron, Feature 9, Wharepapa Road.

Feature 10:
Fumaroles, mud pools
(labelled F10 on feature map)

Grid Reference:
E1890981 N5743026

At this location there are two small fumaroles 0.3 m² with audible bubbling at depth and two mud pools with surface temperatures of 85 °C and 51 °C. Near the pools were two outcrops of silicified pumiceous rock.

Feature 11:
Fumaroles, mud pools
(labelled F11 on feature map)

Grid Reference:
E1890995 N5742955

Forty metres to the south of Feature 10 is a larger area (25 × 50 m) of small mud pools, steaming ground and fumaroles. The temperatures in the mud pools ranged from 30 °C to 90 °C. Amongst the mud pools are large areas of silicified pumiceous rock outcrop. The largest mud pool has a temperature of 35 °C and measured 3 × 5 m.



Plate 94: Area of mud pools, fumaroles, and silicified outcrop, Feature 11, Wharepapa Road.

Feature 12:
Hot clear pools,
sinter terrace
(labelled F12 on feature
map)

Grid Reference:
E1890797 N5743070

This feature comprises an extensive sinter terrace measuring approximately 50×75 m with numerous small, clear, hot pools and one large boiling pool.

At the highest point of the terrace at the northern limit there is a large 10×2 m boiling clear blue pool (Plate 95). Two main upwelling/boiling areas were noted in the pool. The temperature reading on the IR thermometer was 110°C while the thermocouple measured 100°C ; the pH of the pool was 7.3. The boiling areas were vigorous and the steam discharge from the pool was considerable. The discharge from the pool was diffuse from a number of channels and as such was estimated to be in the order of 4-5 l/s. The depth of the pool appeared to be at least 2-3 m. The sinter apron had sulphur deposition in places.

Numerous other shallow pools were observed at the location with temperatures ranging from 27°C at the southern limit of the terrace to 80°C approximately 5 m from the large boiling pool. The water level was very shallow across the terrace and there was considerable silt deposition across the southern half of the area. The discharge stream which forms beyond the lowest point of the terrace had a temperature of 22°C and a flow of roughly 2 l/s.

A field sketch has been prepared indicating the main features at this location (A1-24).



Plate 95: Boiling, clear pool. View of most vigorously boiling area. Note sulphur deposition on edge, Feature 12, Wharepapa Road.



Plate 96: View of sinter terrace looking north to boiling pool (steaming area in background). Note shallow water level and silt deposition in foreground, Feature 12, Wharepapa Road.



Plate 97: Southern limit of terrace. Note dark sinter bank and small stream collecting the terrace run-off, Feature 12, Wharepapa Road.

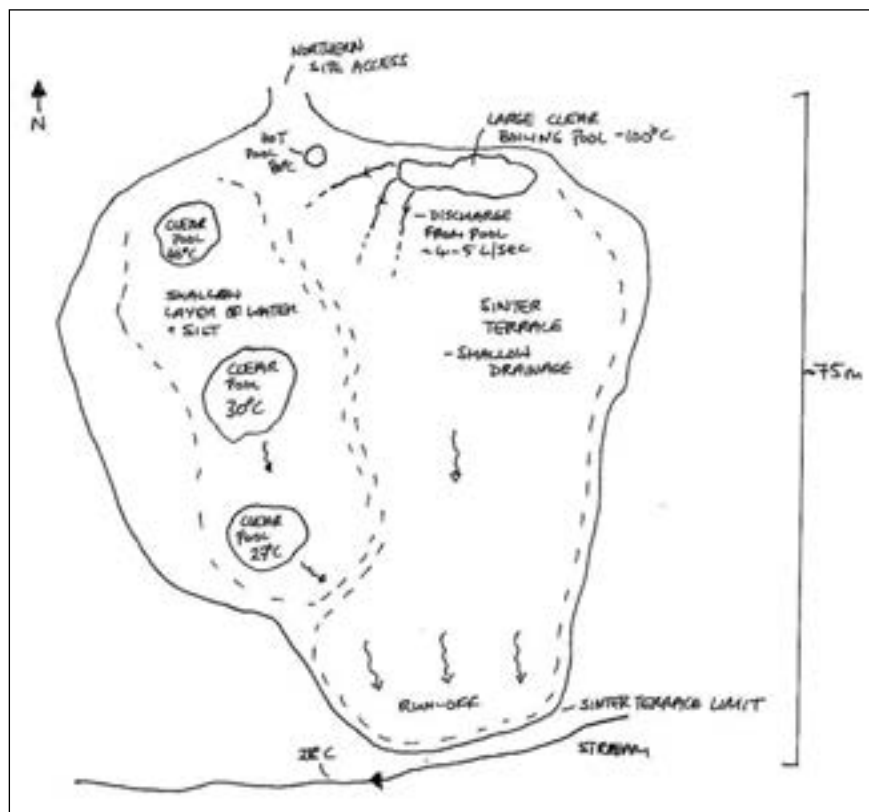


Figure A1-24: Field sketch of boiling pool/sinter Terrace, Feature 12, Wharepapa Road.

Feature 13:
Mud pools
(labelled F13 on feature
map)

Grid Reference:
E1891134 N5743013

There are two mud pools at this location measuring 2 m² each. The temperatures ranged from 58-60 °C. There was also refuse and tree branches in the pools.



Plate 98: Mud pool with refuse, Feature 13, Wharepapa Road.

TOKAANU THERMAL PARK¹

Overview of field work and background:

Several poorly-known thermal manifestations of the Tokaanu geothermal system were visited on Wednesday 7 February 2007. This was a hot, sunny day with the air temperature increasing from *c.*23 °C at 10.00 am to almost 30 °C at 2.00 p.m.

During the second half of the day selected manifestations in the Tokaanu Domain were inspected, along with the old discharging bore to the west of the Domain (BH2).

Visit of two selected manifestations in the Tokaanu Domain:

Manifestations in the Tokaanu Domain, which discharged water at boiling temperature in July 2005, were revisited. The first one was the old Taumatapuhipuhi geyser where geyser activity had ceased in 1966, shortly after commissioning of the first bath house well. The discharge changed then to some periodic ebullient discharge of boiling water as seen by the author on 14 July 2005. When revisited on 7 February 2007, the ebullient cycle had not changed - the temperature of the discharged hot water (98.5 °C) is still close to local boiling point.

A previously boiling spring, located halfway between Taumatapuhi and the bath Admin. Building, and which discharged at *c.*100 °C in July 2005 (see Hochstein 2005), had cooled down and discharged hot water at 72.6 °C when visited on 7 February 2007.

Visit of the old 'Healy Bore (BH 2):

This *c.*97 m deep well lies at the western boundary of the Department of Conservation-administered Tokaanu Thermal Park. The well was drilled in 1942 and was sited by Mr. J. Healy. It freely discharges some deep thermal water (probably since 1951) which has created impressive, *c.*600 m² large silica sinter flats at E1839134 N5683066, covered in part by yellow algae. The site was visited to assess its thermal vegetapāon. Boiling water is discharged at the top of a sinter mound (*c.*3 m diameter). The discharge rate of the thermal water was found to be *c.*1-1.5 l/s. A similar rate had been reported by previous studies, summarized in Hochstein (2005), a summary which includes a short history of this manifestation. The recent growth of shrubs, blackberry, and bracken has made BH 2 an almost inaccessible but still a spectacular site.

¹ Undertaken by Hochstein in 2007.

TOKAANU URUPĀ MUD POOLS¹

These pools are shown on a map in a 1942 paper (see Figure 2 in Healy 1942) where they are listed as ‘two larger mud pots’. The mud pools were visited late afternoon on 7 February 2007 and were found to lie close to E1839752 N5682555, a position which is similar to that shown in the 1942 map by Healy. The pools are within kānuka forest, c.30 m to the east of a track and about 250 m to the southeast of the cemetery; the pools can be located by the sound of their bubbles. The western ‘mud pot’ has a diameter of c.4 m; the one adjacent to the east is c.5 m wide. The level of the larger pool is c.0.5 m below that of the smaller one. A maximum temperature of 87.4 °C was measured with a thermocouple device in a breached ‘mud volcano crater’ near the northeast rim of the smaller eastern pool; the temperature of upwelling liquid mud in other ‘bubbles’ in both pools varied between 74 °C and 84 °C (IR gun). Since little steam was visible, it can be inferred that almost all vapour is condensed by the liquid mud and that the driving agent of the ‘bubbles’ is gas, most likely CO₂ gas. There was no H₂S smell. The pH of the liquid mud was found to be close to neutral (assessed with a pH paper strip).

MAUNGANAMU EAST¹

Overview of field work and background:

Several poorly known thermal manifestations of the Tokaanu geothermal system were visited on 07 February 2007. This was a hot, sunny day with the air temperature of c.23 °C at 10:00 am. The water temperature of the outflow of the 240MW Tokaanu hydro-power station in the tailrace canal had a range of c.14 °C and 17 °C.

Manifestations below the bridge alongside the tailrace canal (locations inferred from an old infra-red (IR) survey of the field (Bromley & Mongillo 1991)) were inspected. These IR anomalies were located on the west bank of the tailrace canal, c.0.6-0.7 km downstream from the SH 41 road bridge.

IR anomalies along the tailrace bank, downstream from the SH 41 bridge:

Three IR anomalies are shown in the Bromley & Mongillo (1991) study to occur along the western bank of the tailrace canal, c.600-700 m downstream from the SH 41 bridge. For most part, the banks are steep and lined by a strip of raupō reedland.

Close to the inferred northern-most site of one of the three IR anomalies, we found a stretch of shore water with surface temperatures of up to 24 °C (IR gun); the ambient water temperatures outside the stretch were c.18 °C. Probing with the thermocouple probe, temperatures between 52 °C and 60 °C were found at the first site at 0.3 m depth. The site (E1840593 N5682576), is distinguished by algae and subsurface plant growth which points to some zonation based on temperature gradients. The thermal water discharge occurred over a stretch along the shore at least c.10 m long; surface (water). Temperatures of 20 °C and 23 °C in this area were observed using the IR gun. At the second site a maximum temperature of 62.1 °C was observed at c.0.3 m depth; the lake bottom also exhibited a growth of brown-grey algae. Smaller seeps of thermal water occurred on land, c.0.2 m above the stream margins, with temperatures of up to 44 °C observed in one seep.

¹ Undertaken by Hochstein 2007.

We did not search for the exact location of the other two IR anomalies located between 50-100 m upstream on the same bank because the manifestations are likely to be very small and possibly in the canal. These could be searched for and located using a boat with the approval of the canal managers.

MAUNGANAMU NORTH WETLAND¹

We began the search for the manifestations with a visit of the Oasis Motel (owner M.R. Foxall) who showed us his 28 m deep thermal bore (present exit temperature was 68 °C in February 2007). Mr Foxall also pointed out the general area (to the east) behind his property where warm ground had been found in the past). As an example we were shown a 2 m deep soak hole (c.1 m diameter, concrete lining) at E1840218 N5682776 where a temperature of 30.5 °C was measured at the water-covered bottom, pointing to the presence of steam-heated, perched groundwater. We could not find the spring sampled by Healy and stopped our search at the western edge of the raupō reedland (near E1840178 N5682636), which is near the property boundary. Further searching would require permission for access from another landowner and possibly some preparatory shrub cutting.

TOKAANU TAILRACE CANAL¹

Overview of field work and background:

Several poorly known thermal manifestations of the Tokaanu geothermal system were visited on 07 February 2007. This was a hot, sunny day with an air temperature of c.23 °C at 10:00 am. The water temperature of the outflow of the 240 MW Tokaanu hydro-power station in the tailrace canal had a range of c.14 °C to 17 °C.

Manifestations above the bridge alongside the tailrace canal were visited to determine locations inferred from an old infrared survey of the field (Bromley & Mongillo 1991).

Infra-red anomalies along the tailrace shores, close to the power station outlet:

An IR anomaly was observed during the 1991 airborne survey close to the southern shore of the tailrace canal, c.100-150 m downstream from the station outlet. Using an IR gun, a c.40 m long stretch of the shore line was searched without finding any temperature anomaly in the shallow water. We also searched for a thermal anomaly at the opposite site along the north bank where, according to Mr A. Hema (Tokaanu Power Station), some minor thermal activity had been noticed in the past c.100 m downstream from the outlet at low outflow level. However, no thermal anomaly was found near that site.

Another IR anomaly located by the 1991 survey points to a thermal site along the northern bank, c.275 m downstream from the power house outlet. The site is near a basic boat launching pad. This time a minor thermal anomaly was found as indicated by near-shore water temperatures of c.18 °C along a c.10 m long stretch; it was surrounded by water with ambient temperatures of c.15.5 °C. In the centre of the anomalous stretch (approximately at

¹ Undertaken by Hochstein in 2007

E1840049 N5681375), water temperatures between 28 °C and 29 °C were found at 0.3 m depth using a thermocouple device. The anomalous temperatures were reproducible when the site was re-occupied. The site lies close to the northeast corner of an old test pond dredged in 1969 to assess the danger of hydrothermal eruptions during excavation of the tailrace canal. The pond covered hot ground with boiling temperatures at shallow depths (Hochstein and Prebble 2006).

NOTES ON THE VASCULAR FLORA OF GEOTHERMAL AREAS

Distinctive vegetation types are a characteristic feature of geothermal areas. There are two categories of characteristic geothermal species: those that are restricted to geothermal sites, and those that have dispersed into geothermal sites because the habitat mimics aspects of the usual habitat of the species (Given 1995). Geothermal kānuka is, in Aotearoa New Zealand, the only example of a plant restricted to geothermal areas (Given 1995). Other plant species strictly associated with geothermal sites within the Waikato Region are so confined by their preference for warmer, subtropical, climates. For these species, geothermal heat creates a warm, humid microclimate that, in the Waikato Region, supports several species of tropical and temperate ferns and fern allies (Given 1995), among others described below.

FERNS AND FERN ALLIES

Annual fern or Jersey fern: *Anogramma leptophylla*:



Anogramma leptophylla is predominantly coastal or lowland in distribution in Aotearoa New Zealand from sites from Auckland to Banks Peninsula, with an outlying population near Wanaka. Elsewhere it is found in Australia, India, Africa, Asia, Europe and South America (Brownsey and Perrie 2021).

The only population of *Anogramma leptophylla* known from the central North Island occurs alongside the lower Te Kiri o Hinekai Stream, Wairākei-Tauhara Geothermal System. At this site it is found on regularly disturbed soils alongside steamy geothermal stream margin habitat.

Threatened species ranking: Threatened-Nationally Vulnerable

Annual fern was found alongside the lower Te Kiri o Hinekai Stream, November 2022.

Cheilanthes sieberi:

In Aotearoa New Zealand this species is found in eastern areas of the North and South Islands, Northland and Three Kings Island, ranging from sea level to around 800 metres altitude. Elsewhere it is found in Australia, Norfolk Island and New Caledonia (Brownsey and Perrie 2021). Usually found in coastal sites, it is a relatively uncommon species at geothermal sites. It is currently known from four sites in the Waikato Region: Waikite Valley, Craters of the Moon, Te Kiri o Hinekai, and Akatarewa East. However it was not found at the last of these sites (Akatarewa East) in 2023 and changes to the habitat there may mean the site is no longer suitable for this species. In geothermal sites it is generally found in more open habitats (i.e. not under a scrub or tree canopy) on geothermally heated ground; elsewhere in its range it can occur under a canopy.

Threatened species ranking: Not threatened



Cheilanthes sieberi at Te Kiri o Hinekai, 9 September 2020.

***Christella* aff. *dentata* (“thermal”):**

Found in the North Island, Kermadec Islands, and probably also in tropics and subtropics of the old world. In New Zealand, *Christella* aff. *dentata* (“thermal”) differs from *C. dentata* by its shorter rhizome and smaller frond (Brownsey & Smith-Dodsworth 2000). Both morphotypes occur in New Zealand, where they are confined to the North Island, with *Christella* aff. *dentata* (“thermal”) occurring in geothermal areas of the central North Island. Brownsey and Perrie (2022b) do not recognise this entity as distinct from *Christella dentata*, but we have followed the Threat Classification System for vascular plants (de Lange *et al.* 2018) for this assessment until a comprehensive assessment of geographic and morphological variation of *C. dentata* is completed.



Christella aff. *dentata* (“thermal”) alongside Otamakokore Stream, Waikite, May 2007.

Christella aff. *dentata* (“thermal”) has been recorded from 11 sites in the Waikato Region, and is known to still be present at 10 of these. It is only found in six geothermal systems in the Waikato Region:

Waikite-Waiotapu-Waimangu Geothermal System (Waikite Geothermal System part), Te Kopia, Orākei Kōrako, Ngā Tamariki (rare), Reporoa, and Wairākei-Tauhaura (both Wairākei and Tauhara Geothermal parts). At geothermal sites in the Bay of Plenty Region it is also found at Waimangu-Rotomahana and Te Rata (Hot Water Beach). In geothermal habitats this taxon is mostly found in steamy habitats alongside geothermal streams and springs.

Several populations have less than ten plants present and are therefore highly vulnerable to extinction (e.g. Hall of Fame Stream and Waikato River Springs/Managamingi Stream). There are seven

populations (including one in the Bay of Plenty Region) with c.50 or more plants present - Waipapa Stream, Orākei Kōrako, Waihunuhuhu, Murphy's Springs, and Waikite; the largest population in New Zealand occurs at Waimangu-Rotomahana in the Bay of Plenty Region (Bycroft and Beadel 2007). These sites are key sites for the conservation of this taxon in the North Island. The population appears to be declining at Otumuheke as the geothermal springs have retreated the down the valley and the temperature of the geothermal stream has cooled. One new population was found in this survey at the lower Te Kiri o Hinekai Stream, which is now the largest population of this species in the Wairākei-Tauhara Geothermal System. This population has established in steamy habitats that have established following the artificial release of hot brine used for energy generation into the lower parts of this stream.

There are previous records from a further three areas in the Taupō Volcanic Zone in the Waikato Region (Tokaanu, Te Kiri o Hinekai, and Te Rau-o-Te Huia-Wairākei), but *Christella* aff. *dentata* ("thermal") is presumed to be extinct from these sites.

Threatened species ranking: Threatened-Nationally Endangered

***Cyclosorus interruptus*:**

This species is found in the North Island of Aotearoa New Zealand, and is widespread in the subtropics and tropics including Australia, Africa, Asia, and many islands in the Pacific. In the North Island it is confined to geothermal areas in the Taupō Volcanic Zone and coastal areas from Kawhia and Bay of Plenty northwards (Brownsey and Perrie 2022b). The populations that occur in geothermal areas (Wairākei-Tauhara Geothermal System) of the southern Waikato Region are at the global southern limit for this species. Within geothermal-influenced sites it grows in or adjacent to geothermal wetlands, geothermal hot springs and streams, and geothermally heated stream margins. It is most often found amongst sedgeland.

In the Waikato Region, *C. interruptus* has been recorded from eight geothermal sites in the following four geothermal systems: Waikite, Waiotapu, Orākei Kōrako, Ngā Tamariki, Wairākei-Tauhara. *C. interruptus* has been recorded historically from Akatarewa Stream (2002) but has not been observed at these sites in recent surveys in spite of extensive searching. The species is thought have become extinct at four geothermal sites in the last 40 years (Bycroft and Beadel 2007). The most stable and viable populations in geothermal habitats in the Waikato Region are at Waikite Valley, Waiotapu and Waihunuhunu. Since the 2014 assessment there has been a marked decline of this species at the Otumuheke site in the Wairākei-Tauhara Geothermal System. The population has declined from an estimate of over 1,000 plants in 2014 when the springs were active in the head of the valley to less than 100 plants (many unhealthy) in June 2023 as the geothermal springs have retreated down the valley. Without management this population is at risk of being lost over the next five years. Other populations are vulnerable due to their small size e.g. Orakiekorako-Red Hills, Waipahihi Valley, and Orakonui.



Cyclosorus interruptus at Waihunuhunu, Orakeikorako Geothermal System. 15 November 2022.

Threatened species ranking: At Risk-Declining

***Dicranopteris linearis*:**

Pantropical.



Dicranopteris linearis at Maungaongaonga, 2005.
geothermal streams and springs.

In Aotearoa New Zealand *Dicranopteris linearis* is confined to geothermal habitats of the Taupō Volcanic Zone, North Island. The populations in geothermal areas are the southern limit for this species in the world. Elsewhere it is widespread in the tropics and subtropics (Perrie and Brownsey 2015). In North Island geothermal habitats it is most frequent on geothermally heated ground and near fumaroles often associated with geothermal kānuka scrub and shrubland, and also other scrub, shrubland, forest, and fernland habitats. It is also occasionally found in steamy habitats associated with

Dicranopteris linearis has been recorded from 17 geothermal sites (six geothermal systems) in the Waikato Region, and four sites in the Bay of Plenty Region (Wildland Consultants 2020f). Many of the populations at sites are either extinct or have a small population. Of the seventeen sites there have been no recent records (2014-2023) from eight sites. Based on recent surveys, it is known from nine sites and four geothermal systems (Waikite-Waiotapu-Waimangu), Te Kopia, Orākei Kōrako, and Wairākei-Tauhara). The largest and most important populations of *D. linearis* in the Waikato Region occur at Te Kopia, Orākei Kōrako-Red Hills, Te Kiri o Hinekai, and Craters of the Moon..

Threatened species ranking: Threatened-Nationally Endangered

***Hypolepis dicksonioides*:**

In Aotearoa New Zealand, *Hypolepis dicksonioides* is known from the North Island, and northern South Island as well as the Kermadec Islands, and Chatham Islands. It is occasionally found in coastal areas of Northland and the Bay of Plenty, and very locally in coastal localities from Wairarapa to Cook Strait and north-west Nelson. Elsewhere it is known from Norfolk Island, Samoa, Tahiti, Cook Islands, Marquesas Islands and is naturalised in South Australia (Brownsey and Perrie 2022b). In New Zealand it is also found in geothermal habitat of the Taupō Volcanic Zone. In geothermal habitats it shows a clear preference for steamy habitats, particularly alongside geothermal streams.



Hypolepis dicksonioides alongside Otamakokore Stream, Waikite Valley, downstream of Corbett Road bridge, May 2007.

It is known from six geothermal sites in two geothermal systems in the Waikato Region (Waikite Valley, Waipahihi Valley, Lower Section Te Kiri o Hinekai Stream and Wairākei Stream, Otumuheke, and Craters of the Moon). At all of these sites, it is naturally rare. *Hypolepis dicksonioides* has been recorded from Otumuheke Stream (2004) but has not been observed in recent surveys and may no longer occur there. However, *H. dicksonioides* is a naturally short-lived, somewhat ephemeral, opportunistic species, which requires disturbance to create fresh habitats to colonise and it may therefore be present at this site. *H. dicksonioides* is also known from two geothermal sites in the Bay of Plenty Region (Wildland Consultants 2020f). All populations at geothermal sites are of botanical interest as they often occur at sites outside its normal altitudinal range. The Waikato populations in geothermal sites (Craters of the Moon, Waipahihi Valley, and Waikite) are vulnerable to competition with pest plants (particularly blackberry, rank exotic grasses, and other woody weeds).

Threatened species ranking: At Risk-Naturally Uncommon

***Lycopodiella cernua*:**

Lycopodiella cernua is an indigenous fern species found outside Aotearoa New Zealand in the tropical and subtropical regions on most continental landmasses and many island groups in this region (Bronsey and Perrie 2020). In New Zealand, *Lycopodiella cernua* usually occurs at coastal sites, some inland lake margins, and geothermal sites where it is a characteristic feature. This species is common at geothermal sites with thermal ground and steamy habitats throughout the Waikato Region where it can occur both in the open and under open shrubland. A population was found in Te Maari Crater in June 2011 prior to the 2012 eruption. At approximately 1,500 metres a.s.l. this is the highest altitude this



species is known from in Aotearoa New Zealand, and it only occurs at this altitude because of the geothermal habitat. In January 2018 a population of *Lycopodiella cernua* was found in a different part of the Te Maari site to where it was found in 2011, showing that this species was still present at the site after the eruption.

Threatened species ranking: Not threatened

Lycopodiella cernua at Te Maari Craters, January 2018.

***Nephrolepis flexuosa* (ladder fern):**

This indigenous species is known with certainty from Aotearoa New Zealand, Raoul, Norfolk and Lord Howe Islands, and also Fiji and Rarotonga (Brownsey and Perrie 2019). It is abundant in coastal forest and scrub on Raoul Island, otherwise in Aotearoa New Zealand it is confined to the North Island where it is only known from active geothermal habitat from near Kawerau to Lake Taupō. *Nephrolepis flexuosa* has its historical global southern limit at Tokaanu near Turangi. The southern most known population is now in the Wairākei-Tauhara Geothermal System at Otumuheke. Its main habitats within geothermal sites are banks alongside steamy geothermal stream margins and springs, fumaroles, and geothermally heated soils in scrub, shrubland, and forest. It also occurs as an epiphyte e.g. Waihunuhunu where it was seen cover a fallen log over a stream in 2022.

Since the 1980s *Nephrolepis flexuosa* has been recorded from 14 geothermal sites in eight geothermal systems in the Waikato Region. There have been no recent records since 2010 at three of the geothermal systems (Tokaanu, Horohoro, and Rotokawa). Of the remaining sites, four geothermal sites have very small populations (less than 50 clumps). The geothermal systems with confirmed populations are: Waikite-Waiotapu-Waimangu, Orākei Kōrako, Wairākei-Tauhara, Te Kopia and Atiamuri. The population at Otumuheke Stream has declined since 2004, and only a small population (one large clump) was present near the stream mouth in June 2023. An additional threat to this species (and also its management) is the potential for mixing with a naturalised and invasive species, tuber ladder fern (*N. cordifolia*). At one geothermal site in the Bay of Plenty, colonies of *Nephrolepis* probably comprise both the indigenous ladder fern and introduced tuber ladder fern. The presence of both species growing together means that it would be difficult to control the invasive species without damaging any of the indigenous plants. The most important populations

for the conservation of *Nephrolepis flexuosa* in the Waikato Region are at Waihunuhunu, where it is common along the entire length of the unnamed geothermal stream; Te Rau-o-Te Huia-Wairākei;



Te Kiri o Hinekai, Waikite Valley, and Te Kopia. One of the authors (CMB) has noticed an incremental increase of the population of this species at Te Kopia since he first recorded it there in 2004 at the north of the site, and it seems to be expanding into geothermally heated ground habitats to the south of the area where it was first observed. There is also a large population at Waimangu-Rotomahana in the Bay of Plenty Region.

Threatened species ranking:
At Risk-Naturally Uncommon

Nephrolepis flexuosa, Maunga Kākaramea (Rainbow Mountain), 7 November 2022.

***Psilotum nudum*:**

Pantropical.

This species is present in the upper North Island, mostly in coastal and lowland forest north of Kawhia and the Bay of Plenty. It is also found in the Kermadec Islands and outside Aotearoa New Zealand is widespread in tropical and subtropical regions including Australia and islands of the Pacific (Brownsey and Perrie 2015).



In the central North Island it is mostly known from geothermal sites and inland from the Waikato River margins and is often found on ignimbrite. It has been recorded from eight geothermal systems in the Waikato Region: Waikite-Waiotapu-Waimangu, Mokai, Ngā Tamariki, Te Kopia, Orākei Kōrako, Wairākei-Tauhara and Tokaanu.

Threatened species ranking:
Not threatened

Psilotum nudum present at the southern end of the Tauhara Geothermal System, Taupō. 30 September 2020.

***Schizaea bifida* (forked comb fern) and *S. fistulosa* (comb fern):**



Schizaea sp. (probably *S. fistulosa*) at Orakonui, 1 October 2020.

S. bifida is present in New Zealand (North and South Islands), also Australia and New Caledonia, while *S. fistulosa* is also present more widely in parts of the subtropics and tropics. *S. bifida* is local throughout New Zealand, while *S. fistulosa* outside of geothermal habitat is confined to northern North and South Islands (Brownsey and Perrie 2014). Both species are known from geothermal areas in the central North Island, including at least one site in the Waikato Region. They are both very inconspicuous species and easily overlooked. The current known habitat in geothermal habitat in the Waikato Region is in dense mosses beneath a geothermal kānuka canopy. *S. bifida* has been found at Waiotapu Ngatamariki and Te Kopia and Ngatamariki Geothermal Systems.

Threatened species ranking: Not threatened

***Schizaea dichotoma*:**

Pantropical.



This species is widespread in the tropics and subtropics, but within Aotearoa New Zealand outside of geothermal sites it is mostly confined to Northland to Kawhia and the Bay of Plenty and the Kermadec Islands, with a clear preference for kauri forest and mānuka scrub (Brownsey and Perrie 2014). It is a naturally uncommon site at geothermal sites in the central North Island. The largest known population in geothermal habitat occurs at Maunga Kākaramea (Rainbow Mountain). At geothermal sites it is often most abundant on the forest floor in forest habitat with local areas of geothermal influence.

Threatened species ranking: At Risk-Naturally Uncommon

Schizaea dichotoma at Maunga Kākaramea (Rainbow Mountain), 7 November 2022.

***Thelypteris confluens*:**

An indigenous fern that outside Aotearoa New Zealand is found in the tropics and subtropical regions including Africa, Asia and Australia. This species is mostly found in lowland areas in the northern North Island of New Zealand, from Te Pahi in the north to the Waitakare in the west, and Bay of Plenty in the east. It is mostly found in coastal wetlands, but extends inland to wetlands near geothermal sites (Brownsey and Perrie 2022b)



Thelypteris confluens at Waikite Wildlife Management Reserve. 2007.

It has been recorded from two geothermal areas in the Waikato Region: Waikite Wildlife Management Reserve in the Waikite Valley (Bycroft and Beadel 2007), and Waihunuhunu. *Thelypteris confluens* has not been seen at Waihunuhunu since 2002 or at Waikite Valley in the two most recent surveys (2014 and 2022). Brownsey and Perrie (2022) note that it is found at Lake Rotokawa near Taupō, this may be at the southern end of the lake that has not been surveyed as part of this study.

Threatened species ranking: At Risk-Naturally Uncommon

DICOTYLEDONOUS TREES AND SHRUBS

***Korthalsella salicornioides*:**



Aotearoa New Zealand endemic found from Northland to Rakiura/Stewart Island. A hemi-parasitic, dwarf mistletoe which grows on a variety of hosts, but mostly on mānuka and species in the kānuka complex including geothermal kānuka.

Populations of this species have been recorded at three geothermal sites in the Waikato Region: Maungaongaonga (old record), Te Kopia, and Tokaanu, with perhaps the largest known population in the region at Te Kopia, although this is an inconspicuous and easily overlooked species, so there may be small populations present at sites where it has not been previously recorded. It is relatively uncommon at all geothermal sites where it is known from.

Threatened species ranking: Threatened-Nationally Critical

Korthalsella salicornioides on geothermal kānuka at Te Kopia, 17 January 2023.

***Kunzea tenuicaulis* (geothermal kānuka):**



Geothermal kānuka scrub at Craters of the Moon, August 2007.

New Zealand endemic. Geothermal kānuka is restricted to geothermal sites in the Taupō Volcanic Zone between Kawerau and Tokaanu, and is mostly found on heated geothermally heated ground including steamfields. It can form a dominant scrub and shrubland vegetation type in these habitats. A key feature of this species is the declining size with increased soil temperatures. It can range from a small tree to almost a ground hugging prostrate species on the most heated soils. Its relationship to the fungus *Pisolithus* sp. is of considerable scientific interest – see Section 3. One of the key threats to this species is the spread of woody introduced pest plants, mostly conifers, but also other species such as Chinese privet. The canopy of these woody

species reduces the vigour of this species. Most of the larger areas of geothermal habitat in the Waikato Region have relatively large examples of geothermal kānuka habitat. The best examples include Waiotapu, Te Kopia, Orākei Kōrako-Red Hills, Rotokawa, Te Kiri o Hinekai, Crater of the Moon and East Taupō.

See Section 6.12 on kānuka taxonomy.

Threatened species ranking: Threatened-Nationally Endangered

SEDGES

***Fimbristylis velata*:**

Pantropical. In New Zealand it occurs occasionally at northern coastal and geothermal sites.

This species has been recorded historically from one geothermal site in the Waikato Region (Craters of the Moon) but has not been observed at this site for over 20 years. *F. velata* also occurs at Lake Whangape in the Waikato Region.

Threatened species ranking: At Risk-Naturally Uncommon

MONOCOTYLEDONOUS HERBS

***Triglochin striata* (arrow grass):**

In New Zealand, generally a coastal species which occasionally occurs inland.

Known from at least four geothermal systems in the Waikato Region from the following geothermal systems: Waikite-Waiotapu-Waimangu, Reporoa, Ohaaki, Wairakei-Tauhara, and Tokaanu-Waihi-Hipaua. One population has apparently been removed from the site by herbicide drift at Orakonui. In geothermal sites it is most often found when geothermal water is flowing over sinter and other bare ground habitats. It is a relatively rare species at all geothermal sites.

Threatened species ranking: Not threatened



Arrow grass at Waikite Valley, February 2011.

ORCHIDS¹⁰

***Calochilus paludosus* (brown bearded orchid):**

Australia and New Zealand.



Currently known from several sites in New Zealand, including areas of geothermally heated ground. Recorded from two geothermal sites in the Waikato Region (Maunga Kākaramaea (Rainbow Mountain) and Te Kopia). It was recorded from Maunga Kākaramaea in November 2022.

Threatened species ranking: At Risk-Naturally Uncommon

Calochilus paludosus on Maunga Kākaramaea

***Calochilus robertsonii* (red bearded orchid):**



Australia and New Zealand.

Recorded from 15-20 coastal and geothermal sites in New Zealand, including four geothermal systems in the Waikato Region: Te Kopia, Waikite-Waiotapu, Orākei Kōrako and Rotokawa Geothermal Systems. It was recorded from Maunga Kākaramaea in November 2022.

Threatened species ranking: At Risk-Naturally Uncommon

Calochilus robertsonii on Maunga Kākaramaea

***Corunastylis pumila*¹ (leek orchid):**

Australia and New Zealand.

New Zealand: North Island (from Te Paki south to about Kawhia, East Cape and the Bay of Plenty), Chatham Island. Recorded from coastal and inland sites in the northern half of the North Island, including one geothermal site in the Waikato Region (Orākei Kōrako-Red Hills).

Threatened species ranking: At Risk-Naturally Uncommon

¹⁰ Orchids are likely to be present at more sites than which they have been recorded, as field survey timing for this project is not conducive to detection of orchids.

***Caladenia alata*¹**

Australia and New Zealand.

Currently known from one geothermal site in the Waikato Region (Maunga Kākaramea/Rainbow Mountain).

Threatened species ranking: At Risk-Naturally Uncommon

***Caladenia atradenia*²**

Australia and New Zealand.

Currently known from one geothermal site in the Waikato Region: Maunga Kākaramea (Rainbow Mountain).

Threatened species ranking: At Risk-Naturally Uncommon

Thelymitra colensoi

Endemic

Definitely known from only a few sites from Aotea Great Barrier Island in the north to Rotorua and Orākei Kōrako in the south. This Data Deficient orchid was sparsely distributed on the edge of geothermal kānuka scrub at the Orākei Kōrako-Red Hills geothermal site during the November 2022 survey.

Threatened species ranking: Data Deficient

¹ Synonym: *Petalochilus alatus*

² Synonym: *Stegostyla atradenia*

CHANGES IN EXTENT OF MAPPED GEOTHERMAL AREAS BETWEEN 1940S/1950S AND 2007 AERIAL PHOTOGRAPHS

In 2011, historical aerial photos of 52 sites held by the Waikato Regional Council library were compared with 2007 aerial photographs (2007 WRAPs). Photos for 12 sites were not able to be located. Of the 52 sites studied, photographs for 15 sites were not clear enough to determine any site change due to uncertainty of the surrounding landscape identification, cloud cover on the historical photograph, or were simply too small to identify any changes in extent. Where possible, existing literature was used to fill information gaps. Using a combination of historical photos and existing literature, the extent of geothermal vegetation has decreased in 23 out of the 37 sites that were able to be assessed (Table A.1). In six sites, the extent of geothermal vegetation has increased compared to what was historically present, and eight sites have no discernable vegetation change.

Many of the historical photographs showed large, light coloured patches, often not present in 2007 aerals. These light coloured patches may be bare ground, but could also be short-statured vegetation (reflecting light), or open water. Bare ground can be indicative of heated soils resulting in less vegetation cover. It is possible that many sites have cooled over the last 60 years as a result of geothermal extraction, resulting in a corresponding increase in vegetation cover. Causes of a reduction in geothermal vegetation cover include an increase in ground temperature beyond the capacity to support vegetation, vegetation clearance, and spread of weeds.

Table A.1: Summary of changes in extent and composition of geothermal vegetation and habitats between historical photos and 2007 aerial photographs.

Site Name	Type of Change
Akatārewa East	Too small to assess.
Akatārewa Stream	Decrease.
Craters of the Moon	Increase.
East Taupō (Broadlands Road part)	Increase.
East Taupō (Crown Park part)	Decrease.
East Taupō (Crown Road part)	Decrease.
Golden Springs	Too small to assess.
Hall of Fame Stream	Too small to assess.
Hipāua	No significant change could be detected.
Horohoro	Too small to assess.
Ketetahi	No significant change could be detected.
Longview Road	Decrease.
Lower sections: Te Kiri o Hinekai Stream and Wairākei Stream (Lower Wairākei Stream part)	Too small to assess.
Matapan Road	No historical photos.
Maunga Kākaramēa (Rainbow Mountain)	Decrease.
Maunganamu (Maunganamu East part)	Decrease.
Maunganamu (Maunganamu West, Maunganamu North Wetland and Tokaanu Tailrace Canal parts)	Too small to assess.
Maungaongaonga	No significant change could be detected.
Murphy's Springs	No historical photos.
Ngarotopounamu/Red Crater	Too small to assess.

Site Name	Type of Change
Northern Paeroa Range	No historical photos.
Ohaaki Steamfield East	Increase.
Ohaaki Steamfield West	Increase.
Orākei Kōrako-Red Hills (Orākei Kōrako part)	Decrease.
Orākei Kōrako-Red Hills (Red Hills part)	Decrease.
Orakonui	Increase.
Otumuheke (Otumuheke part)	Too small to assess.
Otumuheke (Spa Thermal Park part)	Decrease.
Paerata Road	No historical photos.
Rotokawa (Lake Rotokawa part)	Decrease.
Rotokawa (Rotokawa North part)	No significant change could be detected.
Te Kiri o Hinekai	Decrease.
Te Kopia	No significant change could be detected.
Te Maari Craters	Too small to assess.
Te Rau-o-Te Huia-Wairākei (Te Rau-o-Te Huia part)	Decrease.
Te Rau-o-Te Huia-Wairākei (Te Rau-o-Te Huia Stream part)	Decrease.
Te Rau-o-Te Huia-Wairākei (Upper Wairākei Stream (Geyser Valley) part)	Decrease.
Tirohanga Road	No historical photos.
Tokaanu	Decrease.
Tokaanu Lakeshore Wetland	No significant change could be detected.
Tukairangi/Karapiti Forest (Karapiti Forest part)	Decrease.
Tukairangi/Karipiti Forest (Waipouwerawera Stream/Tukairangi part)	Increase.
Waihunuhunu	Decrease.
Waikato River Springs/Mangamingi Stream	Too small to assess.
Waikite Valley	Decrease.
Waiotapu (Ngapouri part)	Decrease.
Waiotapu (Waiotapu North part)	Decrease.
Waiotapu (Waiotapu South part)	Decrease.
Waipahihi Valley	Decrease.
Waipapa Stream	No historical photos.
Whakamaru	Too small to assess.
Whangairorohea	No significant change could be detected.
Whangapoa Springs	No historical photos.
Wharepapa Road	Decrease.

DEFINITIONS OF VEGETATION STRUCTURAL CLASSES USED IN THIS REPORT

(Source: Atkinson 1985)

Fernland	Vegetation in which the cover of ferns in the canopy is 20-100% and in which the fern cover exceeds that of any other growth form or bare ground. Tree ferns >10 cm dbh are excluded as trees (<i>cf.</i> forest).
Flaxland	Vegetation in which the cover of flax in the canopy is 20-100% and in which the flax cover exceeds that of any other growth form or bare ground.
Forest	Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants >10 cm dbh. Tree ferns >10 cm dbh are treated as trees.
Geothermally-influenced bare ground	See definition of nonvegetated bare ground below.
Geothermal water ¹	Areas where 100% of the ground is covered by geothermally sourced water where geothermal water means water heated within the earth by natural phenomena to a temperature of 30 °C or more. Includes all steam, water, and water vapour, and every mixture of all or any of them that has been heated by natural phenomena.
Grassland	Vegetation in which the cover of grass in the canopy is 20-100% and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth form.
Herbfield	Vegetation in which the cover of herbs in the canopy is 20-100% and in which the herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses, or lichens.
Loamfield/peatfield	Land in which the area of loam and/or peat exceeds the area covered by any one class of plant growth form. The appropriate name is given depending on whether loam or peat form the greater part of the ground surface. Loamfields and peatfields are named from the leading plant species when plant cover ≥1%.
Lichenfield	Vegetation in which the cover of lichens in the canopy is 20-100% and in which the lichen cover exceeds that of any other growth form or bare ground.

¹ Definition from Waikato Regional Council Regional Plan.

Mossfield	Vegetation in which the cover of mosses in the canopy is 20-100% and in which the moss cover exceeds that of any other growth form or bare ground.
Nonvegetated Raw-soilfield	Areas bare ground that are bare of vegetation and are too hot to support plant life, are cooled but hydrothermally altered, are sinter pavements, or are subjected to regular mud ejection or gas emission that prevent colonisation and establishment of plants. These areas are often small scale, and may not be visible on aerial photographs. Very hot soils are often associated with steam vents and/or boiling mud craters, and soil temperatures at 10 cm depth are usually >90 °C. Hydrothermally altered soils often occur where geothermal expression has ceased, e.g., dried mud craters, that result in soils with unusual chemical composition. Vigorously boiling mud pools and craters regularly eject hot mud around their margins, which effectively prevents plant colonisation. In cases where toxic gas is emitted, vegetation is either absent, or if present, killed. In this report, this is referred to as geothermally-influenced bare ground.
Reedland	Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Examples include <i>Typha</i> , <i>Bolboschoenus</i> , <i>Schoenoplectus tabernaemontani</i> , <i>Eleocharis sphecelata</i> , and <i>Machaerina articulata</i> .
Sandfield	Land in which the area of bare sand (0.02-2 mm diameter) exceeds the area covered by any one class of plant growth form. Dune vegetation often includes sandfields which are named from the leading species when plant cover is $\geq 1\%$.
Scrub	Woody vegetation in which the cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (<i>cf.</i> forest). Shrubs are woody plants <10cm dbh.
Sedgeland	Vegetation in which the cover of sedges in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. Included in the sedge growth form are many species of <i>Carex</i> , <i>Uncinia</i> , <i>Isolepis</i> , and <i>Bolboschoenus</i> . Tussock-sedges and reed-forming sedges (<i>cf.</i> reedland) are excluded.
Shrubland	Vegetation in which the cover of shrubs in the canopy is 20-80% and in which the shrub cover exceeds that of any other growth form or bare ground. It is sometimes useful to separate tussock-shrublands as a sub-class for areas where tussocks are >20% but less than shrubs.
Treeland	Vegetation in which the cover of trees in the canopy is 20-80%, with tree cover exceeding that of any other growth form, and in which the trees form a

discontinuous upper canopy above either a lower canopy of predominantly non-woody vegetation or bare ground.

Tussockland Vegetation in which the cover of tussocks in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussocks include all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >10 cm in height. Examples of the growth form occur in all species of *Cortaderia*, *gahnia*, and *Phormium*, and in some species of *Chinochloa*, *Poa*, *Festuca*, *Rytidosperma*, *Cyperus*, *Carex*, *Uncinia*, *Juncus*, *Astelia*, *Aciphylla* and *Celmisia*.

Vegetation Type

A term that includes the dominant canopy species and structural class of an area of vegetation, e.g. rimu/tawa-kāmahi forest, *Ficinia nodosa*/*Muehlenbeckia complexa* sedge-vineland.

In addition, cover values and tiers are included, i.e.

(tawa)	less than 5% cover of the bracketed species
(rimu)/tawa	indicates less than 5% cover of rimu emergent over a canopy of tawa
tawa-hinau	indicates tawa and hinau occur in the same tier
↔	mosaic

Vineland Vegetation in which the cover of unsupported (or artificially supported) woody vines in the canopy is 20-100% and in which the cover of these vines exceeds that of any other growth form or bare ground. Vegetation containing woody vines that are supported by trees or shrubs is classified as forest, scrub, or shrubland as appropriate. Examples of woody vines occur in the genera *Actinidia*, *Clematis*, *Lonicera*, *Metrosideros*, *Muehlenbeckia*, *Ripogonum*, *Vitis*, and others.

ABBREVIATIONS AND SYMBOLS

<i>c.</i>	approximately; about
DOC	Department of Conservation
ha	hectare
m	metre
/	separates various tiers of the vegetation in the type descriptions
-	links plants in the same tier
()	less than 5% cover of the bracketed species
⇔	mosaic
IR	Infra red (used for finding hot spots in the ground that may indicate geothermal activity)

COMMON PLANT NAMES USED IN TEXT

*= introduced species

African feather grass*	<i>Cenchrus macrourus</i>
agapanthus*	<i>Agapanthus praecox</i>
akeake	<i>Dodonaea viscosa</i>
allepo pine*	<i>Pinus halepensis</i>
aloe*	<i>Aloe</i> sp.
aluminium plant*	<i>Galeobdolon luteum</i>
American fireweed*	<i>Erechtites hieraciifolia</i>
annual poa*	<i>Poa annua</i>
apple*	<i>Malus ×domestica</i>
arrow bamboo*	<i>Pseudosasa japonica</i>
arrow grass	<i>Triglochin striata</i>
Arum lily*	<i>Zantedeschia aethiopica</i>
Asiatic knotweed*	<i>Reynoutria japonica</i>
banksia*	<i>Banksia</i> sp.
barberry*	<i>Berberis glaucocarpa</i>
bay grass*	<i>Eragrostis brownii</i>
black nightshade*	<i>Solanum nigrum</i>
black pine*	<i>Pinus nigra</i>
black wattle*	<i>Acacia mearnsii</i>
blackberry*	<i>Rubus</i> sp. (<i>R. fruticosus</i> agg.)
blue tussock	<i>Poa colensoi</i>
bracken	Rārahu; <i>Pteridium esculentum</i>
broad-leaved fleabane*	<i>Erigeron sumatrensis</i>
broad-leaved plantain*	<i>Plantago major</i>
broom*	<i>Cytisus scoparius</i>
browntop*	<i>Agrostis capillaris</i>
brush wattle*	<i>Paraserianthes lophantha</i>
buddleia*	<i>Buddleja davidii</i>
buffalo grass*	<i>Stenotaphrum secundatum</i>
bulbous rush*	<i>Juncus bulbosus</i>
Californian thistle*	<i>Cirsium arvense</i>
catsear*	<i>Hypochoeris radicata</i>
Chinese privet*	<i>Ligustrum sinense</i>
coast redwood*	<i>Sequoia sempervirens</i>
cocksfoot*	<i>Dactylis glomerata</i>
common alder*	<i>Alnus glutinosa</i>
cotoneaster*	<i>Cotoneaster glaucophyllus</i>
crack willow*	<i>Salix fragilis</i>
creeping bent*	<i>Agrostis stolonifera</i>
creeping buttercup*	<i>Ranunculus repens</i>
Cretan brake*	<i>Pteris cretica</i>
Douglas fir*	<i>Pseudotsuga menziesii</i>
elephants ears*	<i>Alocasia brisbanensis</i>
English oak*	<i>Quercus robur</i>
eucalyptus*	<i>Eucalyptus</i> sp.
false acacia*	robinia; black locust; <i>Robinia pseudoacacia</i>
feijoa*	<i>Feijoa sellowiana</i>

fennel*	<i>Foeniculum vulgare</i>
floating sweetgrass*	<i>Glyceria fluitans</i>
foxglove*	<i>Digitalis purpurea</i>
geothermal kānuka	<i>Kunzea tenuicaulis</i>
German ivy*	<i>Delairea odorata</i>
gorse*	<i>Ulex europaeus</i>
grape*	<i>Vitis vinifera</i>
greater bindweed*	<i>Calystegia silvatica</i>
grey willow*	<i>Salix cinerea</i>
hangehange	<i>Geniostoma ligustrifolium</i> var. <i>ligustrifolium</i>
harakeke	flax; <i>Phormium tenax</i>
hawksbeard*	<i>Crepis capillaris</i>
hawthorn*	<i>Crataegus monogyna</i>
heather*	<i>Calluna vulgaris</i>
hells bells	<i>Anaphalioides bellidioides</i>
Himalaya fairy grass*	<i>Miscanthus nepalensis</i>
Himalayan honeysuckle*	<i>Leycesteria formosa</i>
holly*	<i>Ilex aquifolium</i>
houhere	lacebark; <i>Hoheria sexstylosa</i>
hydrangea*	<i>Hydrangea macrophylla</i>
Indian doab*	<i>Cynodon dactylon</i>
ivy*	<i>Hedera helix</i>
Japanese cedar*	<i>Cryptomeria japonica</i>
Japanese hill cherry*	<i>Prunus serrulata</i>
Japanese honeysuckle*	<i>Lonicera japonica</i>
jasmine*	<i>Jasminum polyanthum</i>
jointed rush*	<i>Juncus articulatus</i>
kahikatea	<i>Dacrycarpus dacrydioides</i>
kāmahi	<i>Pterophylla racemosa</i>
kānuka	<i>Kunzea robusta</i>
kāpūngāwhā	lake clubrush; <i>Schoenoplectus tabernaemontani</i>
karamū	<i>Coprosma robusta</i>
kikuyu grass*	<i>Cenchrus clandestinus</i>
kiokio	<i>Parablechnum novae-zelandiae</i>
kiwifruit*	<i>Actinidia deliciosa</i>
kōhūhū	<i>Pittosporum tenuifolium</i>
korokio	<i>Corokia</i> sp.
koromiko	<i>Veronica stricta</i> var. <i>stricta</i>
kōtukutuku	<i>Fuchsia excorticata</i>
kōwaowao	hound's tongue fern; <i>Lecanopteris pustulata</i>
	subsp. <i>pustulata</i>
kōwhai	<i>Sophora microphylla</i>
Lawson's cypress*	<i>Chamaecyparis lawsoniana</i>
liquidamber*	<i>Liquidambar styraciflua</i>
lodgepole pine*	<i>Pinus contorta</i>
Lombardy poplar*	<i>Populus nigra</i> 'Italica'
loquat*	<i>Eriobotrya japonica</i>
lotus*	<i>Lotus pedunculatus</i>
lupin*	<i>Lupinus arboreus</i>
macrocarpa*	<i>Hesperocyparis macrocarpa</i>
māhoe	<i>Melicytus ramiflorus</i> subsp. <i>ramiflorus</i>
makomako	wineberry ; <i>Aristotelia serrata</i>
male fern*	<i>Dryopteris filix-mas</i> and <i>D. affinis</i>
mamaku	<i>Cyathea medullaris</i>
mānuka	<i>Leptospermum scoparium</i> agg.

māpou
 maritime pine*
 Mercer grass*
 Mexican daisy*
 Mexican water lily*
 mingimingi
 monkey musk*
 monoao
 montbretia*
 Montpellier broom*
 narrow-leaved carpet grass*
 narrow-leaved plantain*
 necklace fern
 northern rātā
 oak*
 oioi
 olive*
 ornamental cherry*
 Ovens wattle*
 pakau
 pampas*
 paspalum*
 patē
 pātōtara
 paulownia*
 periwinkle*
 plum*
 pōhue
 pōhuehue
 pōhutukawa
 ponga
 poplar*
 prickly mingimingi
 purple linaria*
 purple pampas*
 radiata pine*
 rangiora
 ratstail*
 raupō
 rautāwhiri
 red fescue*
 reed sweetgrass*
 rewarewa
 rhododendron*
 ribbonwood
 rimu
 ring fern
 ripgut brome*
 rose*
 ryegrass*
 Scotch thistle*
 sea rush
 shaking brake
 sharp-fruited rush*
 sheep's sorrel*

Myrsine australis
Pinus pinaster
Paspalum distichum
Erigeron karvinskianus
Nymphaea mexicana
Leucopogon fasciculatus
Mimulus guttatus
Dracophyllum subulatum
Crocasmia ×crocsmiiflora
Teline monspessulana
Axonopus fissifolius
Plantago lanceolata
Asplenium flabellifolium
Metrosideros robusta
Quercus sp.
Apodasmia similis
Olea europaea
Prunus sp.
Acacia pravissima
Pakau pennigera
Cortaderia selloana
Paspalum dilatatum
Schefflera digitata
Leucopogon fraseri
Paulownia tomentosa
Vinca major
Prunus ×domestica
Calystegia sepium subsp. *roseata*
Muehlenbeckia complexa
Metrosideros excelsa
Alsophila dealbata
Populus sp.
Leptecophylla juniperina subsp. *juniperina*
Linaria purpurea
Cortaderia jubata
Pinus radiata
Brachyglottis repanda
Sporobolus africanus
Typha orientalis
Pittosporum colensoi
Festuca rubra subsp. *rubra*
Glyceria maxima
Knightia excelsa
Rhododendron sp.
 mānātu; *Plagianthus regius* subsp. *regius*
Dacrydium cupressinum
Paesia scaberula
Bromus diandrus
 climbing rose; *Rosa* sp.
Lolium rigidum
Cirsium vulgare
 wīwī; *Juncus kraussii* var. *australiensis*
 turawera; *Pteris tremula*
Juncus acuminatus
Rumex acetosella

silver birch*	<i>Betula pendula</i>
silver wattle*	<i>Acacia dealbata</i>
soft rush*	<i>Juncus effusus</i> var. <i>effusus</i>
Spanish heath*	<i>Erica lusitanica</i>
strawberry dogwood*	<i>Dendrobenthamia capitata</i>
strawberry tree*	<i>Arbutus unedo</i>
strobilus pine*	<i>Pinus strobus</i>
swamp kiokio	<i>Parablechnum minus</i>
swamp millet	<i>Isachne globosa</i>
sweet vernal*	<i>Anthoxanthum odoratum</i>
tall fescue*	<i>Lolium arundinaceum</i> subsp. <i>arundinaceum</i>
tānekaha	<i>Phyllocladus trichomanoides</i>
tangle fern	<i>Gleichenia microphylla</i>
tarata	lemonwood; <i>Pittosporum eugenoides</i>
Tasmanian blackwood*	<i>Acacia melanoxylon</i>
tāwiniwini	<i>Gaultheria antipoda</i>
tī kōuka	cabbage tree; <i>Cordyline australis</i>
toatoa	<i>Haloragis erecta</i> subsp. <i>erecta</i>
toetoe ¹	<i>Austroderia fulvida</i>
toru	<i>Toronia toru</i>
tōtara	<i>Podocarpus totara</i> var. <i>totara</i>
tōtorowhiti	<i>Dracophyllum strictum</i>
tradescantia*	<i>Tradescantia fluminensis</i>
tree lucerne*	<i>Chamaecytisus palmensis</i>
tūrutu	<i>Dianella nigra</i>
tutu	<i>Coriaria arborea</i> var. <i>arborea</i>
umbrella sedge*	<i>Cyperus eragrostis</i>
Vasey grass*	<i>Paspalum urvillei</i>
veldt grass *	<i>Ehrharta erecta</i>
wall lettuce*	<i>Mycelis muralis</i>
water fern	<i>Histiopteris incisa</i>
water figwort*	<i>Scrophularia auriculata</i>
water forget-me-not*	<i>Myosotis laxa</i> subsp. <i>caespitosa</i>
water pepper*	<i>Persicaria hydropiper</i>
water purslane*	<i>Ludwigia palustris</i>
watercress*	<i>Nasturtium officinale</i>
whauwhaupaku	five finger; <i>Pseudopanax arboreus</i>
whēkī	<i>Dicksonia squarrosa</i>
whēkī-ponga	<i>Dicksonia fibrosa</i>
white clover*	<i>Trifolium repens</i>
wild portulaca*	<i>Portulaca oleracea</i>
wild seradella*	<i>Ornithopus perpusillus</i>
willow herb*	<i>Epilobium ciliatum</i>
willow-leaved hakea *	<i>Hakea salicifolia</i>
yarrow*	<i>Achillea millefolium</i>
Yorkshire fog*	<i>Holcus lanatus</i>
yucca*	<i>Yucca</i> sp.

¹ The name toetoe is generally used for all of the species all species in the genus *Austroderia*. In this report it refers to *A. fulvida*, the most common species at geothermal sites in the Waikato, unless otherwise specified.

COMMON FAUNA NAMES USED IN TEXT

BIRDS**Indigenous**

Kāhu/swamp harrier
 Kakīānau/black swan
 Kārearea/New Zealand ‘bush’ falcon
 Karoro/southern black-backed gull
 Kawau paka/little shag
 Kawau tūi/little black shag
 Kererū/New Zealand pigeon
 Koekoeā/long-tailed cuckoo
 Korimako/bellbird
 Kōtare/sacred kingfisher
 Kōtuku ngutupapa/royal spoonbill
 Kuruwhegi/Australasian shoveler
 Māpunga/black shag
 Mātātā/North Island fernbird
 Matuku hūrepo/Australasian bittern
 Matuku moana/white-faced heron
 Miromiro/North Island tomtit
 Pāpango/New Zealand scaup
 Pārera/grey duck
 Pīhoihoi/New Zealand pipit
 Pīpīwharau/roa/shining cuckoo
 Pīwakawaka/North Island fantail
 Poaka/pied stilt
 Pōpokatea/whitehead
 Pūkeko
 Pūtangitangi/paradise shelduck
 Pūweto/spotless crane
 Riroriro/grey warbler
 Ruru/morepork
 Spur-winged plover
 Taranui/Caspian tern
 Tarāpuka/black-billed gull
 Tarāpunga/red-billed gull
 Tauhou/silvereye
 Tētē-moroiti/grey teal
 Toutouwai/North Island robin
 Tūi
 Tūturiwhatu/banded dotterel
 Wahou/welcome swallow
 Wewēia/New Zealand dabchick

Circus approximans
Cygnus atratus
Falco novaeseelandiae “bush falcon”
Larus dominicanus dominicanus
Phalacrocorax melanoleucos brevirostris
Phalacrocorax sulcirostris
Hemiphaga novaeseelandiae
Eudynamis taitensis
Anthornis melanura melanura
Todiramphus sanctus vagans
Platalea regia
Anas rhynchotis variegata
Phalacrocorax carbo novaehollandiae
Bowdleria punctata vealeae
Botaurus poiciloptilus
Egretta novaehollandiae
Petroica macrocephala toitoi
Aythya novaeseelandiae
Anas superciliosa
Anthus novaeseelandiae novaeseelandiae
Chrysococcyx lucidus lucidus
Rhipidura fuliginosa placabilis
Himantopus himantopus leucocephalus
Mohoua albigilla
Porphyrio melanotus melanotus
Tadorna variegata
Porzana tabuensis tabuensis
Gerygone olivacea
Ninox novaeseelandiae novaeseelandiae
Vanellus miles novaehollandiae
Hydroprogne caspia
Larus bulleri
Larus novaehollandiae scopulinus
Zosterops lateralis lateralis
Anas gracilis
Petroica longipes
Prothemodera novaeseelandiae novaeseelandiae
Charadrius bicinctus bicinctus
Hirundo neoxena neoxena
Poliiocephalus rufpectus

Introduced

Australian magpie
 California quail
 Canada goose

Gymnorhina tibicen
Callipepla californica bunnescens
Branta canadensis

Chaffinch
Common myna
Common pheasant
Common starling
Dunnock
Eastern rosella
Eurasian blackbird
Eurasian skylark
European goldfinch
European greenfinch
Feral chicken
Feral goose
House sparrow
Mallard
Rock pigeon
Song thrush
Yellowhammer

Fringilla coelebs
Acridotheres tristis
Phasianus colchicus
Sturnus vulgaris
Prunella modularis
Platycercus eximius
Turdus merula
Alauda arvensis
Carduelis carduelis
Carduelis chloris
Gallus gallus gallus
Anser anser
Passer domesticus
Anas platyrhynchos
Columba livia
Turdus philomelos
Emberiza citrinella

MAMMALS

Indigenous

Pekapeka/long-tailed bat (North Island)

Chalinolobus tuberculatus “North Island”

Introduced (feral)

Brown hare
Cat
Cattle
European rabbit
European hedgehog
Feral pig
Goat
Horse
Possum
Rat
Red deer
Sheep

Lepus europaeus
Felis catus
Bos taurus
Oryctolagus cuniculus cuniculus
Erinaceus europaeus
Sus scrofa
Capra hircus
Equus caballus
Trichosurus vulpecula
Rattus sp.
Cervus elaphus scoticus
Ovis aries

FISH

Indigenous

Longfin eel

Anguilla dieffenbachii

Introduced and Naturalised

Mosquitofish

Gambusia affinis

OTHER

Rainbow skink
Argentine ant

Lampropholis delicata
Linepithema humile

GEOTHERMAL VEGETATION, HABITAT TYPES, AND CODES WITHIN EACH GEOTHERMAL/HABITAT CLASS

Areas are the extent of each vegetation type within the Waikato Region (hectares).

Structural Vegetation Class	Vegetation Class	Geothermal Vegetation/ Habitat Type	Code	Area (ha)
Forest	Indigenous forest (kānuka and geothermal kānuka dominant)	Kānuka forest	01.01.01	<0.1 ha
		Kānuka forest and kānuka shrubland	01.01.02	c.5.5 ha
		Geothermal kānuka forest	01.01.03	c.0.6 ha
	Exotic forest	Mixed exotic conifer/mixed indigenous shrubs and ferns forest	01.02.01	c.2.1 ha
		Grey willow forest	01.02.03	c.0.5 ha
		Tasmanian blackwood-mānuka-kānuka-whauwhaupaku-kāmahi-tī kōuka forest	01.02.04	c.0.1 ha
		Exotic conifers/mingimingi-geothermal kānuka forest	01.02.05	c.2.8 ha
		Radiata pine/geothermal kānuka-mānuka forest	01.02.07	c.6.9 ha
		Exotic conifers/geothermal kānuka-mingimingi forest		
		Wilding pines/geothermal kānuka forest		
		Wilding pines/geothermal kānuka-mingimingi forest		
	Mixed exotic and indigenous forest	Mixed exotic and indigenous species forest	01.03.01	<0.1 ha
		Exotic conifers/geothermal kānuka forest mixed exotic and indigenous species forest	01.03.02	c.1.5 ha
	Mixed indigenous broadleaved species forest	Mixed indigenous broadleaved species forest	01.04.01	c.1.6 ha
		Mixed indigenous broadleaved species and geothermal kānuka forest	01.04.02	c.5.0 ha
		Mixed planted indigenous broadleaved species forest		
Treeland	Indigenous treeland	Mixed indigenous and exotic trees/blackberry-rank exotic grasses- <i>Hypolepis ambigua</i> treeland	02.01.03	c.0.2 ha
		Geothermal kānuka-mixed exotic trees/Yorkshire fog- <i>Hypolepis ambigua</i> treeland	02.01.04	c.0.5 ha
	Exotic treeland	Grey willow/harakeke- <i>Cyperus ustulatus</i> treeland	02.02.01	c.0.5 ha
Vineland	Exotic vineland	<i>Calystegia sepium</i> -Japanese honeysuckle-blackberry vineland	03.01.01	c.0.1 ha
		Grape vineland	03.01.02	c.0.2 ha
		Japanese honeysuckle-(<i>Cyperus ustulatus</i>) vineland	03.01.03	<0.1 ha
Scrub	Geothermal kānuka-dominant scrub	Geothermal kānuka scrub	04.01.01	c.208.6 ha
		Tasmanian blackwood/geothermal kānuka scrub	04.01.02	c.0.6 ha
		Exotic conifers/geothermal kānuka scrub	04.01.03	c.1.9 ha
		Geothermal kānuka-monoao scrub	04.01.06	c.31.4 ha
		(Kāmahi)/geothermal kānuka-(monoao) scrub	04.01.08	c.25.3 ha

Structural Vegetation Class	Vegetation Class	Geothermal Vegetation/ Habitat Type	Code	Area (ha)
		Geothermal kānuka-mānuka-(mixed indigenous broadleaved species)/blackberry scrub	04.01.09	c.44.1 ha
		Geothermal kānuka-mixed exotic woody species scrub	04.01.11	c.1.3 ha
		Geothermal kānuka-kānuka- mānuka-mingimingi mixed indigenous broadleaved species-treefern scrub	04.01.12	c.64.8 ha
		(Exotic conifer)/geothermal kānuka-kānuka- mānuka-mingimingi mixed indigenous broadleaved species-treefern scrub	04.01.13	c.3.4 ha
	Geothermal kānuka-mingimingi scrub	Geothermal kānuka-mingimingi scrub	04.02.01	c.29.6 ha
		Geothermal kānuka-mingimingi-mānuka scrub	04.02.02	c.63.3 ha
		(Exotic conifer)/geothermal kānuka-mingimingi scrub	04.02.03	c.55.4 ha
	Mingimingi-dominant scrub	Mingimingi scrub	04.03.01	c.1.3 ha
		Wilding pine/mingimingi-blackberry-bracken-geothermal kānuka scrub	04.03.02	c.0.3 ha
		Exotic conifer/geothermal kānuka-mingimingi scrub	04.03.03	c.9.4 ha
		Exotic pine/mingimingi scrub		
		Mingimingi-mixed indigenous species scrub		
		(Mānuka)/mingimingi scrub	04.03.05	c.2.0 ha
		(Silver birch)/mingimingi-(geothermal kānuka) scrub	04.03.06	<0.1 ha
		Exotic conifers/mingimingi-Chinese privet scrub	04.03.07	c.0.1 ha
	Mānuka-dominant scrub	Mānuka scrub	04.04.01	c.31.3 ha
		Mānuka-mingimingi scrub	04.04.02	c.4.3 ha
		Exotic pine/mānuka-geothermal kānuka scrub	04.04.03	c.0.2 ha
		Mānuka-geothermal kānuka-exotic species scrub	04.04.04	c.1.1 ha
		Mānuka-mingimingi-blackberry-bracken scrub	04.04.05	c.4.2 ha
		Mānuka-mingimingi-geothermal kānuka scrub	04.04.06	c.0.4 ha
		Mānuka scrub (planted)	04.04.07	c.1.8 ha
		Mānuka/rank grassland scrub	04.04.08	c.1.0 ha
	Whauwhaupaku-dominant scrub	Whauwhaupaku-mixed indigenous species scrub	04.05.01	c.1.0 ha
	Kānuka-dominant scrub	Kānuka-geothermal kānuka scrub	04.06.01	c.4.3 ha
	Mixed indigenous species scrub	Mānuka-geothermal kānuka-mingimingi/bracken scrub	04.08.01	c.18.9 ha
		Whauwhaupaku-kāmahi-kōhūhū scrub	04.08.02	c.0.9 ha
		Rewarewa-kāmahi/geothermal kānuka-mingimingi scrub	04.08.03	c.2.0 ha
		Kānuka-mānuka-rautāwhiri-tarata scrub	04.08.04	c.0.1 ha
	Mixed exotic and indigenous scrub	Mixed indigenous and exotic scrub	04.09.02	c.0.4 ha
		Black wattle/mānuka-blackberry-bracken scrub	04.09.04	c.1.6 ha
	Exotic species-dominant scrub	Blackberry scrub	04.10.01	c.1.5 ha
		Silver birch-Chinese privet/blackberry-(geothermal kānuka) scrub	04.10.02	<0.1 ha
		Chinese privet scrub	04.10.03	c.0.9 ha
		Blackberry-bracken scrub	04.10.05	c.0.8 ha
		Arrow bamboo scrub	04.10.06	c.0.1 ha

Structural Vegetation Class	Vegetation Class	Geothermal Vegetation/ Habitat Type	Code	Area (ha)
		Chinese privet-(mānuka)-(geothermal kānuka) scrub	04.10.07	c.0.1 ha
		Mixed indigenous and exotic trees and shrubs/ blackberry scrub	04.10.08	c.4.1 ha
Shrubland	Geothermal kānuka-dominant shrubland	Geothermal kānuka shrubland	05.01.01	c.28.2 ha
		Exotic pine/geothermal kānuka-mingimingi shrubland	05.01.02	c.0.4 ha
		(Wilding pine)/geothermal kānuka-exotic species shrubland	05.01.03	<0.1 ha
		Geothermal kānuka/geothermally-influenced bare ground shrubland	05.01.07	<0.1 ha
		Burnt geothermal kānuka shrubland	05.01.09	c.6.1 ha
	Mingimingi-dominant shrubland	Mingimingi- <i>Histiopteris incisa</i> shrubland	05.02.01	c.0.1 ha
		Mingimingi-geothermal kānuka-monoao shrubland	05.02.02	c.0.1 ha
	Mingimingi-mānuka shrubland	Mingimingi-mānuka shrubland	05.03.01	c.0.3 ha
	Mānuka-dominant shrubland	Mānuka shrubland	05.04.01	c.2.0 ha
		Mānuka/bracken-blackberry shrubland	05.04.02	c.0.6 ha
		Kānuka-geothermal kānuka shrubland	05.04.03	<0.1 ha
		Mānuka/mixed sedges, reeds and ferns shrubland	05.04.04	c.0.3 ha
		Mānuka/mixed indigenous wetland species shrubland	05.04.06	c.0.8 ha
		Mānuka/mixed indigenous woody species/lichen shrubland	05.04.07	c.2.9 ha
	Kānuka-dominant shrubland	Kānuka-mānuka/oioi shrubland	05.06.02	c.0.9 ha
	Mixed indigenous shrubland	Mixed indigenous shrubs/mixed fern species shrubland	05.07.01	c.0.1 ha
		Planted indigenous species/rank exotic grasses shrubland	05.07.02	c.0.5 ha
		Sprayed geothermal shrubland	05.07.04	c.0.3 ha
	Mixed indigenous and exotic shrubland	Blackberry-bracken shrubland	05.08.07	c.5.9 ha
		Mixed indigenous and exotic shrub shrubland	05.08.08	c.3.0 ha
		Wilding pine/mixed indigenous and exotic species mosaic shrubland	05.08.09	c.0.2 ha
	Exotic shrubland	Blackberry-broom/Yorkshire fog shrubland	05.09.03	c.0.1 ha
		Blackberry-bracken-broom-(geothermal kānuka) shrubland	05.09.07	c.0.3 ha
		Blackberry-pampas/buffalo grass shrubland	05.09.09	<0.1 ha
		Blackberry-broom- <i>Histiopteris incisa</i> -bracken shrubland	05.09.10	c.0.2 ha
Tussockland	Pampas tussockland	Pampas-blackberry tussockland	06.01.01	c.0.1 ha
		Common alder/pampas tussockland	06.01.02	c.0.1 ha
		Pampas tussockland	06.01.03	<0.1 ha
Fernland	Indigenous fernland	<i>Dicranopteris linearis</i> fernland	07.01.01	c.0.2 ha
		Bracken-mingimingi-blackberry fernland	07.01.02	c.0.1 ha
		<i>Histiopteris incisa</i> fernland	07.01.03	<0.1 ha
		Mixed indigenous fernland	07.01.07	c.2.3 ha
		<i>Christella</i> aff. <i>dentata</i> ("thermal")- <i>Nephrolepis flexuosa</i> -blackberry fernland	07.01.09	c.0.1 ha
		<i>Nephrolepis flexuosa</i> fernland	07.01.10	c.0.1 ha
		<i>Deparia petersenii</i> fernland	07.01.12	<0.1 ha
		<i>Cheilanthes sieberi</i> -bay grass fernland	07.01.13	c.0.1 ha
		<i>Cheilanthes sieberi</i> fernland		
		<i>Lycopodiella cernua</i> fernland	07.01.15	c.0.1 ha

Structural Vegetation Class	Vegetation Class	Geothermal Vegetation/ Habitat Type	Code	Area (ha)
		Whekī fernland	07.01.18	c.1.9 ha
		Bracken fernland	07.01.19	c.0.2 ha
		<i>Hypolepis ambigua</i> - <i>Histiopteris incisa</i> fernland	07.01.21	<0.1 ha
		-Sprayed <i>Nephrolepis flexuosa</i> fernland - <i>Gleichenia microphylla</i> fernland	07.01.22	c.0.1 ha
Grassland	Exotic grassland	Yorkshire fog grassland	08.01.01	c.0.3 ha
		Mercer grass grassland	08.01.03	<0.1 ha
		(Mānuka)-(geothermal kānuka)-harakeke/narrow-leaved carpet grass-Yorkshire fog grassland	08.01.06	c.0.4 ha
		Indian doab grassland	08.01.07	c.0.3 ha
		(Geothermal kānuka)/rank exotic grasses grassland	08.01.08	<0.1 ha
		Reed sweet grass-raupō- kāpūngāwhā-grassland	08.01.10	c.3.2 ha
		(Grey willow)-(pampas)/tall fescue- <i>Cyperus ustulatus</i> - <i>Carex virgata</i> -blackberry grassland	08.01.13	c.0.2 ha
		Mixed exotic grassland	08.01.15	c.1.0 ha
		Buffalo grass-pampas-blackberry grassland	08.01.17	<0.1 ha
Sedgeland	Indigenous sedgeland	<i>Cyperus ustulatus</i> -raupō sedgeland	09.01.01	<0.1 ha
		Oioi sedgeland	09.01.02	<0.1 ha
		Mānuka/ <i>Machaerina rubiginosa</i> -swamp kiokio-blackberry- <i>Carex virgata</i> sedgeland	09.01.03	<0.1 ha
		Mixed <i>Carex</i> species-Yorkshire fog sedgeland	09.01.04	c.0.1 ha
		Bracken- <i>Machaerina rubiginosa</i> -mixed fern sedgeland	09.01.05	c.2.0 ha
		Kāpūngāwhā/water pepper- <i>Persicaria decipiens</i> sedgeland	09.01.06	c.0.1 ha
		Kāpūngāwhā-(<i>Cyperus alternifolius</i> subsp. <i>flabelliformis</i>) sedgeland	09.01.07	<0.1 ha
		Harakeke/kāpūngāwhā sedgeland	09.01.08	c.0.1 ha
		<i>Machaerina juncea</i> - <i>M. arthrophylla</i> -kāpūngāwhā-sedgeland	09.01.09	c.1.0 ha
		Mixed indigenous sedges, reeds, and rushes sedgeland	09.01.13	c.5.6 ha
		Harakeke/ <i>Machaerina rubiginosa</i> sedgeland		
		Mixed indigenous sedgeland	09.01.14	c.1.4 ha
		<i>Cyperus ustulatus</i> sedgeland	09.01.15	c.0.1 ha
Rushland	Exotic rushland	Soft rush-paspalum rushland	10.01.01	<0.1 ha
		Bulbous rush rushland	10.01.02	c.0.2 ha
Reedland	Reedland	Raupō reedland	11.01.01	c.48.1 ha
		(Crack willow)/raupō reedland	11.01.03	<0.1 ha
		(Tī kōuka)-(mānuka)/raupō- <i>Cyperus ustulatus</i> -kāpūngāwhā reedland	11.01.04	c.1.2 ha
		Grey willow/raupō reedland	11.01.05	c.0.2 ha
		Raupō-harakeke-mixed sedges and rushes reedland	11.01.06	c.8.4 ha
		(Grey willow)/whekī/raupō-harakeke-mixed sedges reedland	11.01.07	c.2.0 ha
Herbfield	Herbfield	<i>Glossostigma elatinoides</i> - <i>G. diandrum</i> herbfield	13.01.03	<0.1 ha
Stonefield	Stonefield	(<i>Rytidosperma setifolium</i>)-(blue tussock)/stonefield/loam and mud	18.01.01	c.0.7 ha
Sandfield	Sandfield	Geothermal sand	19.01.01	<0.1 ha
Bare ground	Bare ground	Geothermally-influenced bare ground	20.01.01	c.94.7 ha
		Sinter	20.01.04	c.3.6 ha

Structural Vegetation Class	Vegetation Class	Geothermal Vegetation/ Habitat Type	Code	Area (ha)
Flaxland	Flaxland	(Mānuka)/harakeke- <i>Cyperus ustulatus</i> flaxland	21.01.01	c.1.7 ha
		Whekī/harakeke-raupō flaxland	21.01.02	c.1.8 ha
		Harakeke flaxland	21.01.03	c.0.3 ha
Water	Geothermal water and mudpools	Geothermal water	22.01.01	c.116.1 ha
		Mudpools	22.01.02	c.2.1 ha
		Geothermal streams and springs	22.01.03	c.5.3 ha

THREAT CLASSIFICATION SYSTEM

From Townsend *et al.* (2008), and Michel (2021) followed in de Lange *et al.* (2018).

NATIONALLY CRITICAL

A. Very small population (natural or unnatural)

A taxon is ‘Nationally Critical’, regardless of population trend and regardless of whether the population size is natural or unnatural, when evidence¹ indicates that:

1. There are fewer than 250 mature individuals; or
2. There are ≤ 2 sub-populations and ≤ 200 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 1 ha (0.01 km²).

B. Small population (natural or unnatural) with a high ongoing or predicted decline

A taxon is ‘Nationally Critical’ when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The population comprises 250-1,000 mature individuals; or
2. There are ≤ 5 sub-populations and ≤ 300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 10 ha (0.1 km²).

Trend

There is an ongoing or predicted decline of 50-70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

C. Population (irrespective of size or number of sub-populations) with a very high ongoing or predicted decline (>70%)

A taxon is ‘Nationally Critical’ when the population has an ongoing trend or predicted decline of >70% in the total population due to existing threats taken over the next 10 years or three generations, whichever is longer.

¹ Evidence in this context is defined as quantitative data and supporting information about the status of a candidate taxon.

NATIONALLY ENDANGERED

A. Small population (natural or unnatural) that has a low to high ongoing or predicted decline

A taxon is 'Nationally Endangered' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 250-1000 mature individuals; or
2. There are ≤ 5 sub-populations and ≤ 300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 10 ha (0.1 km^2).

Trend

There is an ongoing or predicted decline of 10-50% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

B. Small stable population (unnatural)

To trigger this pathway to 'Nationally Endangered', taxa must have current population sizes that result from unnatural causes. Such taxa are defined as 'Nationally Endangered' when evidence indicates that they fit at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 250-1,000 mature individuals; or
2. There are ≤ 5 sub-populations and ≤ 300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 10 ha (0.1 km^2).

Trend

The population is stable ($\pm 10\%$) and is predicted to remain stable over the next 10 years or three generations, whichever is longer.

C. Moderate population and high ongoing or predicted decline

A taxon is 'Nationally Endangered' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 1,000-5,000 mature individuals; or
2. There are ≤ 15 sub-populations and ≤ 500 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 100 ha (1 km^2).

Trend

There is an ongoing or predicted decline of 50-70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

NATIONALLY VULNERABLE

A. Small, increasing population (unnatural)

To trigger 'Nationally Vulnerable', taxa must have current population sizes that result from unnatural causes. Such taxa are defined as 'Nationally Vulnerable' when evidence indicates that they fit at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 250-1,000 mature individuals; or
2. There are ≤ 5 sub-populations and ≤ 300 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 10 ha (0.1 km^2).

Trend

The population is increasing ($>10\%$) and is predicted to continue to increase over the next 10 years or three generations, whichever is longer.

B. Moderate, stable population (unnatural)

To trigger 'Nationally Vulnerable', taxa must have current population sizes that result from unnatural causes. Such taxa are defined as 'Nationally Vulnerable' when evidence indicates that they fit at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 1,000-5,000 mature individuals; or
2. There are ≤ 15 sub-populations and ≤ 500 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 100 ha (1 km^2).

Trend

The population is stable ($\pm 10\%$) and is predicted to remain stable over the next 10 years or three generations, whichever is longer.

C. Moderate population, with population trend that is declining

A taxon is 'Nationally Vulnerable' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 1,000-5,000 mature individuals; or
2. There are ≤ 15 sub-populations and ≤ 500 mature individuals in the largest sub-population; or
3. The total area of occupancy is ≤ 100 ha (1 km^2).

Trend

There is an ongoing or predicted decline of 10-50% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

D. Moderate to large population and moderate to high ongoing or predicted decline

A taxon is 'Nationally Vulnerable' when evidence indicates that it fits at least one Status criterion and the Trend criteria as follows:

Status

1. The total population size is 5,000-20,000 mature individuals; or
2. There are ≤ 15 sub-populations and $\leq 1,000$ mature individuals in the largest sub-population; or
3. The total area of occupancy is $\leq 1,000$ ha (10 km^2).

Trend

There is an ongoing or predicted decline of 30-70% in the total population due to existing threats, taken over the next 10 years or three generations, whichever is longer.

E. Large population and high ongoing or predicted decline

A taxon is 'Nationally Vulnerable' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 20,000-100,000 mature individuals; or
2. The total area of occupancy is $\leq 10,000$ ha (100 km^2).

Trend

There is an ongoing or predicted decline of 50-70% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

NATIONALLY INCREASING

Small population that has experienced a previous decline (or for which it is uncertain whether it has experienced a previous decline) and that is forecast to increase $>10\%$ over the next 10 years or 3 generations, whichever is longer.

A taxon is 'Nationally Increasing' when it has previously experienced a decline and it fits the trend criterion of an ongoing or forecast increase of 10% or more over the next 10 years or 3 generations, whichever is longer and it fits one or both of the size criteria:

- The total population size is 1000–5000 mature individuals
- The total area of occupancy is 10–100 ha ($0.1\text{--}1 \text{ km}^2$)

Note: Taxa that have an increasing trend but whose populations are smaller than the size criteria listed here for Nationally Increasing are either 'Threatened-Nationally Critical' or 'Threatened-Nationally Vulnerable'.

CRITERIA FOR 'AT RISK' TAXA

Taxa that qualify as 'At Risk' do not meet the criteria for any of the 'Threatened' categories. However, they are declining (though buffered by a large total population size and/or a slow

decline rate), biologically scarce, recovering from a previously threatened status, or survive only in relictual populations.

Four 'At Risk' categories exist: 'Declining', 'Recovering', 'Relict' and 'Naturally Uncommon'. Definitions for each are provided below.

Declining

'Declining' taxa do not qualify as 'Threatened' because they are buffered by a large total population size and/or a slower decline rate. However, if the declining trends continue, these taxa may be listed as 'Threatened' in the future.

A. Moderate to large population and low ongoing or predicted decline

A taxon is 'Declining' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 5,000-20,000 mature individuals; or
2. The total area of occupancy is ≤ 1000 ha (10 km^2).

Trend

There is an ongoing or predicted decline of 10-30% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

B. Large population and low to moderate ongoing or predicted decline

A taxon is 'Declining' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is 20,000-100,000 mature individuals; or
2. The total area of occupancy is $\leq 10,000$ ha (100 km^2).

Trend

There is an ongoing or predicted decline of 10-50% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

C. Very large population and low to high ongoing or predicted decline

A taxon is 'Declining' when evidence indicates that it fits at least one Status criterion and the Trend criterion as follows:

Status

1. The total population size is $> 100,000$ mature individuals; or
2. The total area of occupancy is $> 10,000$ ha (100 km^2).

Trend

There is an ongoing or predicted decline of 10-70% in the total population or area of occupancy due to existing threats, taken over the next 10 years or three generations, whichever is longer.

Recovering

Moderate to large population that has (or may have) experienced a previous decline and that is forecast to increase by $\geq 10\%$ over the next 10 years or three generations, whichever is longer. A taxon is 'Recovering' when it has previously experienced a decline (or for which it is uncertain whether there has been a previous decline) and it fits the trend criterion of an ongoing or forecast increase of 10% or more over the next 10 years or 3 generations, whichever is longer, and it fits one or both of the size criteria:

- The total population size is 5000–20 000 mature individuals
- The total area of occupancy is 100–1000 ha (1–10 km²)

Note: Taxa that have an increasing trend after a previous decline but whose populations are smaller than the size criteria listed here for Recovering are either 'Threatened-Nationally Critical', 'Threatened-Nationally Vulnerable' or 'Threatened-Nationally Increasing'. Taxa that have an increasing trend after a previous decline but whose populations are larger than the size criteria listed here are either 'At Risk-Naturally Uncommon', 'At Risk-Relict' or 'Not Threatened'.

Relict

Taxa that have undergone a documented decline within the last 1,000 years, and now occupy less than 10% of their former range and meet one of the following criteria:

- A. Have 5,000-20,000 mature individuals and are stable ($\pm 10\%$)
- B. Have more than 20,000 mature individuals and are stable or increasing at $>10\%$

The range of a relictual taxon takes into account the area currently occupied as a ratio of its former extent. 'Relict' can also include taxa that exist as reintroduced and self-sustaining populations within or outside their former known range.

Naturally Uncommon

Taxa whose distribution is naturally confined to specific substrates (e.g. ultramafic rock), habitats (e.g. high alpine fellfield, hydrothermal vents), or geographic areas (e.g. subantarctic islands, sea-mounts), or taxa that occur within naturally small and widely scattered populations. This distribution is not the result of past or recent human disturbance. Populations may be stable or increasing. Note that a naturally uncommon taxon that has fewer than 250 mature individuals qualifies for 'Nationally Critical'. Taxa that have more than 20,000 mature individuals are not considered 'Naturally Uncommon', unless they occupy an area of less than 100,000 ha (1,000 km²).

DEFINITION FOR EACH DATA FIELD IN THE GIS SHAPEFILE

Data Field	Definition
Site Name	Site name
Site Part	Name of site where that site has been merged with another site in this version of the report.
NZTM Easting and Northing	New Zealand Transverse Mercator (NZTM) coordinates. Easting represents the eastward distance or location on a map, and Northing represents the northward distance or location on a map.
Site Elevation	Altitude in metres (m) (minimum and maximum).
Bioclimatic Zone	A zone of vegetation that relates to the temperatures at different altitudes and latitudes.
Geothermal System	The geothermal system within which a site is located.
Ecological District	Ecological District.
Territorial Local Authority	Local authority (Rotorua District or Taupō District).
Regional Authority	Regional Authority (Waikato or Bay of Plenty)
Site Area	Area (ha) of site.
Ecological Significance Ranking	Significance ranking of a site based on the Waikato Region Policy Statement Criteria (Local, Regional, National, or International).
Hydroclass	The hydrological classification of a particular site e.g. Terrestrial, palustrine, riverine, lacustrine.
Vegetation Map Identification	Code related to the vegetation type shown on report map.
Structural Class Code	A numerical code (two characters) based on the vegetation structural class (growth form) of the canopy species (e.g. forest) (e.g. 01).
Vegetation Class Code	A numerical code (four characters) which incorporates the structural class and the dominant species) (e.g. 01.02).
Vegetation Code	A numerical code (six characters) based on structural class, vegetation class (e.g. 01.02.03), and vegetation type/ habitat (see below).
Vegetation Type/Habitat	A vegetation/habitat type including the dominant species following the Atkinson (1985) method for vegetation classification (see Appendix 11).

WAIKATO REGIONAL COUNCIL CRITERIA FOR THE EVALUATION AND ASSESSMENT OF RELATIVE ECOLOGICAL SIGNIFICANCE OF INDIGENOUS VEGETATION AND HABITATS OF INDIGENOUS FAUNA

From: Updated guidelines for determining areas of significant indigenous vegetation and habitats of indigenous fauna in the Waikato Region. May 2019. Prepared for Waikato Regional Council by Wildland Consultants Ltd.

Table A.3: Criteria for the assessment of significance and reasons for why a site is significant

Site Name:

Area (ha):

Ecological District:

Land Tenure:

Location (grid reference and general location):

General Description:

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
PREVIOUSLY ASSESSED SITE				
1 It is indigenous vegetation or habitat that is currently, or is recommended to be, set aside by statute or covenant or by the Nature Heritage Fund, Ngā Whenua Rāhui committees, or the Queen Elizabeth the Second National Trust Board of Directors specifically for the	This may include sites protected under the Conservation Act, Resource Management Act, or with QEII National Trust, Ngā Whenua Rāhui, or Nature Heritage Fund. Some areas may be protected for reasons other than biodiversity protection. If unsure, check the reasoning for	Department of Conservation Waikato Regional Council Ngā Whenua Rāhui QEII National Trust Nature Heritage Fund	Y / N / NS	What type of legally protected area is it? e.g. Scenic Reserve, National Park, QEII Covenant. _____ _____

¹ Terms highlighted in **bold** type are defined in the glossary on Pages 39-40.

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
protection of biodiversity, and meets at least one of Criteria 2-11.	protection with the authority responsible for the gazetting of the site.	Territorial Authority (District or City council).		
ECOLOGICAL VALUES				
In the Coastal Marine Area , it is indigenous vegetation or habitat for indigenous fauna that has been reduced in extent or degraded due to historic or present anthropogenic activity to a level where the ecological sustainability of the ecosystem is threatened. ^{2,3}	See footnote 8.	Waikato Regional Council Coastal Plan (in preparation) ⁸	Y / N / NS	
3 It is vegetation or habitat that is currently habitat for indigenous species or associations of indigenous species that are: - Classified as threatened or at risk, or Endemic to the Waikato Region, or - At the limit of their natural range.	Species that are threatened with extinction are indigenous species that have been evaluated and placed within any of the 'Threatened' or 'At Risk' categories within the New Zealand Threat Classification System⁴. Care should be taken when assessing this criterion for species which are otherwise common in the wider landscape/ecological region/district but which are listed as Threatened or At Risk as a precautionary measure due to potential risk factors e.g. common Myrtaceae species	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA) Department of Conservation Waikato Regional Council University of Waikato Published reports or maps	Y / N / NS	List the subject species and their threat category, e.g. Threatened-Nationally Critical, At Risk-Declining, At Risk-Naturally Uncommon, regionally uncommon. List source of information. _____ _____ _____ _____ List any Threatened or At Risk species that use the site which are international migrants. _____ _____ List any regionally endemic species present.

² In addition to this criterion, any potential SNA identified within the Coastal Marine Area should be assessed against all eleven criteria within this guidance document **AND** Policy 11 of the New Zealand Coastal Policy Statement.

³ Mapping of significant indigenous biodiversity areas within the Coastal Marine Area (CMA) will be identified by the proposed Waikato Regional Coastal Plan. Notification of the revised Coastal Plan is anticipated in 2023, following which guidance and information within the plan should also be consulted when assessing areas in the CMA.

⁴ When listing Threatened, At Risk, or Data deficient species for this criterion, please ensure the most up-to-date threat classification publications are used for the relevant organism grouping.

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
	which are now classified as Threatened or At Risk due to the threat posed by Myrtle rust. In these instances, professional ecological judgment should be used. With respect to fauna habitat, professional ecological judgement should be used when assessing significance, particularly when evaluating relative significance of occasional site use by highly mobile fauna. Where there is doubt, refer to the guidelines on rarity and distinctiveness given in Appendix 2.			_____ _____ List any species at the limits of their natural range. _____ _____
4 It is indigenous vegetation, habitat, or an ecosystem type that is under-represented (20% or less of its known or likely original extent remaining) in an Ecological District, Ecological Region, or nationally.	Maps of ecological regions and districts are available from Department of Conservation or Waikato Regional Council. A type of indigenous vegetation or habitat could refer to a broad unit such as podocarp/tawa forest, or a more detailed classification and mapping unit such as harakeke (<i>Phormium tenax</i>) flaxland. Definitions and examples of vegetation/habitat structural classes and vegetation types are provided in Atkinson (1985). See Section 5 for other publications which provide examples of vegetation types for various habitats. Comparison with known or likely original extent may require	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA) Department of Conservation Waikato Regional Council Published reports or maps	Y / N / NS	List under-represented vegetation/habitat type(s) and state whether they are under-represented at a national, regional, or ecological district scale? _____ _____ _____ _____ _____ List sources of information for determining whether an ecosystem/vegetation type is under-represented. _____ _____ _____ _____

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
	analysis (e.g. using a Geographic Information System) of current extent and previous extent. As a starting point, use the vegetation/habitat type analysis provided in Appendix 1 of this document which is based on the potential historic ecosystems of New Zealand by Singers and Rogers (2014)². If protected natural area programme reports (PNAP survey reports) are available for your area, these will provide a more detailed, comprehensive analysis of vegetation types.			_____
5 It is indigenous vegetation or habitat that is, and prior to human settlement was, nationally uncommon, such as geothermal, Chenier plain, or karst ecosystems, hydrothermal vents or cold seeps.	Geothermal habitats can include geysers, springs, sinter terraces, and hydro-thermally altered soils. They provide habitat for geothermally-influenced vegetation, and heat-tolerant bacteria. A Chenier plain is a plain comprising shell ridges with infilled muds and other sediment between the ridges. An extensive area at Miranda provides habitat for international wader migrants. Karst ecosystems are limestone systems, providing habitat for specialist limestone plants (e.g. <i>Asplenium cimmeriorum</i>, <i>Gymnostomum calcereum</i>) and fauna (e.g. cave wētā).	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA) Department of Conservation Waikato Regional Council	Y / N / NS	Type of feature: _____ _____ _____ Area: _____ Condition: _____ _____ _____

² Care should be taken when using this data set as some vegetation and habitat types within some parts of the Waikato Region (coastal and northern Waikato) are not well delineated or accurately described by the methodology used for this data set. To avoid doubt, multiple publications or data sets should be utilised to ensure an accurate assessment of this criterion for any given site.

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
	Note that these three examples are not a comprehensive list of nationally uncommon vegetation or habitat types. Other nationally uncommon and/or historically rare ecosystems are defined in Williams <i>et al.</i> (2007) and Holdaway <i>et al.</i> (2012). Where there is doubt, refer to the guidelines on rarity and distinctiveness given in Appendix 2.			
6 It is wetland habitat for indigenous plant communities and/or indigenous fauna communities (excluding exotic rush/pasture communities) that has not been created and subsequently maintained for or in connection with: (a) waste treatment; or (b) wastewater renovation; or (c) hydroelectric power lakes (excluding Lake Taupō); or (d) water storage for irrigation; or (e) water supply storage; unless in those instances they meet the criteria in Whaley <i>et al.</i> (1995).	Wetlands have been severely depleted nationwide, and are recognised as a nationally rare habitat type. Wetlands may have fluctuating water levels and the edge of a wetland may be difficult to define but will generally be where wetland plant species (e.g. raupō) are replaced with dryland species (e.g. kānuka); soil analysis may be required to accurately delineate wetland boundaries in some instances (see Fraser <i>et al.</i> 2018). Note that mānuka can occur in wetland and dryland habitats. The definition of wetlands also includes coastal wetlands, e.g. ephemeral wetlands associated with sand dunes, mangroves, and estuaries. See Section 5 for publications which provide good information on wetland delineation. All artificially-created wetlands listed in Criterion 6a-e should	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA) Department of Conservation Waikato Regional Council Published reports or maps Copies of Whaley <i>et al.</i> (1995) can be obtained from Waikato Regional Council	Y / N / NS	Type of wetland habitats/indigenous communities present: _____ _____ _____ Origins of wetland (natural, artificial): _____ _____ If the wetland was constructed, or created artificially (e.g. ponding following road construction) what was the purpose for which it was created (if known): _____ _____ Area (ha): _____

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
	also be evaluated using the criteria in Whaley <i>et al.</i> (1995), as well as criteria 1-5 and 7-11 in Table 1. The significance criteria from Whaley <i>et al.</i> (1995) are reproduced in Appendix 3.			
7. It is an area of indigenous vegetation or naturally occurring habitat that is large relative to other examples in the Waikato Region of similar habitat types, and which contains all or almost all indigenous species typical of that habitat type. Note that this criterion is not intended to select the largest example only in the Waikato Region of any habitat type.	This criterion is not intended to select the largest single example of a habitat type in the Waikato Region. Refer to vegetation maps (e.g. Leathwick <i>et al.</i> 1995, Singers and Rogers 2014), natural area inventories, DOC compilations of Sites of Special Wildlife Importance (SSWI), DOC Conservation Management Strategies for Waikato, Bay of Plenty, Wanganui, Auckland, and Tongariro/ Taupō Conservancies, Protected Natural Area Programme survey reports to help determine the species that are typical of each habitat type and to determine which other parts of the Waikato Region have similar habitat, and the size of those examples. Where there is doubt, refer to the representativeness, and diversity and pattern guidelines given in Appendix 2.	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA) Department of Conservation Waikato Regional Council Published reports or maps	Y / N / NS	Broad habitat types present: _____ Area (ha) Notable flora or fauna: _____ How does the size compare with other similar habitat types in the Region? _____ Would you consider this to be among the best examples of its type nationally (Y/N), in the Waikato Region (Y/N), or in a particular ecological region/ district (Y/N)? Provide justification. _____ _____
8 It is aquatic habitat (excluding artificial water bodies, except for those created for the maintenance and enhancement of biodiversity or as mitigation as part of a consented activity) that is within a	Excludes artificial water bodies, except those created for the maintenance and enhancement of biodiversity or as mitigation for a consented activity. Groundwater systems in this context relate to spring-fed streams and wetlands, other	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA)	Y / N / NS	Catchment: _____ Area (ha) or length of habitat: _____

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
stream, river, lake, groundwater system, wetland, intertidal mudflat or estuary, or any other part of the coastal marine area and their margins, that is critical to the self-sustainability of an indigenous species within a catchment of the Waikato Region, or within the coastal marine area. In this context 'critical' means essential for a specific component of the life cycle and includes breeding and spawning grounds, juvenile nursery areas, important feeding areas and migratory and dispersal pathways of an indigenous species. This includes areas that maintain connectivity between habitats.	wetlands that are primarily fed by ground water (e.g. fens and seepages), and underground water systems. Therefore, a groundwater system in this context is potentially significant in its role of maintaining such spring or ground-fed streams and wetlands. It is likely that sound technical advice will need to be obtained from an appropriately qualified and experienced aquatic ecologist and/or hydrologist. For areas below mean high water springs (MHWS), consult guidance on aquatic habitat within the Waikato Regional Council Coastal Plan (in preparation)².	Department of Conservation Waikato Regional Council University of Waikato		Species dependent on the system: _____ _____ _____
9 It is an area of indigenous vegetation or habitat that is a healthy, representative example of its type because:	Fencing and pest control would be required for most mainland sites in the Waikato Region (irrespective of habitat type).	Consultant Ecologist Department of Conservation Waikato Regional Council	Y / N / NS	Rank the following factors High (H), Medium (M) or Low (L): • Structural intactness _____ - Ratio of indigenous:exotic species _____
• its structure, composition, and ecological processes are largely intact; and, if protected from the adverse effects of plant and	Ecologists assessing this criterion should take into account the site's size, shape, buffering from external effects, and connection to other natural areas. Other factors to be considered include	Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA)		• Connectivity to other natural areas _____ • Size of the area in the context of the relevant ecological district _____ • Degree of protection from likely threats (e.g., fenced, buffered) _____ • Species diversity _____

² Mapping of significant indigenous biodiversity areas within the Coastal Marine Area (CMA) will be identified by the proposed Waikato Regional Coastal Plan. Notification of the revised Coastal Plan is anticipated in 2023, following which guidance and information within the plan should also be consulted when assessing areas in the CMA.

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
animal pests and of adjacent land and water use (e.g. stock, discharges, erosion, sediment disturbance), can maintain its ecological sustainability over time.	indigenous regeneration and recruitment (e.g. the presence of fruit, seedlings, nests, juveniles, fauna), structural tiers, hydrological processes in wetlands, invasive weeds, pest animals, domestic stock, threat management, management history. Where there is doubt, refer to the representativeness, and diversity and pattern guidelines given in Appendix 2.	Published reports or maps This criterion will require the input of an experienced and qualified ecologist. Good information will be required, and, in most instances, a field visit will be necessary.		List no. of responses to the above questions: H _____ M _____ L _____ Indicate overall ecological quality of the site: _____ Would you consider this to be among the best examples of its type nationally (Y/N), in the Waikato Region (Y/N), or in a particular ecological region/district (Y/N)? Provide justification: _____ _____ _____
10 It is an area of indigenous vegetation or habitat that forms part of an ecological sequence that is either not common in the Waikato Region or an ecological district, or is an exceptional, representative example of its type.	Ecological sequences that are not common in the Waikato Region include, but are not restricted to, indigenous dune vegetation through to coastal scrub or forest, lake margins or geothermal systems to indigenous forest, coastal to montane or alpine vegetation. Such sequences should be largely intact (e.g. perhaps bisected by roads but not by large tracts of non-indigenous land cover), such that they can be traversed by most indigenous species that are reliant on such sequences for the completion of part or all of their life-cycles (e.g. by movement of key fauna or dispersal of propagules such as seeds).	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA) Department of Conservation Waikato Regional Council Published reports or maps	Y / N / NS	Does the site include or is it part of one of the best or only examples of this type of ecological sequence nationally (Y/N), regionally (Y/N), or in the relevant ecological district (Y/N)? Location: _____ Key elements of sequence: _____ _____ _____ _____ _____ Justification: _____ _____ _____ _____ _____ _____

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
	It will probably be necessary to provide or obtain a map(s) of the sequence and the main vegetation types and habitats that it comprises. GIS analysis using a vegetation map and an appropriate evaluation framework, e.g. ecological district boundaries, may demonstrate whether a sequence is uncommon or one of the better examples. An exceptional, representative sequence will be one of the best examples of its type in the Waikato Region, taking into account its intactness, composition, and ecological processes. Where there is doubt, refer to the diversity and pattern guidelines given in Appendix 2.			
ROLE IN PROTECTION OF ECOLOGICALLY SIGNIFICANT AREA				
11	It is an area of indigenous vegetation or habitat for indigenous species (which habitat is either naturally occurring or has been established as a mitigation measure) that forms, either on its own or in combination with other similar areas, an ecological buffer, linkage or corridor, and which is necessary to protect any site identified as significant under Criteria 1-10 from external adverse effects. This criterion also includes riparian vegetation that protects a significant aquatic habitat e.g. a freshwater fishery, lake, river, or stream that is important for the sustainability of an indigenous species, or a coastal or marine system. This criterion can also include sites which act as 'stepping stone' habitat between otherwise geographically isolated, significant sites. Determination of how far stepping stone habitat can be from other significant sites will depend on which species is used as an example.	Consultant Ecologist Crown Research Institute, e.g. Landcare Research or National Institute of Water and Atmospheric Research (NIWA) Department of Conservation Waikato Regional Council Published reports or maps	Y / N / NS	Key ecological function(s) of the site (buffer, ecological linkage, other): Which site(s) does this area provide a buffer or linkage for? Which of criteria 1-10 does the buffered or linked site comply with? Justification:

A. Criteria ⁵	B. Definitions and Further Information ¹	C. Likely Information Sources	D. Response (Yes? No? Not sure?)	E. If Yes, provide the information requested below to justify your decision and to assist with determining level of significance.
	Therefore, care should be taken to consult a suitably qualified ecologist when determining whether a site meets this criterion. Where there is doubt, refer to the ecological context guidelines given in Appendix 2.			

Table A.4: Relative importance of an area of significant indigenous vegetation or significant habitat of indigenous fauna.

In Column A, circle the criteria numbers for which you scored a 'Yes' in Table 1. Then consider the factors to be assessed, and complete Column D, using your answers in Table 1, Column E to justify your response.

A. RPS Criteria met (see Table 1, Section 3 above)	B. Factors to be assessed ²	C. Notes	D. Response (Yes / No / Not Sure)
	<u>INTERNATIONALLY SIGNIFICANT</u> A site is Internationally Significant if you respond 'YES' to any of the questions in this section.	Internationally significant natural areas have usually been identified in previous assessments. These sites are so important that some of them are already protected by international conventions. For example, the Tongariro National Park is a World Heritage Area, and there are three wetlands in the Waikato listed as Wetlands of International Importance under the international Ramsar Convention (Whangamarino Swamp, Kopuatai Peat Dome, and the Firth of Thames estuary). Other natural areas may be internationally significant if they contain high quality vegetation or habitat that is unique in the world - for example, geothermal systems at Waiotapu and Orakeikorako.	

² Terms highlighted in **bold** type are defined in the glossary on Pages 39-40.

A. RPS Criteria met (see Table 1, Section 3 above)	B. Factors to be assessed ¹	C. Notes	D. Response (Yes / No / Not Sure)
		Internationally significant sites are likely to attract the interest of overseas and NZ scientists, and be a primary attraction for international and national tourists, e.g. Miranda bird sanctuary, Tongariro National Park.	
1	Has it been recognised under international legislation or convention, or recommended for protection by a suitably qualified body, as an internationally significant area (e.g. as a World Heritage Site or a Ramsar site)?	A suitably qualified body able to recommend a site for international recognition includes Department of Conservation, QEII National Trust, Ngā Whenua Rāhui, and Nature Heritage Fund ² .	Y / N / NS
2	Is it a coastal habitat or ecosystem type within the Coastal Marine Area , which has been depleted or degraded on an international scale <i>and</i> is it degraded to the extent where ecological sustainability is threatened internationally?	For example, shell barrier beaches at Miranda, seagrass beds, or some shellfish beds.	Y / N / NS
3	Is it currently habitat for an indigenous species (or genetically distinct population) which is threatened with extinction (in the categories Nationally Critical, Nationally Endangered, or Nationally Vulnerable) and is endemic to the Waikato Region ?	For a site to meet the criterion for international significance it must comprise significant habitat for a species (or genetically distinct population) on an international basis. It must also provide habitat for the species (or genetically distinct population), and/or the genetic entity must be indigenous to the site. Nationally threatened Waikato endemics include Northern striped gecko, Moehau stag beetle, <i>Corybas carsei</i> .	Y / N / NS
3	Is it a key habitat for the completion of the life cycle of a species (or genetically distinct population) that migrates internationally, the populations of which would be threatened if these habitats were not sustained?	An example of key habitat for international migrants is the Firth of Thames.	Y / N / NS
3	Is it significant habitat for a threatened international migrant at the limit of its natural range?		Y / N / NS
5	Is it one of the best international examples of an ecosystem type which is nationally uncommon?	For example, shell barrier beaches at Miranda.	Y / N / NS
If the site meets	Is the site the best or only remaining large representative example in New Zealand of a suite of relatively intact indigenous ecosystems and ecological	This would need to be justified by several well-qualified and experienced ecologists.	Y / N / NS

² DOC = Department of Conservation, WRC = Waikato Regional Council, NHF = Nature Heritage Fund, NWR = Ngā Whenua Rāhui, QEII = QEII National Trust.

A. RPS Criteria met (see Table 1, Section 3 above)	B. Factors to be assessed ¹	C. Notes	D. Response (Yes / No / Not Sure)
several of: 2 & 9, or 4 & 9, or 5 & 9, or 6 & 9, or 7 & 9, or 8 & 9, or 9 & 10	sequences e.g. a wetland /forest complex with altitudinal sequences?		
	<u>NATIONALLY SIGNIFICANT</u> The site is at least Nationally Significant if you can answer 'YES' to any of the questions in this section.	Nationally Significant natural areas include sites that contain healthy populations of threatened species (such as kōkako and kākā habitat at Pureora), or are very good examples of nationally rare habitat or vegetation (such as the large wetlands in the northern Waikato). They also include sites that are the only location where certain species occur, such as the Mahoenui giant wētā. Nationally significant sites tend to attract the interest of scientists, technical specialists, and/or tourists from other parts of New Zealand.	
1	Is it protected, or recommended for protection, under the Conservation Act 1987 (as an Ecological Area, or Forest Sanctuary), National Parks Act 1980, Marine Reserves Act 1971, or Reserves Act 1977 (as a Nature Reserve or Scientific Reserve)?	In the Waikato Region these include, but are not limited to, Tongariro National Park, Waihaha Ecological Area, Waipapa Ecological Area, Mangatutu Ecological Area, Rapurapu Ecological Area, Ecological Areas on the Coromandel Peninsula.	Y / N / NS
2	Is it a coastal habitat or ecosystem type within the Coastal Marine Area which has been depleted or degraded on a national scale <i>and</i> is it degraded to the extent where ecological sustainability is threatened nationally ² ?	Examples in the Waikato Region include rhodolith beds.	Y / N / NS

² Mapping of significant indigenous biodiversity areas within the Coastal Marine Area (CMA) will be identified by the proposed Waikato Regional Coastal Plan. Notification of the revised Coastal Plan is anticipated in 2023, following which guidance and information within the plan should also be consulted when assessing areas in the CMA.

A. RPS Criteria met (see Table 1, Section 3 above)	B. Factors to be assessed ¹	C. Notes	D. Response (Yes / No / Not Sure)
3	Is it habitat used on a regular basis by, or is key habitat for, an indigenous species (or genetically distinct population) in the threat categories 'Nationally Critical', 'Nationally Endangered', or 'Nationally Vulnerable'?	Sites where low numbers are present on only a few occasions (and are unlikely to be important for the long-term viability of the species) do not meet this criterion. For a site to meet this criterion for national significance, it will be of importance for the viability of the species (or genetically distinct population) on a national basis. The site will provide habitat for the species (or genetically distinct population), and it will either be used on an ongoing basis, or be important for sustaining a population on a seasonal basis for key components of its life cycle (e.g. feeding site), or be an important migratory site, breeding site, or over-wintering site.	Y / N / NS
3	Is it one of the best quality examples nationally of habitats used on an ongoing basis by a species (or a genetically distinct population) in the At Risk categories 'Declining', 'Recovering', 'Relict', or 'Naturally Uncommon'?	For example, Archey's frog habitat at Whareorino.	Y / N / NS
3	Is it a key habitat for the completion of the life cycle of a nationally Threatened or At Risk species (or genetically distinct population) that migrate nationally and that would be threatened if these habitats were not sustained?	For example, over-wintering habitat for black stilt at Kawhia Harbour, or over-wintering habitat for banded dotterel at Kawhia Harbour and Aotea Harbour.	Y / N / NS
2 & 9, or 4 & 9 or 5 & 9 or 6 & 9	Is it indigenous vegetation or habitat for indigenous species that is under-represented nationally (20% or less remains), or nationally uncommon (including wetland) that is a good quality example that is representative of its type?	Good quality examples would receive mostly high or medium ratings for Criterion 9 in Table 1, taking into account size, presence of plant and animal pests, stock damage, and other damaging effects. For the definition of vegetation types refer to Criterion 4 in Table 1 above: Column B, Definitions and Further Information.	List no. of responses to criterion 9 in Table 1: H _____ M _____ L _____ Y / N / NS
	<u>REGIONALLY SIGNIFICANT</u> The site is at least Regionally Significant if you can respond 'YES' to any of the questions in this section.	Regionally significant natural areas include the best examples in the Waikato Region of habitats that may be common elsewhere in New Zealand - for example, our best dune systems or largest mangrove-filled estuaries, or large examples of more common vegetation types. They may also include degraded examples of nationally rare features.	

A. RPS Criteria met (see Table 1, Section 3 above)	B. Factors to be assessed ¹	C. Notes	D. Response (Yes / No / Not Sure)
1	Is it protected, or has been recommended to be protected, under the Reserves Act 1977, as a Wildlife Management Reserve, Wildlife Refuge, Scenic Reserve, Ngā Whenua Rāhui Kawenata, or for any conservation purpose under the Conservation Act such as a Conservation Area or Conservation Park, specifically for the protection of biodiversity?		Y / N / NS Status: _____ Recommended Status: _____
1	Is it protected, or has it been recommended to be protected, as a QEII Open Space Covenant, Ngā Whenua Rāhui Kawenata, or Nature Heritage Fund reserve for biodiversity protection purposes other than those outlined for sites of international or national significance?		Y / N / NS
2	Is it a coastal habitat or ecosystem type within the Coastal Marine Area which has been depleted or degraded on a regional scale <i>and</i> is it degraded to the extent where ecological sustainability is threatened regionally?	For example, green-lipped mussel (<i>Perna canaliculus</i>) beds, subtidal seagrass beds, estuarine habitat.	Y / N / NS
3	Is it habitat of considerable importance for the conservation of an indigenous species (or genetically distinct population) in the 'At Risk' category ('Declining', 'Recovering', 'Relict', and 'Naturally Uncommon'), or is important habitat for a non-threatened species that is endemic to the Waikato Region , or at the limits of its natural range .	Assessment of whether a species is regionally uncommon in the Waikato Region would have to be justified by a well-qualified and experienced ecologist(s) very familiar with the species and ecology of the Waikato Region. Sites where low numbers are present on only a few occasions and sites that are unlikely to be important for long-term viability of the species, or genetically distinct population, do not meet this criterion.	Y / N / NS Species: _____ Threat Status: _____
3	Is it habitat of importance for the conservation of a regionally uncommon species (or genetically distinct population) within the Waikato Region, although the species is secure elsewhere?	For a site to meet this criterion for regional significance, the site will be of importance for the viability of a particular species (or genetically distinct population) on a regional basis. The site will provide habitat for the species (or genetically distinct population), and it will either be used on an ongoing basis , or be important for sustaining a population on a seasonal basis for key components of its life cycle (e.g. feeding site), or be an important migratory site, breeding site, or over-wintering site.	Y / N / NS Species: _____ Threat Status: _____
3	Is it habitat considered (by several qualified and experienced ecologists) to be of importance for the		Y / N / NS

A. RPS Criteria met (see Table 1, Section 3 above)	B. Factors to be assessed ¹	C. Notes	D. Response (Yes / No / Not Sure)
	sustainability of a 'data-deficient' species on a regional basis.	Small populations of threatened plants, which are not significant on a national basis, but in the Threatened categories Nationally Critical, Nationally Endangered, or Nationally Vulnerable, may be placed in this category.	Species: _____ Threat Status: _____
2 & 9 or, 4 & 9	Is it indigenous vegetation or habitat for indigenous species that is under-represented regionally (i.e. within relevant ecological regions and districts) and which is a good quality example that is representative of its type (taking into account size, plant and animal pests, stock damage, and other damaging effects)?	Good quality examples would receive high or medium ratings for Criterion 9 in Table 1. Assessment must be justified by a suitably qualified and experienced ecologist.	Y / N / NS List no. of responses to question 9 in Table 1: H _____ M _____ L _____
4, 5, or 6	Is it a relatively large example of indigenous vegetation or habitat for indigenous species that is under-represented nationally, or nationally uncommon (including wetlands), but which is degraded in quality (taking into account presence of plant and animal pests, stock damage, and other damaging effects)?	Assessment must be justified by a well-qualified and experienced ecologist. Use the results from Criterion 9 in Table 1 to determine the relative quality of the site.	Y / N / NS
4	Is it the Region's only remaining representative example (irrespective of its size) of a particular indigenous vegetation type or indigenous species habitat that is degraded in quality?	Representative examples are vegetation/habitat types that are typical or characteristic of the indigenous biodiversity of an ecological district and which include all the expected species/assemblages for a particular ecological district and/or landform. The reality for many landscapes, particularly throughout much of the Waikato, is that a ' representative example' will be the largest and most diverse remaining example of indigenous vegetation and habitats. Degraded sites would receive mostly Low scores for the factors listed in Criterion 9.	Y / N / NS List no. of responses to question 9 in Table 1: H _____ M _____ L _____

A. RPS Criteria met (see Table 1, Section 3 above)	B. Factors to be assessed ¹	C. Notes	D. Response (Yes / No / Not Sure)
9 or 8 & 9 or 10 & 9	Is it one of the best representative examples in the Waikato Region of indigenous vegetation, or habitat for indigenous fauna, or an ecological sequence ?	Assessment must be justified by a well-qualified and experienced ecologist.	Y / N / NS
7 & 9	Is it a large, good quality example of indigenous vegetation or habitat for indigenous species representative of the ecological character typical of the Waikato Region?	This may include examples of indigenous vegetation that are large or moderately large relative to other similar habitats in the Region or within the relevant ecological district. They should be relatively intact and retain the main elements of their original composition structure. Examples would include relatively large tracts of indigenous forest and habitats on the Hakarimata Range and Kaimai Range.	Y / N / NS
11	Is it a buffer (or a key part of a buffer) to a site that is of international or national significance?	The site buffered must have first been shown to be of national or international significance using relevant sections in Table 2 above.	Y / N / NS
All	<u>LOCALLY SIGNIFICANT</u> The site is at least of Local Significance if you answered "Yes" to at least one of criteria 2-11 in Table 1 but did not answer "Yes" to any of the questions above in Table 2.	Locally significant natural areas are healthy examples of relatively common vegetation and habitat types. They are often small areas, but large enough to enable key ecological processes to occur, such as regeneration of seedlings or reproduction and recruitment of indigenous fauna. These sites may not be particularly significant in their own right, but nevertheless play an important part in a network of natural areas. For example, a locally significant site might be important as a seasonal feeding or breeding area. It might also act as a 'stepping stone' between other natural areas, allowing indigenous fauna to move in search of food or mates. Such sites are likely to provide representative examples of common or typical vegetation types or habitat for common indigenous species. They will not be among the best examples in the Region but will meet Criterion 9 as healthy, functioning, and ecologically viable sites.	Y / N
HOW SIGNIFICANT IS THE SITE?		Circle the highest level for which you allocated at least one "Yes" response in Table 2. This indicates the relative importance of the site.	International, National, Regional, Local

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