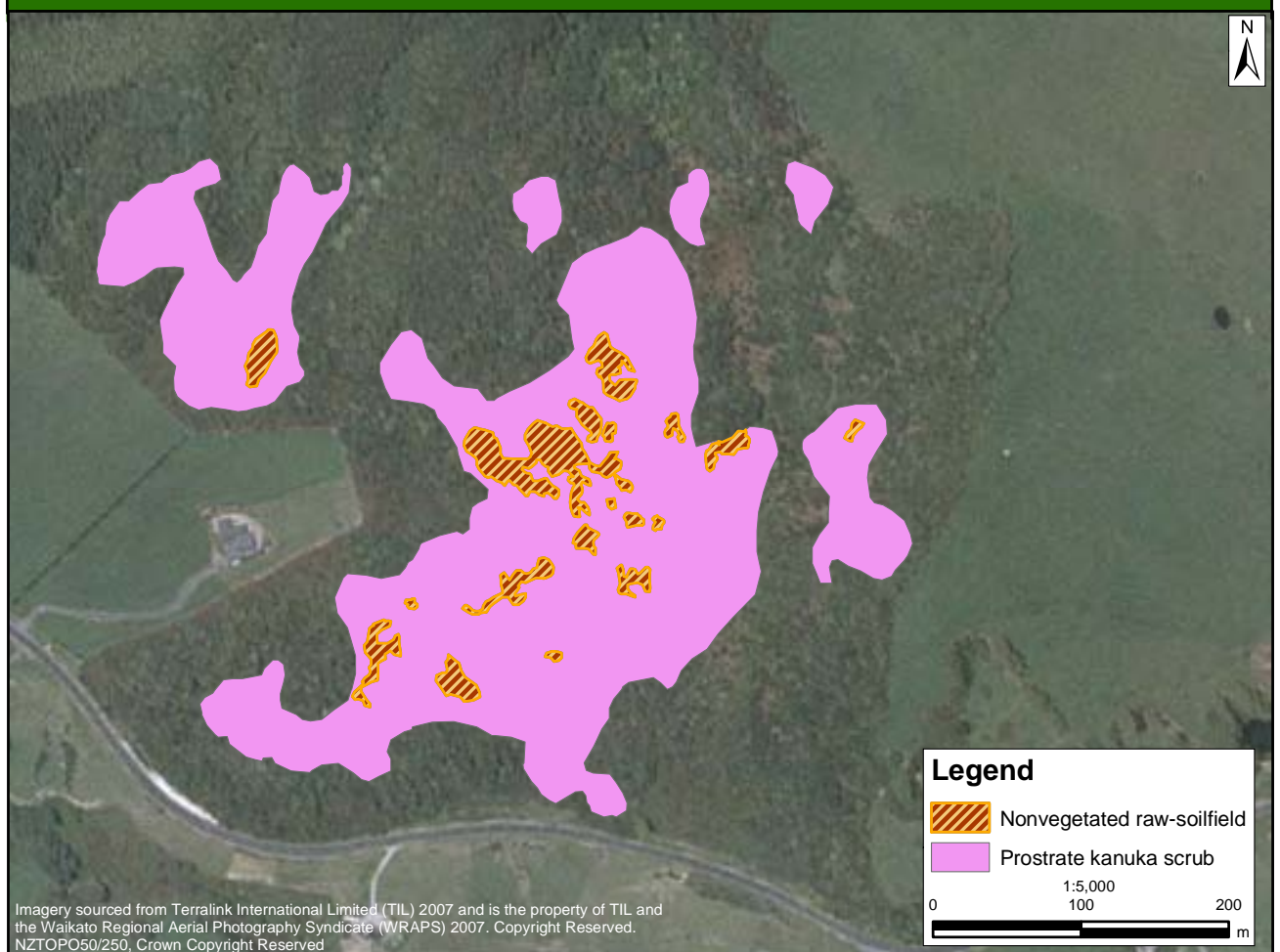
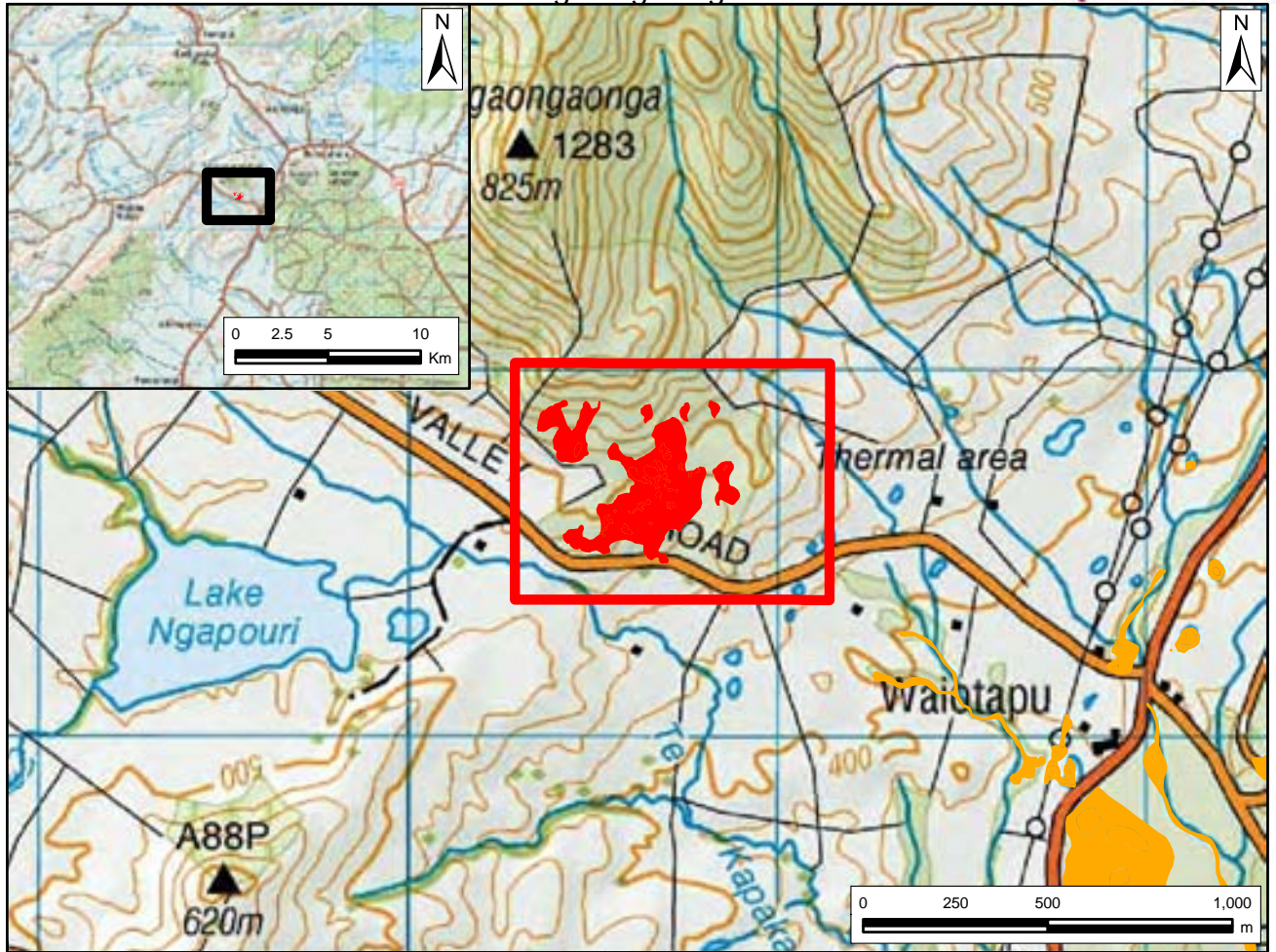


1.3 WAIOTAPU GEOTHERMAL FIELD

List of Geothermal Sites

WTV01	Maungaongaonga
WTV02	Ngapouri
WTV03	Waiotapu North
WTV04	Maungakakamea (Rainbow Mountain)
WTV05	Waiotapu South



MAUNGAONGAONGA

Site Number: WTV01¹
Grid Reference: NZTopo50 BF37 926 516
GPS reference: NZTM E1892615 N5751642
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Protected (Maungaongaonga Scenic Reserve)
Altitude: c.540 m
Extent of Geothermal Habitat: c 9.1 ha
Extent of Geothermal Vegetation: c 9.1 ha
Date of Field Survey: 27 May 2004

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.01	<p>Prostrate kanuka-dominant scrub Prostrate kanuka scrub A dense canopy of prostrate kanuka up to 1.5 m high dominates this area, in association with locally scattered manuka, mingimingi, and local patches of monoao (up to 50% cover in places). The groundcover is dominated by moss (<i>Dicranoloma billardierei</i> and <i>Sphagnum cristatum</i>) with local scattered turutu (<i>Dianella nigra</i>) and hound's tongue fern (<i>Microsorium pustulatum</i>). Manuka and monoao form a dense scrub up to 2 m high, in association with prickly mingimingi (<i>Leptecophylla juniperina</i> subsp. <i>juniperina</i>) and locally scattered whauwhaupaku. Kamahi and toru (<i>Toronia toru</i>) occur on several rocky outcrops. The groundcover associated with these outcrops comprises scattered turutu with local <i>Gleichenia microphylla</i> and a few examples of hound's tongue fern. Small patches of <i>Nephrolepis flexuosa</i> and <i>Dicranopteris linearis</i> are present beneath the prostrate kanuka canopy.</p>	Hillslope and rocky outcrops	c.8.4 ha
05.01 05.01.01 ²	<p>Prostrate kanuka-dominant shrubland Prostrate kanuka shrubland (not mapped) Prostrate kanuka forms a low discontinuous canopy (c.0.1-1.0 m 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 <i>Cladonia capitellata</i> (a lichen) (Beadel 1995a) are also present. <i>Lycopodiella cernua</i> is locally present in areas of relatively high geothermal activity. <i>Histiopteris incisa</i> is common near steam vents. This vegetation type occurs sporadically amongst the prostrate kanuka scrub.</p>	Hillslope	

¹ Previously identified as U16/11 in Wildland Consultants (2004).

² Areas of this vegetation type occur within the area mapped as 04.01.01, however were too small to be mapped separately.

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
28.01	Nonvegetated raw-soilfield	Hillslope	c.0.7 ha
28.01.01	Nonvegetated raw-soilfield Geothermal clays, mud pools, geothermally altered soils, and fumaroles.		

Indigenous Flora: Prostrate kanuka (classified as „At Risk-Declining’ in de Lange *et al.* 2009), a species endemic to geothermal areas, is present. A population of *Korthalsella salicornioides*, a semi-parasitic mistletoe (classified as „At Risk-Naturally Uncommon’ in de Lange *et al.* 2009), is also present.

A few patches of *Nephrolepis flexuosa*, (classified as „At Risk-Naturally Uncommon’ in de Lange *et al.* 2009), a species which in New Zealand is confined to geothermal areas in the North Island, and at least 50 plants of *Dicranopteris linearis* (classified as „At Risk-Declining’ in de Lange *et al.* 2009, and known from only c.24 sites in New Zealand), are present at this site (numbers based on 2004 field assessment).

Other species of interest present are *Lycopodiella cernua* (which is a characteristic feature of geothermal areas) and *Schizaea bifida* (Beadel 1995a). *S. bifida* was not recorded in the 2004 survey.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including tui, silvereye, and fantail.

Current Condition (2004 Assessment): The geothermal vegetation is largely unmodified. It is relatively untracked and adventive species are uncommon.

**Threats/Modification/
Vulnerability:**

Invasive pest plants (2004 Assessment): Weeds are uncommon in this site. The main weed species present are blackberry (1-5%), radiata pine (<1%), Douglas fir (*Pseudotsuga menziesii*) (<1%), Spanish heath (<1%), gorse (*Ulex europaeus*) (<1%) and narrow-leaved carpet grass (*Axonopus fissifolius*) (<1%). The distribution of environmental weeds in Maungaongaonga Scenic Reserve was mapped and described in Wildland Consultants (1998).

Human impacts (2004 Assessment): This site is vulnerable to damage from human trampling, as can be seen from the vegetation destruction associated with an informal track (Beadel 1995a) however this track now appears to be little used.

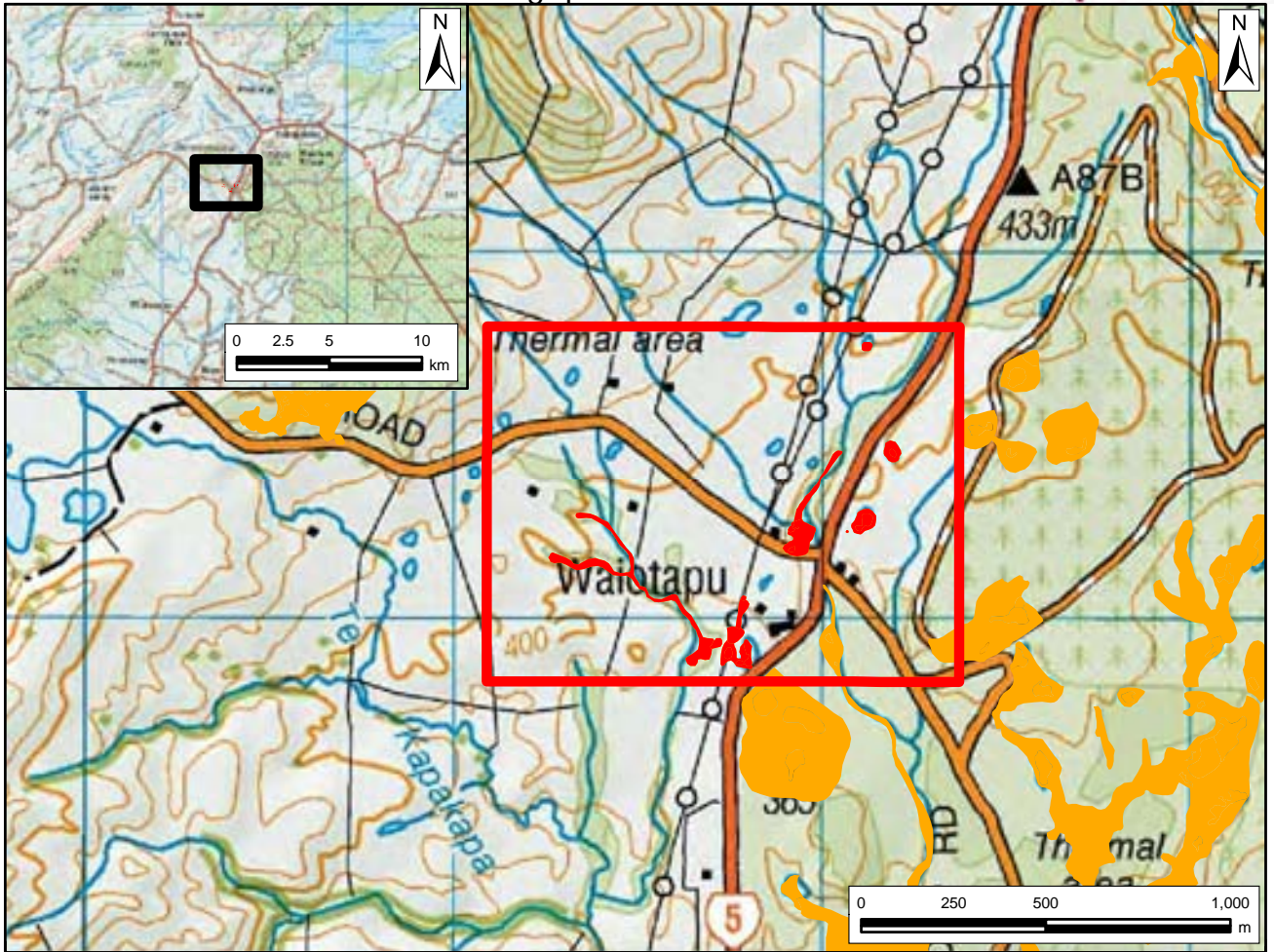
Grazing (2004 Assessment): Livestock are not a threat to this area.

Adjoining land use (2004 Assessment): Farmland; indigenous forest and scrub.





Site Change:

Recent change: No new field assessment undertaken since 2004. Any change to area mapped is based on better quality aerial photographs rather than any real site change. The authors do not consider any change to geothermal vegetation at this site to be significant.

<i>Historical:</i>	It is difficult to determine the difference between geothermal and non-geothermal scrub on the historic black and white photos (Historical photo: SN 172 Run 1158 Photos 2-4, 1941). However, surrounding the geothermal vegetation, the vegetation has developed from scrub in 1941 to secondary forest. There is considerably more bare ground visible historically, and the cooler geothermal soils have probably been invaded by blackberry in recent years. Overall, based on the above assessment, we consider that no real change can be proven in the extent of geothermal vegetation 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, is needed.
Significance Level:	National (Table 1 - Criteria 1, 3, 5, 9, 10; Table 2 - Factor 6, 8).
Significance Justification:	This site is of national significance because it comprises a very high quality example of geothermal vegetation, a nationally uncommon vegetation type. The site is part of an ecological sequence that extends from geothermal vegetation (including prostrate kanuka shrubland and <i>Lycopodiella cernua</i> herbfield) to tall forest (including tall podocarp-hardwood forest and early successional types; Nicholls 1974a; Clarkson 1981b; Beadel 1995a) (from c.460 m to c.580 m). The vegetation is of good quality and is relatively unmodified. Four 'At Risk' plant species (prostrate kanuka, <i>Korthalsella salicornioides</i> , <i>Nephrolepis flexuosa</i> and <i>Dicranopteris linearis</i>), are present, as well as several species which, within the central North Island, are limited to geothermal areas. It is protected as a Scenic Reserve.
Notes:	This site has been previously surveyed and mapped in 1995 (Beadel 1995a). 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 & Bill 2000; Clarkson 1981b; Nicholls 1974; Wildland Consultants 1998 & 2004.



Legend

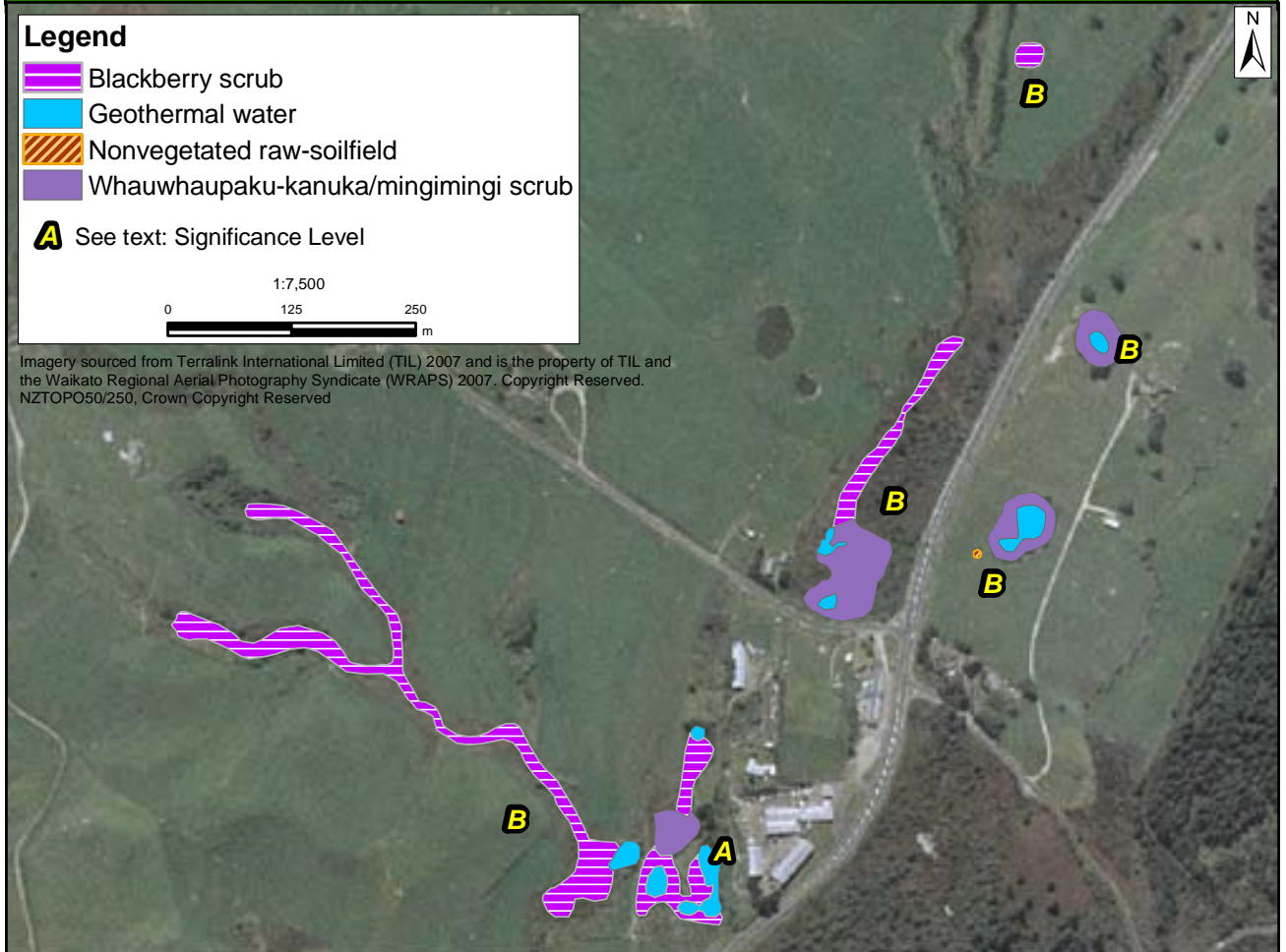
-  Blackberry scrub
-  Geothermal water
-  Nonvegetated raw-soilfield
-  Whauwhaupaku-kanuka/mingimingi scrub

A See text: Significance Level

1:7,500

0 125 250 m

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NGAPOURI

Site Number: WTV02¹
Grid Reference: NZTopo50 BF37 934 511
GPS Reference: NZTM E1893493 N5751107
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Protected (Ngapouri Covenant) and unprotected private land
Altitude: c.400 m
Extent of Geothermal Habitat: c.3.6 ha
Extent of Geothermal Vegetation: c.3.1 ha
Date of Field Survey: 12 August 2004

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.05 04.05.03	Indigenous scrub-dominant communities Whauwhaupaku-kanuka/mingimingi scrub Whauwhaupaku comprises the canopy (c.6 m high) with locally scattered wheki (<i>Dicksonia squarrosa</i>), kohuhu and kamahi, the latter confined to the area north of Waikite Valley Road. The groundcover is dominated by bracken with local patches of <i>Paesia scaberula</i> . The example of this vegetation type south of Waikite Valley Road is surrounded by blackberry.	Small gullies, flat, and undulating marginal strip	c.1.0 ha
04.08 04.08.01	Blackberry-dominant scrub Blackberry scrub This area comprises a dense cover of blackberry with whauwhaupaku, kanuka and manuka (up to 4 m high) scattered throughout, and local patches of kanuka and broom along the margin of SH 5. The groundcover comprises local patches of bracken and <i>Paesia scaberula</i> along hot pool margins. To the south of Waikite Valley Road the understorey includes locally common <i>Carex secta</i> , <i>Hypolepis ambigua</i> and <i>Juncus effusus</i> . Throughout the area extending parallel to Waikite Valley Road steaming vents are scattered on streamside banks.	Small gullies, flat and undulating marginal strip	c.2.0 ha
22.01 22.01.01	Geothermal water Geothermal water Heated pools.	Flat	c.0.5 ha
28.01 28.01.01	Nonvegetated raw-soilfield Nonvegetated raw-soilfield Heated soils, sinter and mud pools.	Crater	<0.1 ha

Indigenous Flora: *Lycopodiella cernua*, a characteristic feature of geothermal areas, is present.

¹ Previously identified as U16/7 in Wildland Consultants (2004).

Fauna: Common indigenous and introduced bird species typical of the habitat are present including grey warbler, tui, fantail, pukeko and spur-winged plover.

Current Condition (2004 Assessment): The vegetation is highly modified. Adventive plants are common and many parts south of Waikite Valley Road are grazed.

**Threats/Modification/
Vulnerability:**

Invasive pest plants (2004 Assessment): Large parts of this site are dominated by invasive exotic plants including blackberry (51-75% cover), broom (1-5% cover), crack willow (*Salix fragilis*) (1-5% cover), Tasmanian blackwood (*Acacia melanoxylon*), wilding pines, and apple (*Malus × domestica*) (all with <1% cover).

Human impacts (2004 Assessment): Herbicide drift, and run-off from State Highway 5 to the immediate east and farmland to the west, affect this site. Building refuse has been dumped in a fumarole and it appears that some surface water is drawn off for use in the nearby Arataki Honey factory.

Grazing (2004 Assessment): The areas to the north of Waikite Valley Rd are well fenced from stock, but sheep have access to the southern areas.

Adjoining land use (2004 Assessment): Farmland; Arataki Honey factory.

Site Change:

Recent change: Not assessed. Little change has been noted in this area, which is well known to the authors.

Historical: On aerial photographs taken in 1941 (Historical photos: SN172 Run 1158, Photo 4, 5 - 1941), it appears geothermal vegetation and habitat may have been more extensive, particularly behind (west of) the Waiotapu Hotel, prior to more intensive farm development. Several pools evident on the 1941 aerial photographs are no longer present. This may be a result of wetland drainage in the vicinity. It also appears that there are bare areas in what is now farmland on the north side of Waikite Valley Road, particularly upslope toward Maungaongaonga. These also may have been geothermal habitat which has been destroyed in land development. Most areas of geothermal vegetation is unlikely to be visible in aerial photographs as it is either in gullies or covered in vegetation unlikely to be discernible from other adjacent vegetation on aerial photographs.

Management Requirements: The southern areas require fence maintenance, removal of existing rubbish from fumaroles, and the prevention of further rubbish dumping.

Significance Level: A: Regional (Table 1- Criteria 1, 5; Table 2 - Factor 10).
B: Local (Table 1 - Criterion 5; Table 2 - Factor 19).

Significance Justification: A: The parts of the site identified as A on the map are of regional significance because they are protected as a conservation covenant under the Reserves Act 1977.

B: The parts of the site identified as B on the map are locally significant

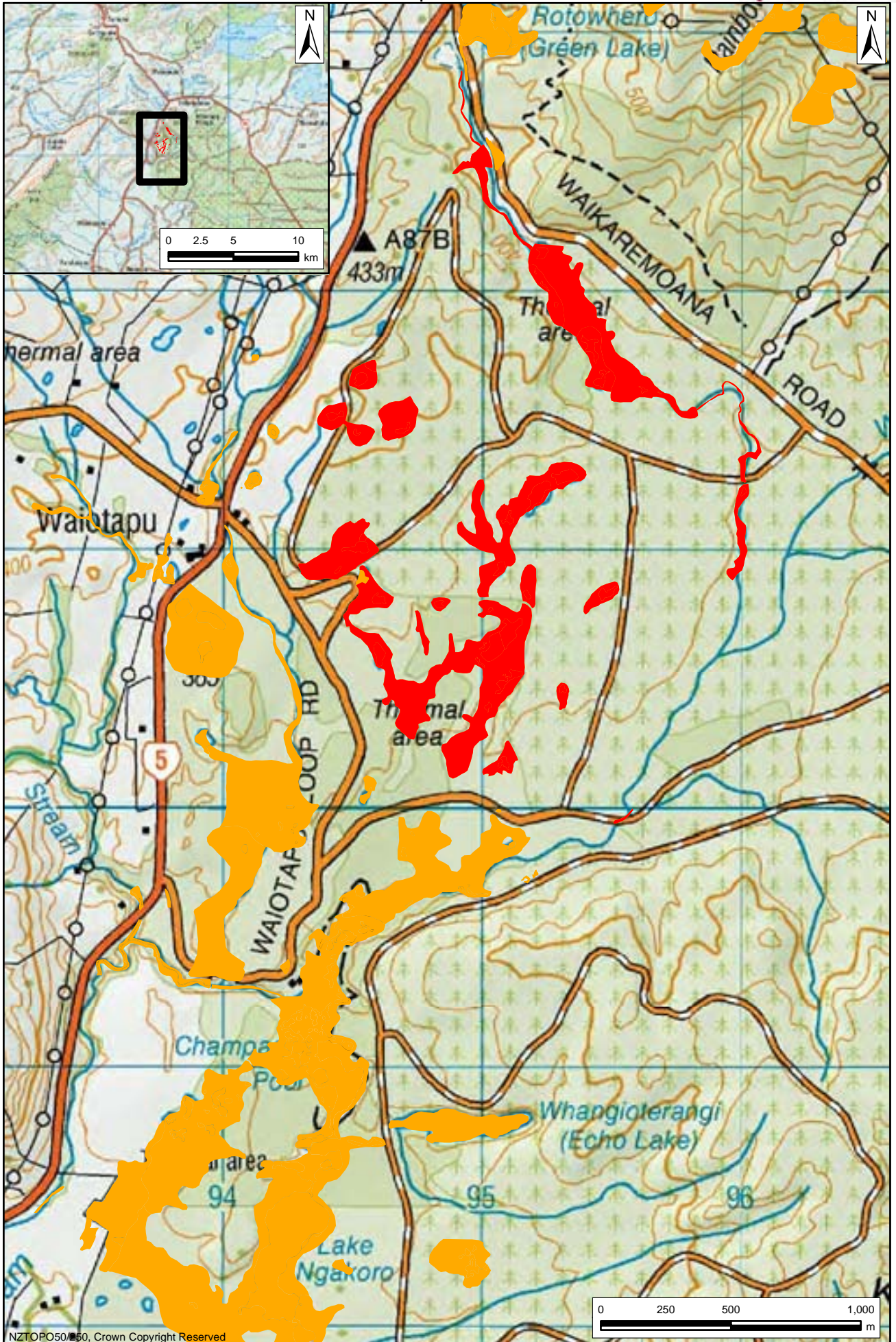
because they are small examples of geothermal habitat (some of which is degraded), which is a nationally uncommon habitat.

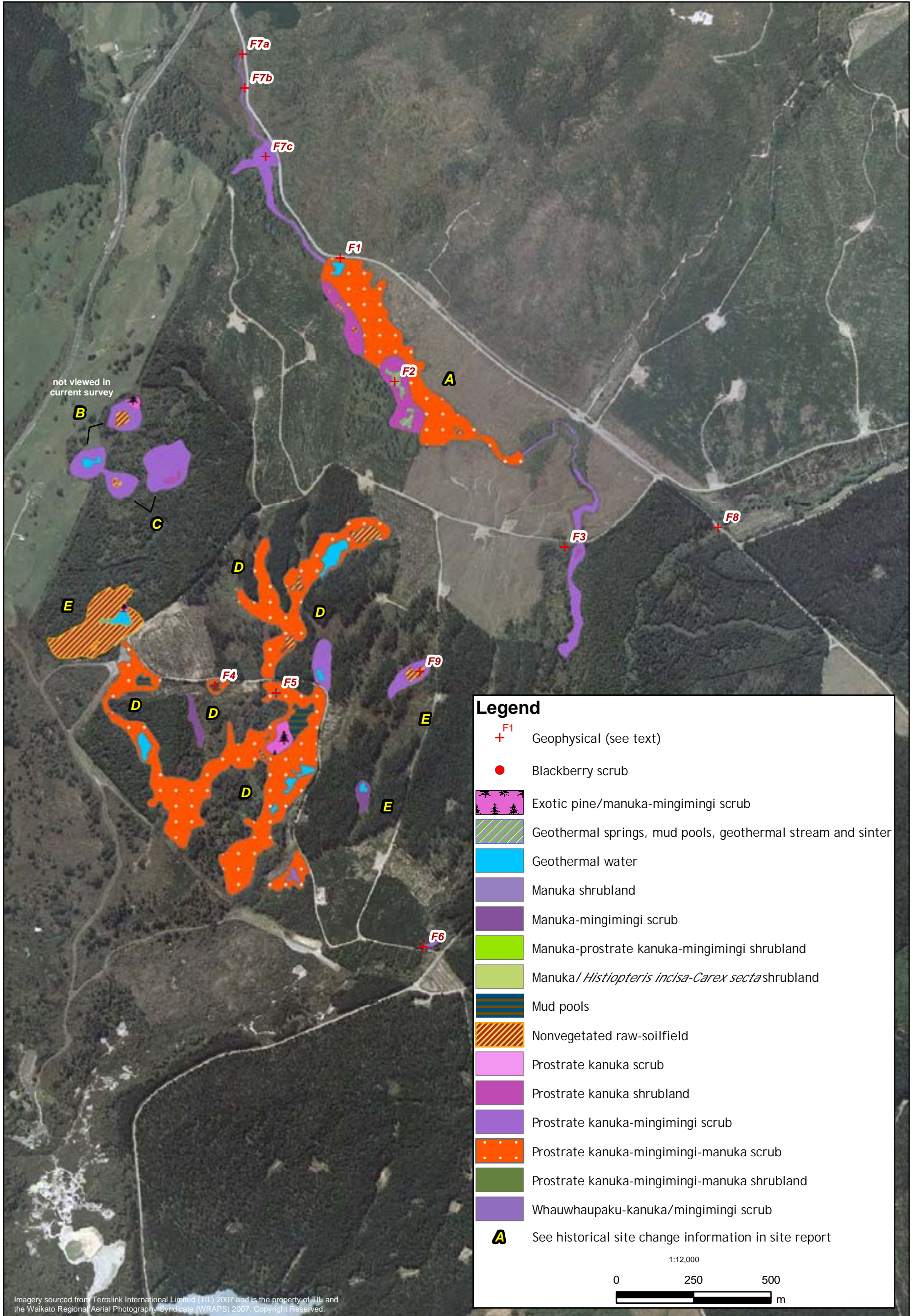
Notes:

Parts of the geothermal vegetation and habitats that are not protected are subject to grazing and extensive areas are dominated by pest plants. These unprotected areas are 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 regularly monitored for management issues and formal protection and a restoration plan for these areas would enhance and/or protect the highly significant ecological values of this field.

References:

Beadel 1995b; Beadel & Bill 2000; Wildland Consultants 2004.





WAIOTAPU NORTH¹

Site Number: WTV03²
Grid Reference: NZTopo50 BF37 949 502
GPS reference: NZTM E1894927 N5750233
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Unprotected private land and protected (Waiotapu Scenic Reserve)
Altitude: c.380-420 m
Extent of Geothermal Habitat: c.51.9 ha
Extent of Geothermal Vegetation: c.48.9 ha
Date of Field Survey: 26-29 July 2011

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.02	Prostrate kanuka-dominant scrub Prostrate kanuka-mingimingi scrub Prostrate kanuka and mingimingi (c. 1-3 m high) form a dense cover, with manuka and kanuka common throughout, and occasional kamahi and wilding pines. In wet areas and along stream margins, manuka becomes more common. The groundcover comprises scattered bracken and <i>Histiopteris incisa</i> . Wilding pines, Japanese cedar (<i>Cryptomeria japonica</i>), broom, and blackberry become common at the margins of this area. At many sites pine control has been undertaken since 2004.	Sides of crater, flat and lake margins	c.8.8 ha
04.01 04.01.03	Prostrate kanuka-dominant scrub Prostrate kanuka-mingimingi-manuka scrub Prostrate kanuka 0.3-3 m tall with common areas of mingimingi. Manuka dominates in wet areas. Similar to Type 04.01.02 in composition. These are generally large areas and only representative parts of the site were surveyed.		c.31.0 ha
04.03 04.03.02	Manuka-dominant scrub Manuka-mingimingi scrub Manuka and mingimingi (2-4 m high) dominate the canopy with emergent wilding pines scattered throughout. The groundcover is sparse, with scattered <i>Gleichenia microphylla</i> , turutu and <i>Hypolepis distans</i> . Several plants of <i>Dicranopteris linearis</i> are present in this vegetation type.	River terraces, flat, and gently undulating	c.0.7 ha
04.03 04.03.13	Manuka-dominant scrub Exotic pine/manuka-mingimingi scrub Similar to Vegetation Type 04.03.02 described	River terraces, flat, and gently undulating	c.0.8 ha

¹ This site was called Waiotapu 2 in Beadel & Bill (2000).

² Previously identified as U16/1 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	above, but with a greater occurrence of wilding pines (radiata pine and black pine (<i>Pinus nigra</i>)) which are both scattered throughout and locally form small groves. Black wattle, prickly mingimingi, wheki, wheki-ponga (<i>Dicksonia fibrosa</i>) and broom are also scattered throughout. Several heated pools, seepages, boiling mud and heated ground patches occur in this type.		
04.08 04.08.01	Blackberry-dominant scrub (not mapped) Blackberry scrub About 30 m north of the bridge to the northeast of the site (see F8 on map) near E1896462 N5751308. Steam was seen rising from blackberry. It was too difficult to find the exact location to enable it to be described in more detail.		
05.01 05.01.01	Prostrate kanuka-dominant shrubland Prostrate kanuka shrubland Dense prostrate kanuka (c.0.3-4 m high) dominates, with mingimingi scattered throughout; also locally scattered prickly mingimingi, monoao and wilding pines (e.g. lodgepole pine (<i>Pinus contorta</i>)) with occasional patches of <i>Lycopodiella cernua</i> .	Hillslope, gently rolling	c.2.7 ha
22.01 22.01.01	Geothermal water Geothermal water Geothermally-influenced lakes and pools, mud pools.	Flat and craters	c. 1.8 ha
22.01 22.01.02	Geothermal water Mud pools Mud pools surrounded by raw-soilfield, occasional hot springs.	Flat, craters	c.0.8 ha
22.01 22.01.04	Geothermal water Geothermal springs, mud pools, geothermal stream and sinter		c.0.4 ha
28.01 28.01.01	Nonvegetated raw-soilfield Nonvegetated raw-soilfield This includes heated ground, sinter pavements, hot water springs and seepages, boiling mud and steaming ground.	River terraces, flat, and gently undulating	c.4.9 ha

Geophysical Assessment¹

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 north-western edge of the lake. The temperature was measured (using the IR thermometer)

¹ Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.

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 1-2L/sec. 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.



Plate 18: Large clear blue hot (boiling) pool. Note: Discharge was to the

south, towards stream in the background. Sinter terrace also visible on lhs of photo, Feature 2, Waiotapu North.



Plate 19: Small shallow pools discharging to the west. Note: minor sulphur deposition and sinter terrace, Feature 2, Waiotapu North.

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 north-eastern 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). The majority 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 less than 1L/sec. 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: View from southeast of sinter terrace and shallow pool area. Note stream flow from right to left in background and main discharge channel on lhs of photo, Feature 3, Waiotapu North.



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.

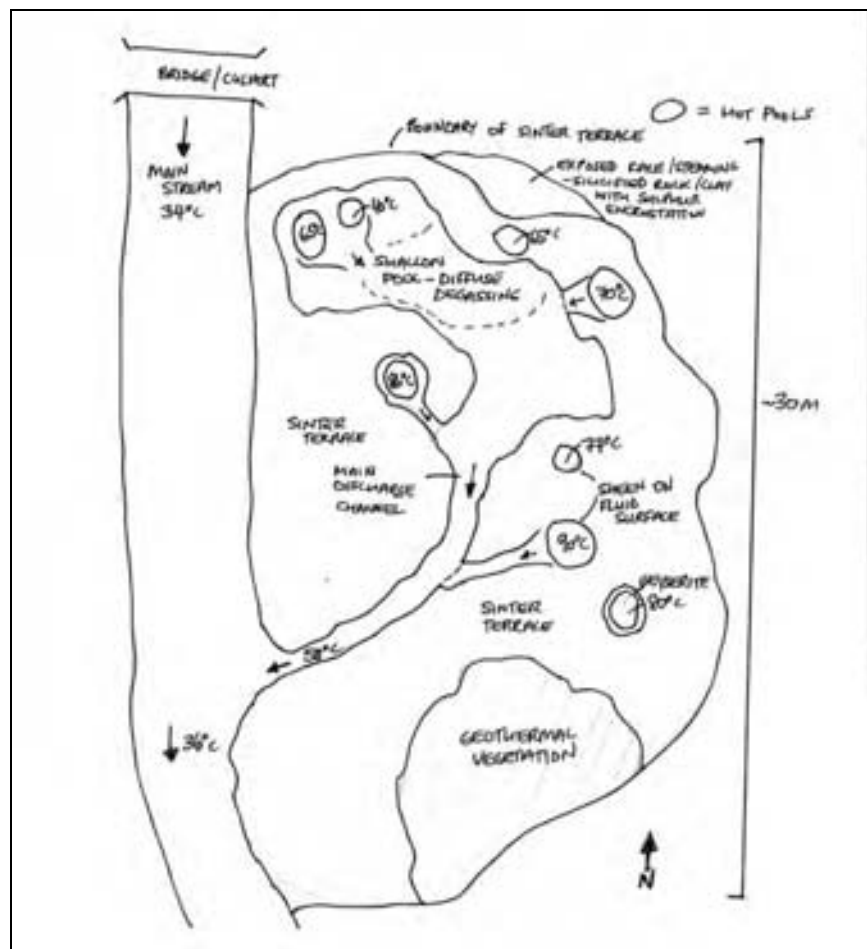


Figure A1-7: Field sketch of Hot pools and sinter terrace, Feature 3, Waiotapu North.

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 these was noted to erupt 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
Grid Reference: E1895025 N5750791

The lake measures approximately 30 m² and has a minor steam discharge at its surface. It is cloudy and its pale green colour suggests a sulphuric input. Access was not sufficient to take a temperature measurement.

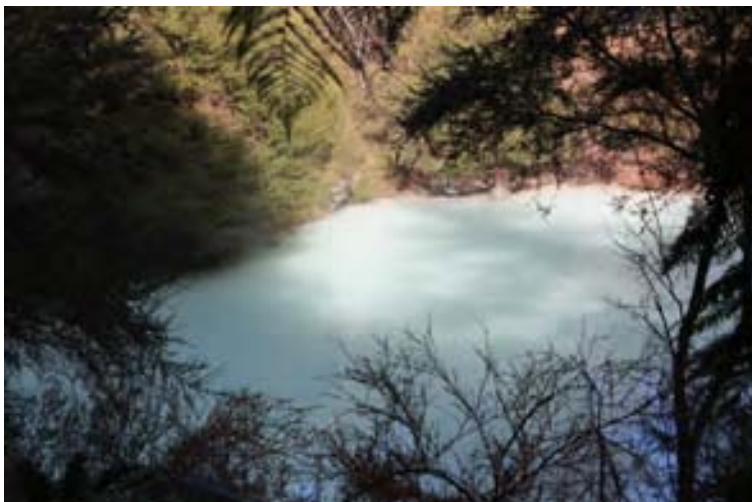


Plate 25: Pale green lake with minor steam discharge, Feature 5, Waiotapu North.

Feature 6: Hot Springs, Steaming Ground
Grid Reference: E1895507 N5749948

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 <0.1L/sec 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 this was deposition of silica 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 200L/sec.



Plate 26: Steaming ground and hot springs on western bank of stream, Feature 6, Waiotapu North.

Grid Reference: E1895977 N5753920
Feature 7: Freshwater Stream with geothermal inputs

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 200L/sec. 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.*1L/sec). The temperatures ranged from 33°C to 79°C and had pH values of approximately 6.
- (b) Grid Reference: E1894928 N5752731. Small clear pool on the eastern bank with a temperature of 95°C discharging approximately 0.5L/sec through a 2m 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. Small spring outflow at an outcrop of silicified clay discharging 95°C fluid into stream. Flow is approximately 0.2L/sec.



Plate 27: Area of hot pools discharging into stream (a), Feature 7, Waiotapu North.



Plate 28: Small clear, near boiling pool, 0.2L/sec 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 would appear to be 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.

Indigenous Flora: Prostrate kanuka and *Dicranopteris linearis* (both classed as „At Risk-Naturally Uncommon’ in de Lange *et al.* 2009) are present. A small population of *Lycopodiella cernua*, a species which is characteristic of geothermal areas, is present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present, including tui, grey warbler, fantail, tomtit, silvereye, Australasian harrier, bellbird, and welcome swallow. Pied stilt (classed as „At Risk-Declining’ in Miskelly *et al.* 2008) were observed nesting on the site in Beadel & Bill 2000. Possum and pig sign was evident in 2004.

Current Condition (2011 Assessment): Small to moderate sized areas of geothermal vegetation, many with impressive geothermal features, separated by plantation forests, exotic scrub and farmland. Whilst there is a relatively low diversity of some of the threatened species that can occur at geothermal sites, the site is of high ecological interest as a result of a wide diversity of geothermal habitats present. The site links the geothermal habitat of Waiotapu South with the Maungakakamea (Rainbow Mountain) and Ngapouri sites.

**Threats/Modification/
Vulnerability:**

Invasive pest plants (2004 Assessment): The margins of the geothermal vegetation is dominated by invasive exotic plants; wilding pines are still common, with a cover of 5-25%, despite the considerable control of wilding pines that has been undertaken since 2004. Also present is broom (6-24% cover), blackberry (1-5% cover), Spanish heath (1-5% cover), grey willow (1-5% cover), apple, climbing rose (*Rosa* sp.), and *Cotoneaster glaucophyllus* (all with <1% cover). Blackberry and grey willow are often common on geothermal stream margins.

Human impacts (2004 Assessment): This site has well maintained roads, and Kerosene Creek is a popular bathing area for tourists and locals, however the main areas with geothermal vegetation are seldom visited as most can not be seen from the main roads.

Grazing (2004 Assessment): Livestock have no access to this site and are only a potential threat to the Landcorp Protective Covenant; however the fencing in this area is currently stock proof.

Adjoining land use (2004 Assessment): Plantation forests, farmland, Waiotapu Scenic Reserve.

Site Change:

Recent change: Several new units of vegetation were identified which were not found in the 2004 survey. These were mostly found based on areas being more visible in recently cleared pine plantation, as well as being more visible on better quality 2007 aerial photographs. Some minor loss of geothermal vegetation has occurred in places following harvesting of pine trees; however in most instances it appears that the land manager has taken reasonable care to avoid damage to geothermal sites. Replanting of plantation trees has generally taken place outside of geothermal areas.

Historical: 1941 aerial photographs (Historical photos: SN 172 Run 1158 Photos 6-7, 1941) were compared with 2007 aerial photographs. At this site the

boundaries between geothermal vegetation and non-geothermal vegetation, particularly scrub and shrubland, is difficult to determine on aerial photographs. On aerial photographs it is only possible to determine changes to the larger geothermal sites. In the area identified as A on the aerial photograph, the southern part of the site is now in plantation. The site in 2007 is only about two-thirds of the size of the site in 1941. Some of the bare ground has been invaded by shrubs and pine trees. These are probably in areas of lower geothermally-active soils.

It is difficult to determine change in the area marked C. Wilding pines have established in parts of the site, but otherwise these areas are similar in 1941 to the geothermal vegetation visible in the 2007 photos.

The two areas identified as D on the accompanying map were in a poor condition in 1941. It appears that stock had access to the western parts of these sites and vegetation had been cleared through part of the sites, possibly for power lines. However, the area of scrub around geothermal features extends further around the site. There is also the possibility of more raw geothermal soilfield to the west of these units. This area is about 5-20% larger than current size.

Pines and shrubs have invaded further into raw-soilfield habitats in areas marked as D. There has been a 10-25% reduction in raw-soilfields, mud pools, geothermal water habitat in this area, and a 25-50% reduction of shrubland habitats because of plantation forestry, and wilding pines. Few wilding pines were present in the southern part of this vegetation type 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%. Some vegetation would have already been cleared prior to 1941.

Management Requirements:

Wilding pines in core geothermal areas, particularly those in the prostrate kanuka scrub, need to be removed. An infestation of African feather grass (*Cenchrus macrourus*) occurs near the mud pools to the southwest of this site, adjacent to geothermal areas mapped as part of this study. This infestation was reported to the landowner and the Waikato Regional Council, and it has since been controlled by the Council.

Care needs to be taken during plantation management and harvesting in adjacent plantation forests. The forest managers have taken steps to address these issues (see Beadel & Bishop 1997; Wildland Consultants 2004).

Significance Level:

Regional (Table 1 - Criteria 1, 3, 5; Table 2 - Factors 12, 14).

Significance Justification:

Waiotapu North is of regional significance because, in association with „Waiotapu South’, is an important habitat of prostrate kanuka, which is an „At Risk’ species. In addition, the site comprises a relatively large example of a nationally uncommon habitat type. *Dicranopteris linearis* („At Risk-Naturally Uncommon’) is also present. If protected from the adverse effects of plant and animal pests and of adjacent land use (e.g. discharges, erosion) the site will maintain its ecological sustainability over time.

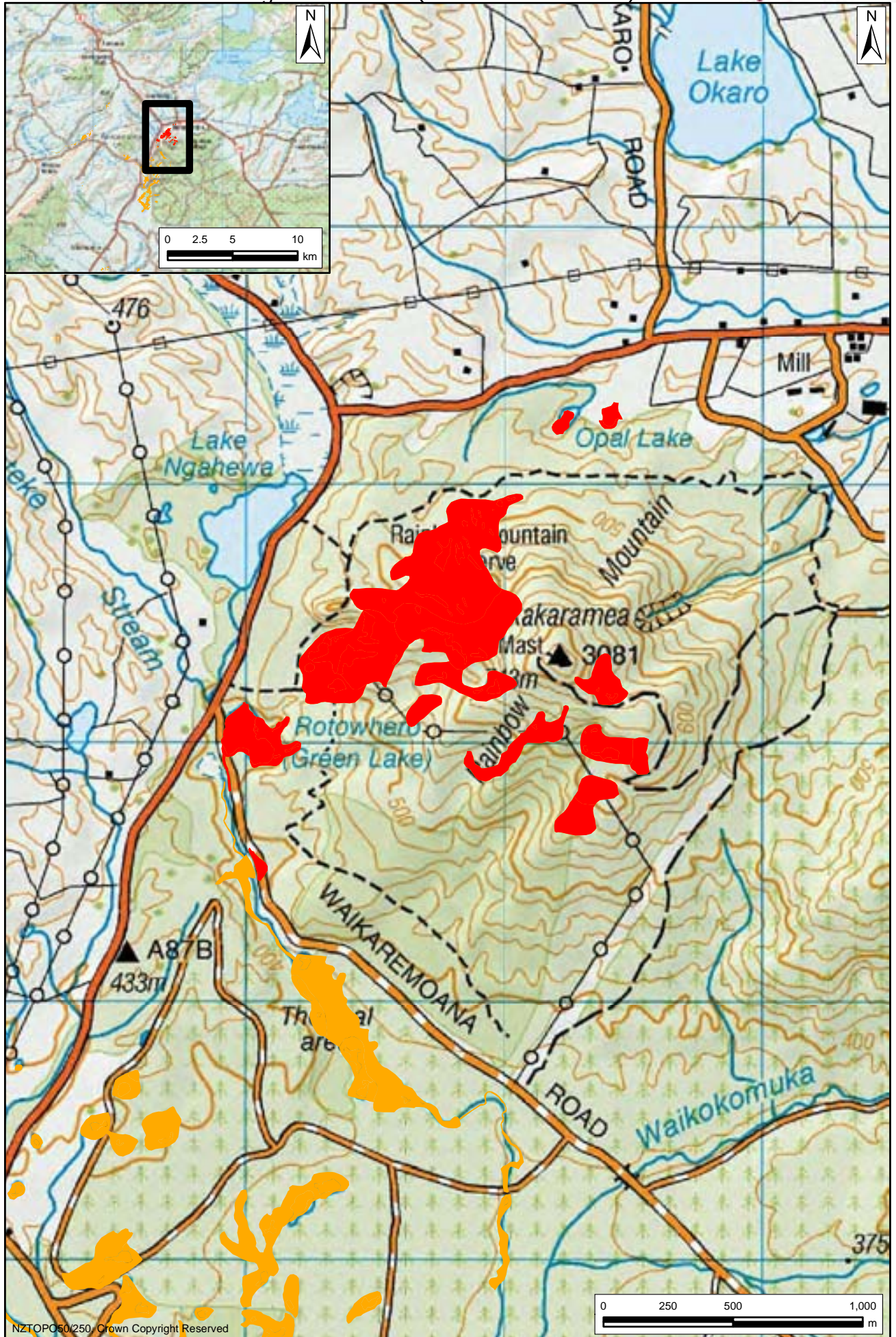
Notes:

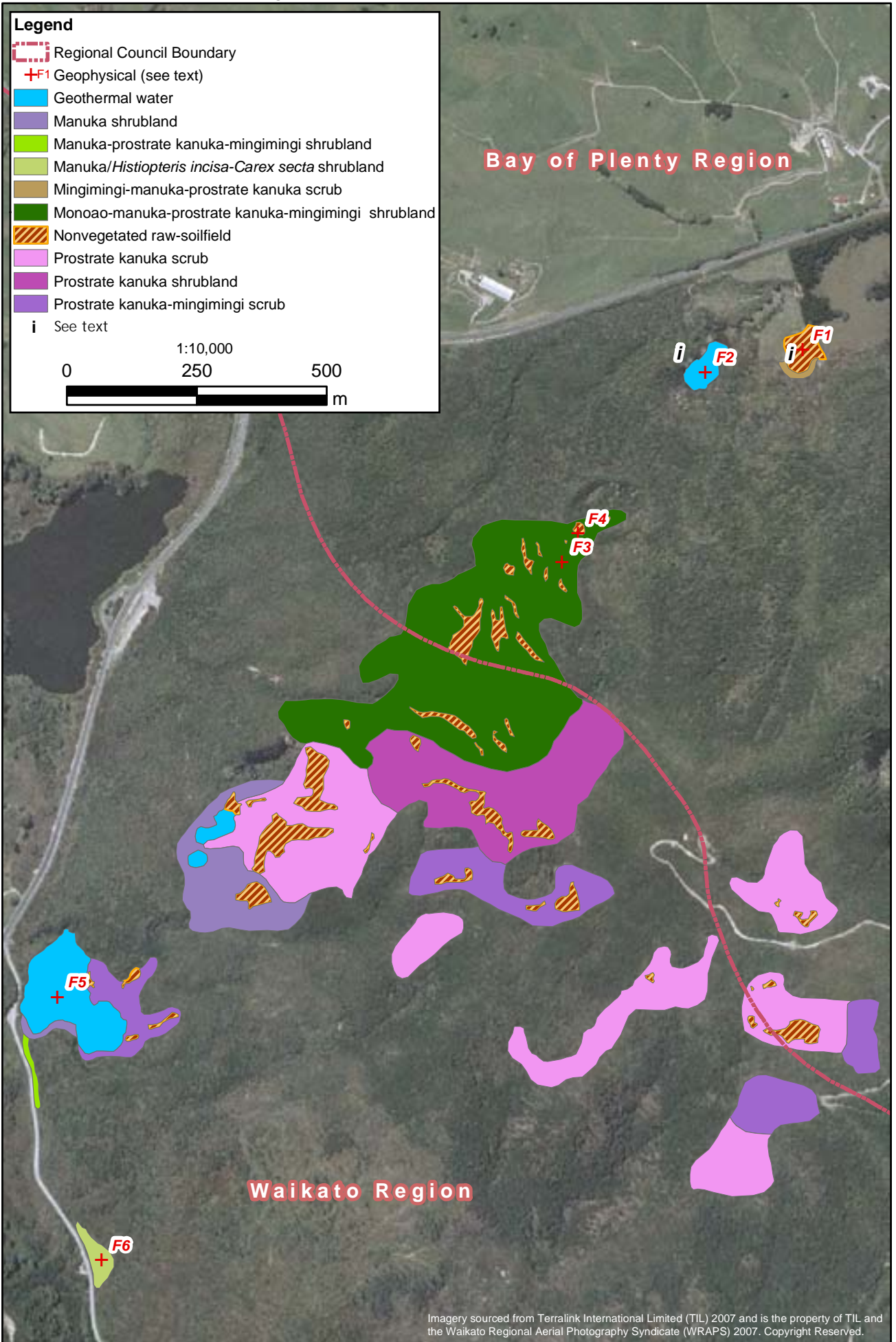
Ecological surveys and assessments were made of the parts of this site managed by Kaingaroa Timberlands in April 2004 (see Wildland Consultants 2004b). It was determined that these areas were a “high conservation value forest” as defined by the Forest Stewardship Council criteria for assessment of high conservation value forests.

Parts of the geothermal vegetation and habitats that are not protected are subject to grazing and extensive areas are dominated by pest plants. These unprotected areas are 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 regularly monitored for management issues and formal protection and a restoration plan for these areas would enhance and/or protect the highly significant ecological values of this field.

References:

Beadel & Bishop 1997; Beadel & Bill 2000; Given 1995; Wildland Consultants 2004.





MAUNGAKAKARAMEA (RAINBOW MOUNTAIN)

Site Number: WTV04¹
Grid Reference: NZTopo50 BF37 956 534
GPS Reference: NZTM E1895633 N5753443
Local Authority: Rotorua
Ecological District: Atiamuri; Rotorua Lakes
Geothermal Field: Waiotapu
Bioclimatic Zone: Lowland - submontane
Tenure: Protected (Rainbow Mountain Scenic Reserve) and unprotected private land
Altitude: c.400-740 m
Extent of Geothermal Habitat: c.53.97 ha
Extent of Geothermal Vegetation: c.50.57 ha
Date of Field Survey: 26 July 2010

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.01	Prostrate kanuka-dominant scrub Prostrate kanuka scrub Prostrate kanuka dominates the canopy (0.3-3 m high) with kamahi and kanuka scattered throughout; there is locally scattered mingimingi, prickly mingimingi, tawiniwini (<i>Gaultheria antipoda</i>), toru, rewarewa (<i>Knightsia excelsa</i>) and toatoa (<i>Phyllocladus toatoa</i>). The groundcover comprises bracken, <i>Gleichenia microphylla</i> , and turutu.	Hillslope and road escarpment	c.14.5 ha
04.01.02	Prostrate kanuka-mingimingi scrub This area is a mosaic of prostrate kanuka scrub (described above) and mingimingi scrub (dominated by mingimingi). Kamahi, rewarewa, manuka, and karamu occur over mingimingi, turutu, <i>Gleichenia microphylla</i> , tawiniwini, and bracken in cooler areas. Fumaroles are abundant throughout this vegetation type. Wilding pines, particularly radiata pine, are establishing in places. Monoao occurs amongst patches of prostrate kanuka scrub.	Hillslope and shallow basin	c.6.2 ha
05.01 05.01.01	Prostrate kanuka-dominant shrubland Prostrate kanuka shrubland The areas of geothermal activity are dominated by a low cover of prostrate kanuka shrubland (0.3-0.75 m high), with patches of mossfield interspersed with areas of nonvegetated heated ground and steaming ground. Monoao, mingimingi and <i>Cladia retipora</i> are locally scattered in this area. Other vascular species present include turutu, toru, <i>Lycopodiella cernua</i> , and kanuka in association with mingimingi, manuka, and prickly mingimingi. Kamahi, with prostrate kanuka, occurs at the margins of the thermal areas. Local populations of <i>Dicranopteris linearis</i> and <i>Nephrolepis flexuosa</i> are present. Wilding pines are establishing in this	Hillslope, spur tops and cliffs	c.21.7 ha

¹ Previously identified as U16/2 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	vegetation type.		
05.03 05.03.01	Manuka-dominant shrubland Manuka shrubland Manuka is dominant over an understorey of mingimingi, bracken, turutu, and kiokio, with prostrate kanuka in more geothermally active areas. In wet areas <i>Sphagnum cristatum</i> often forms the ground cover. Occasional plants of wheki and kamahi are present. <i>Histiopteris incisa</i> and <i>Carex geminata</i> occur locally near areas of hot water.	Hillslope	c.3.2 ha
05.03.27	Manuka/<i>Histiopteris incisa</i>-<i>Carex secta</i> shrubland The canopy, 2-4 m high, is mainly manuka with prostrate kanuka and mingimingi scattered throughout. Other species present include wheki-ponga, wheki, karamu, broom, and grey willow. The groundcover is dominated by <i>Histiopteris incisa</i> and <i>Carex secta</i> , with local patches of raupo in the wetter geothermal areas. Whauwhaupaku, kohuhu and kamahi occur around the margins of this type, and locally throughout. Several crack willow are present.	Wetland at toeslope	c.0.4 ha
22.01 22.01.01	Geothermal water Geothermal water (geothermal lake) Geothermally influenced lakes.	Basins	c.3.4 ha
28.01 28.01.01	Nonvegetated raw-soilfield Nonvegetated raw-soilfield Geothermally-altered soil, mud, sinter, explosion craters and fumaroles.	Flat, hill, hillslope	c.4.3 ha

Geophysical Assessment:¹

Feature 1: Thermal Ground, Steaming Ground (see Plates 31-33)

The feature comprises an area of bare ground with a silicified crust measuring approximately 65 × 40 m. Steam discharged in three areas, an area near the western boundary, an area in the centre (Plate 31), and an elevated outcrop of pumiceous altered rock at the southern end (Plate 32). The outcrop area had significant steam discharge from numerous small (<5 cm) fumaroles, along with abundant sulphur encrustation. Kaolinite was noted across much of the top surface of the area. The soil temperatures at 10 cm depth were highest nearest the outcrop (97°C) while the rest of the area had temperatures ranging from 22°C on the eastern perimeter to 56°C on the western perimeter.

A large cold (3°C, air temp: 4°C) lake is adjacent to the geothermal feature (Plate 33). While there was no evidence of geothermal heating, an area in the centre of the lake was noted to be bubbling or degassing - although no steam was visible. A man-made bund lies between the lake and the thermal ground. The lake pH was 8.7.

¹ Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.



Plate 31: View of thermal ground looking south from bund. Note outcrop left of centre, Feature 1, Maungakakamea (Rainbow Mountain).



Plate 32: Steaming outcrop, southern end of area, Feature 1, Maungakakamea (Rainbow Mountain).



Plate 33: Cold lake adjacent to area. Note: water vapour in background is due to sunlight heat, not caused by geothermal effects, Feature 1, Maungakakamea (Rainbow Mountain).

Feature 2: Cold Acidic Lake

This feature is a cold lake, 4°C (air temp: 5°C), with a pH of 3.3. At the northern end of the lake on the western side there is a small outcrop of silicified rock (Plate 34). Soil temperatures were not above ambient temperatures at 10 cm depth in this area. No steam was noted on or surrounding the lake, but there was a small area where the surface was disturbed by bubbling. In the middle of the lake on the western side there is an area of exposed face. No steam was noted in this area. At the southern end of the lake there is a steep cliff face (Plate 35). The lake had a green colour and measures approximately 80 × 30 m.



Plate 34: Relic altered rock on northwestern edge of lake, Feature 2, Maungakakamea (Rainbow Mountain).



Plate 35: View of lake from north, Feature 1, Maungakakamea (Rainbow Mountain).

Feature 3: Northern Slope, Exposed thermal ground
Grid Reference: E1895947 N5753865

This feature consists of isolated areas of bare ground consisting of pink and white kaolinite clay (Plate 36). Ground temperatures at 10 cm depth are approximately 12°C. The areas range from 2 × 2 m to 4 × 1 m in size.



Plate 36: Area of exposed ground consisting of pink and white kaolinite clay, Feature 3, Maungakakamea (Rainbow Mountain).

Feature 4: Exposed Slope
Grid Reference: E1895977 N5753920

This feature is a large face of altered white and red kaolinite clay (Plates 37-39). There was no evidence of steaming ground. Ground temperatures at 10 cm depth were 12°C. Within the clay matrix are angular pumice fragments which are highly silicified.



Plate 37: View of exposed slope, Feature 4, Maungakakamea (Rainbow Mountain).



Plate 38: Close up of exposed slope, Feature 4, Maungakakamea (Rainbow Mountain).



Plate 39: Kaolinite clay matrix with silicified pumice fragments, Feature 4, Maungakakamea (Rainbow Mountain).

Feature 5: Lake Rotowhero

Grid Reference: E1894921 N5752951

This feature is a dark green lake with steam across the majority of its surface. The temperature was 26°C and the pH was 3.4 indicating an acidic input. The eastern end of the lake had an area of increased steam discharge near an area of exposed red/orange slope. The stream outflow (approximately 60-70 litres/sec) from the lake had a temperature of between 28-32°C and a pH of 3.4. A small hot pool with clear fluid and grey base was located along the outflow channel closer to the lake at its southern end. It had a temperature of 83°C and measured approximately 0.3 × 0.5 m.



Plate 40: Lake Rotowhero. Steam and exposed slope in background, Feature 5, Maungakakamea (Rainbow Mountain).

Feature 6: Geothermal wetland

Grid Reference: E1895026 N5752555

The outflow from Lake Rotowhero flows through an area of geothermal wetland to the east of the main stream. The area measures approximately 20×20 m. The area consists of hot clear pools which are actively degassing H_2S . The temperatures of the pools range from $34^{\circ}C$ to $65^{\circ}C$. There is various geothermal and wetland vegetation mixed in with the geothermal features (Plate 41). There are also areas of steaming ground associated with this area. The outflow from this area is culverted beneath the access road into the main stream. The temperature of the outflow is approximately $46^{\circ}C$ and the flow is in the region of 60L/sec.



Plate 41: Geothermal wetland with numerous hot clear pools, Feature 6, Maungakakamea (Rainbow Mountain).

Indigenous Flora:

The following species characteristic of geothermal vegetation occur here: prostrate kanuka, *Schizaea dichotoma* and *Dicranopteris linearis* (all classed „At Risk-Naturally Uncommon’ in de Lange *et al.* 2009), a small population of *Nephrolepis flexuosa* (classed as „At Risk-Declining’ in de Lange *et al.* 2009), and *Schizaea* sp. (cf. *S. fistulosa*). *D. linearis* is known from only c.24 sites in New Zealand. Four orchid species - *Calochilus paludosus*, *C. robertsonii*, *Petalochilus alatus* (recorded on 10 October 2006; Bycroft 2006), and *Stegostyla atradenia* (all classed as „At Risk-Naturally Uncommon’ in de Lange *et al.* 2009) - have been recorded at the site (Rotorua Botanical Society 2006) but were not recorded in 2004 or during the current study. Several populations of *C. robertsonii* were recorded at this site in November 2005 (Chris Bycroft pers. comm.).

Other species of interest found in the reserve in previous surveys but not necessarily in geothermal areas are *Ileostylus micranthus* (P. Cashmore pers. comm.), *Thelymitra carnea*, *T. nervosa*, *T. ixioides*, *T. pulchella*, *T. pauciflora*, and *Psilotum nudum* (see species list, Rotorua Botanical Society 2006).

Other species typical of geothermal habitats present include manuka, turutu, *Lycopodiella cernua*, *Morelotia affinis*, monoao, and bracken.

(Note: All species mentioned above have been seen by one of the authors, between 2000 and 2011, unless referenced)

Fauna:

Common indigenous bird species typical of the habitat are present, including North Island robin, spur-winged plover, grey warbler, blackbird, Australian magpie, welcome swallow, fantail, and bellbird. Dabchick were recorded at Feature 2 (F2 on map).

**Current Condition
(2011 Assessment):**

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. However, stock have access to a new small area of geothermal activity recently found by the authors to the north of the site. This small area is in a poor condition.

**Threats/Modification/
Vulnerability:*****Invasive pest plants
(2011 Assessment):***

Wilding pines are the key invasive exotic plant species in areas of geothermal vegetation. Whilst geothermal hot spots appear to be resistant to weed invasion, wilding pines are a threat to the prostrate kanuka scrub which occurs on cooler soils and this is particularly apparent on the eastern side. Pest gymnosperm species known from the reserve include bishop pine (*Pinus muricata*), lodgepole pine, European larch (*Larix deciduas*), black pine, maritime pine, radiata pine, and strobus pine (*Pinus strobus*). 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 small. Crack willow and grey willow are present alongside stream margins. In total, wilding pines cover <1% of the area in which geothermal vegetation occurs. Spanish heath was found at this site in 2006, by John Hobbs, but was removed by him. Any new infestations should be removed. Gorse (<1%) and Spanish heath (<1%) are present in geothermal areas alongside Kerosene Creek Road and site

margins. *Hakea salicifolia* (1-5% cover) has become considerably more common on the north faces of the reserve. Chinese privet (<1%) is also present on the north-facing slopes.

*Human impacts
(2011 Assessment):*

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
(2011 Assessment):*

Livestock are not a threat to most of this area, however horses and sheep have access to the northern part of the site near SH38 (see F1 on map)

*Adjoining land use
(2011 Assessment):*

Surrounded by indigenous vegetation in Rainbow Mountain Scenic Reserve. Farmland; roads; plantation forests.

Site Change:

Recent change:

The most notable change since the previous survey is the continued control of pines by Department of Conservation. The site is in a markedly improved condition as a result. Other changes to the site are as a result of new parts of the site identified on better quality aerial photographs (2007 photos), and additional units of geothermal vegetation have been found.

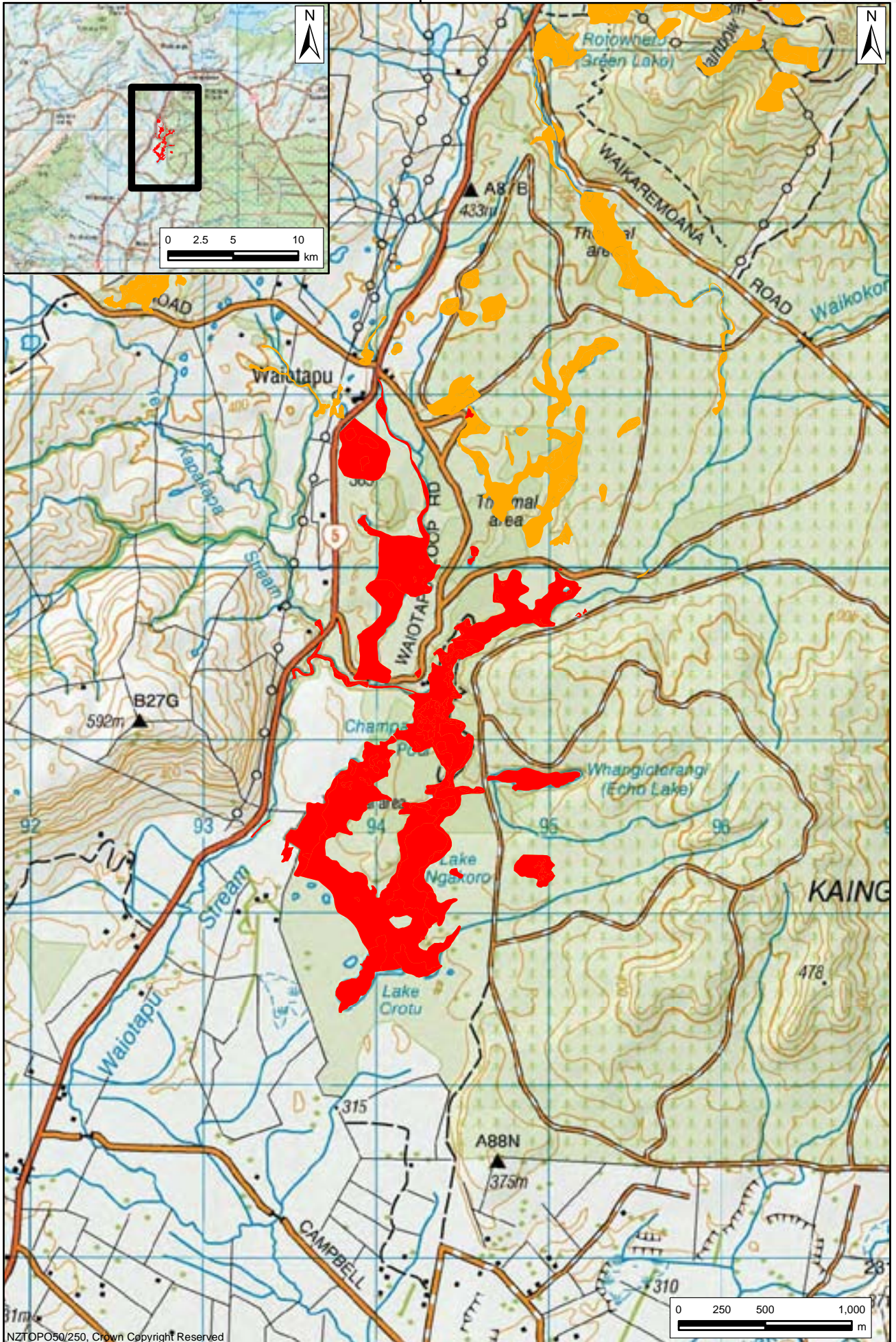
Historical:

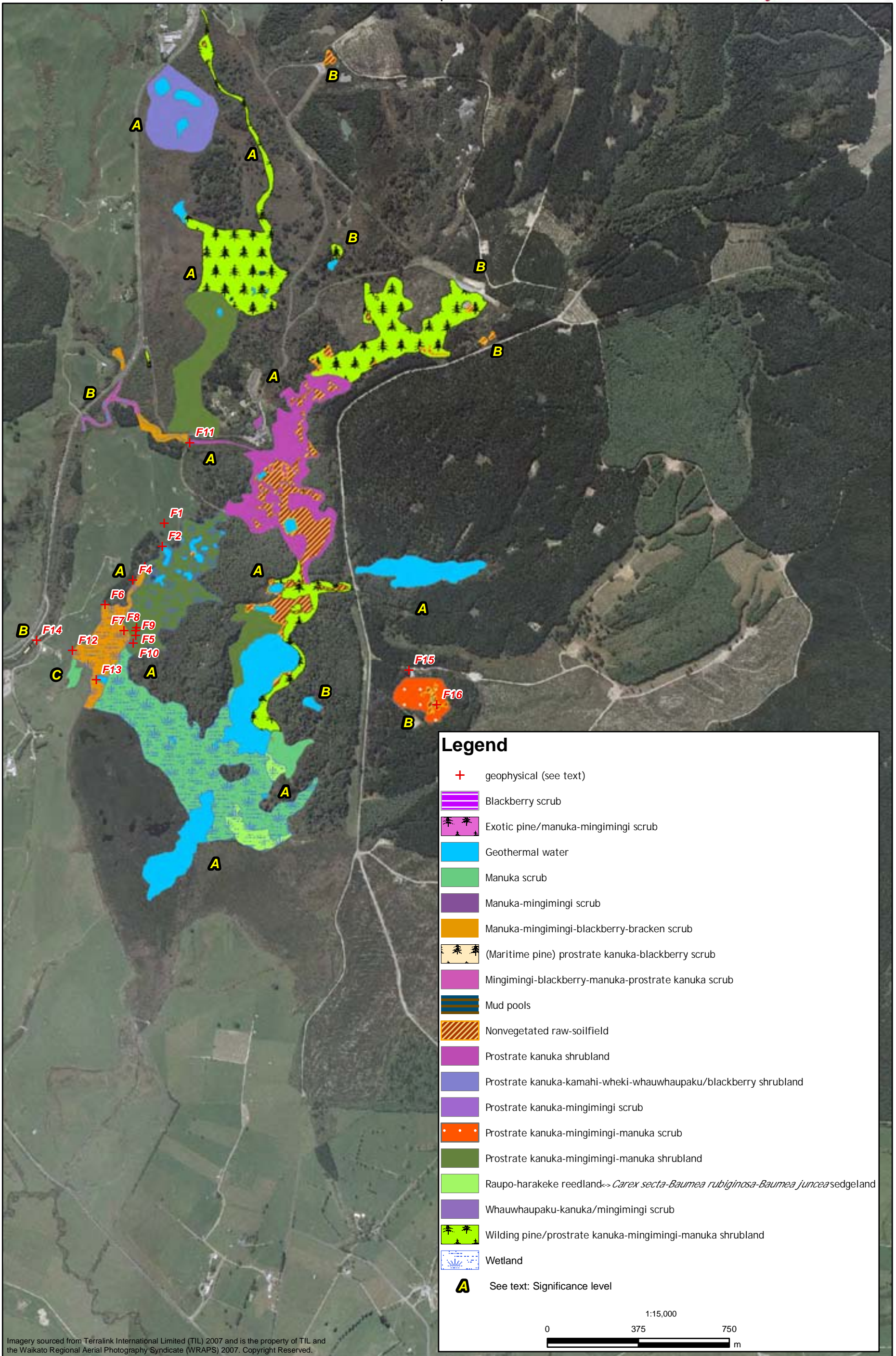
A series of 1941 photographs were compared with 2007 photographs (Historical photos: SN 172 Run 1157 Photos 7-12, 1941; SN 172 Run 1158 Photos 7-8, 1941). In most places it is difficult to determine the differences between geothermal and non-geothermal scrub and shrublands. The following points were noted:

- A small lake, which may have been geothermal, is no longer present to the south-west of Lake Rotowhero (approximately E1894870 N5752800). There was also significantly more bare ground in this southern portion of the site, on the 1941 photographs (c.f. 2007), probably as a result of weed invasion, and establishment of plantation forests on historically geothermal soils.
- There was considerably more bare ground visible on the eastern and northern slopes of Maungakakamea. This is partly as a result of cooling geothermal soils, and establishment of shrubs and exotic pines.
- More bare ground was evident on margins of Lake Rotowhero, but not markedly so.
- There seems to have been a considerable reduction of geothermal vegetation (including a geothermal lake) to the north of the site, near SH38, as land has been converted to industrial and farm uses. A geothermal lake and surrounding vegetated and nonvegetated raw-soilfield have been converted to pasture. The lake at F3 on the map may have also been more active in 1941, with bare ground on northern and southern margins of the lake.

If it is taken into account that many areas that were historically bare geothermal sites have been invaded by indigenous shrubs, and wilding pines, are still geothermally active, then 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. Fencing of geothermal features to the north of the site near SH38 should be considered. Stock have access to geothermal features in this part of the site.
Significance Level:	National (Table 1 - Criteria 1, 3, 5, 7, 9; Table 2 - Factor 8).
Significance Justification:	<p>This site is of national significance because it is a good quality, relatively large example of geothermal vegetation - a nationally uncommon habitat type. It is a good quality representative example of an ecological sequence grading from geothermal vegetation to tall forest - manuka-kanuka shrubland, whauwhaupaku-kohuhu forest, kamahi forest, and totara (<i>Podocarpus totara</i> var. <i>totara</i>)-rimu (<i>Dacrydium cupressinum</i>)/kamahi forest (Nicholls 1974; Clarkson 1981b; Beadel 1995a), over an elevation gradient of 380-743 m.</p> <p>It 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 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, B.D. 1981a).</p> <p>Eight species classed as „At Risk’ have been recorded at the site: prostrate kanuka, <i>Schizaea dichotoma</i>, <i>Nephrolepis flexuosa</i>, <i>Dicranopteris linearis</i>, <i>Calochilus paludosus</i>, <i>C. robertsonii</i>, <i>Petalochilus alatus</i>, and <i>Stegostyla atradenia</i>.</p>
References:	Beadel & Bill 2000; Burns 1997b; Bycroft 2006; Clarkson 1981a & 1982b; Merrett & Burns 1998a; Rotorua Botanical Society 2006; Watt 1986; Wildland Consultants 1998 & 2004.





WAIOTAPU SOUTH¹

Site Number WTV05²
Grid Reference: NZTopo50 BF37 945 487
GPS reference: NZTM E1894491 N5748676
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Waiotapu
Bioclimatic Zone: Submontane
Tenure: Protected (Waiotapu Stewardship Area, Waiotapu Scenic Reserve)
Altitude: c.320-380 m
Extent of Geothermal Habitat: c.129.9 ha
Extent of Geothermal Vegetation: c.05109.5 ha
Date of Field Survey: 9 December 2010, 10 July 2011

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.01 04.01.11	Prostrate kanuka-dominant scrub (Maritime pine)/prostrate kanuka-blackberry scrub Several hot springs on margin of Waiotapu Stream. Scattered maritime pine overhangs the stream. Prostrate kanuka is common on stream margins and springs. Blackberry and mingimingi dominate less geothermally active areas. Other common species include turutu, <i>Histiopteris incisa</i> , broom, harakeke, and Yorkshire fog. This vegetation type extends at least 50 m downstream and 20 m upstream of the bridge.	Stream margins	c.0.2 ha
04.02 04.02.19	Mingimingi-dominant scrub Mingimingi-manuka-blackberry-indigenous broadleaved species scrub This vegetation occurs along stream margins. Blackberry becomes dominant on cooler soils, but with abundant steam. <i>Histiopteris incisa</i> , turutu, and bracken are common. This vegetation type was mostly viewed from a distance.	Stream margins	c.0.8 ha
04.03 04.03.01	Manuka-dominant scrub Manuka scrub Extensive areas of wetland to south. Pig sign was abundant throughout. Manuka 2-4 m tall dominates with <i>Baumea rubiginosa</i> , kiokio, <i>Carex secta</i> , <i>Hypolepis distans</i> , and exotic grasses such as Yorkshire fog in drier areas. Free-standing water was present in most areas during survey. Prostrate kanuka and mingimingi were common around sinter and hot springs. Patches of <i>Schoenoplectus tabernaemontani</i> , <i>Carex secta</i> , and <i>Carex virgata</i> are present. Arrow grass occurs in several locations on sinter, and raupo reedland occurs locally.	Wetland	c.23.9

¹ This site was called Waiotapu 1 in Beadel & Bill (2000).

² Previously identified as U17/1 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.03.18	Manuka-mingimingi-blackberry-bracken scrub A highly diverse vegetation type with large extensive areas of manuka, scrub, mingimingi scrub, blackberry scrub, and bracken fernland. Broom is common in places, and wheki and wheki-ponga occur in wet areas. Scattered wilding maritime pines are present. Mud pools and hot springs are common, with sinter present near many of the hot springs.	Flat, rolling hills, gently undulating	c.5.9
05.01 05.01.01	Prostrate kanuka shrubland Prostrate kanuka shrubland Prostrate kanuka forms a low discontinuous canopy (c.0.1-1.0 m high) in association with scattered mingimingi, and local <i>Lycopodiella cernua</i> in areas of relatively high geothermal activity.	Gently undulating, flat	c.11.9 ha
05.01.15	Prostrate kanuka-mingimingi-manuka shrubland A dense canopy of prostrate kanuka, mingimingi and manuka, with locally dominant kanuka and local monoao. Maritime pine is locally common on cooler soils along the margins of these areas.	Flat area , gently rolling hills	c.21.7 ha
05.01.18	Wilding pine/prostrate kanuka-mingimingi-manuka shrubland Wilding radiata and maritime pine occur over kanuka, mingimingi, manuka, broom, prickly mingimingi, <i>Coprosma lucida</i> , blackberry, and whauwhaupaku. Occasional black wattle is present. The groundcover includes bracken, <i>Carex secta</i> , turutu, <i>Hypolepis ambigua</i> , kiokio, swamp kiokio and <i>Paesia scaberula</i> . This type forms a narrow strip along the margins of heated streams, with local small areas of steaming ground. In or near these areas wilding pines (mostly radiata pine and maritime pine) occur over prostrate kanuka (1-6 m high), mingimingi, prickly mingimingi and manuka. Local kamahi and whauwhaupaku are present. The groundcover is sparse and includes turutu, <i>Lycopodiella cernua</i> and <i>Gleichenia microphylla</i> . Boiling mud pools are scattered throughout this area. Blackberry is very dense in non-geothermal areas.	Flat areas, stream margins and wetland Flat area and gently rolling hills	c.27.7 ha
05.01.19	Prostrate kanuka-kamahi-wheki-whauwhaupaku/blackberry shrubland Prostrate kanuka, kamahi, wheki and whauwhaupaku comprise the canopy over blackberry with <i>Hypolepis ambigua</i> and <i>Paesia scaberula</i> locally common around steam vents.	Stream margin	c.6.8 ha
07.14 07.14.01 ¹	Cyclosorus-dominant fernland Cyclosorus interruptus fernland (not mapped) <i>Cyclosorus interruptus</i> occurs amongst raupo reedland and on margins of sinter terraces, in association with heated areas.	Wetland	

¹ Areas of this vegetation type occur within the area mapped as 10c, however were too small to be mapped separately.

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
11.01 11.01.16	<p>Raupo reedland Raupo-harakeke reedland ↔ <i>Carex secta</i>-<i>Baumea rubiginosa</i>-<i>Baumea juncea</i> sedgeland</p> <p>This area comprises a mosaic of harakeke-raupo reedland and <i>Carex secta</i>-<i>Baumea rubiginosa</i>-<i>Baumea juncea</i> sedgeland with patches of manuka shrubland throughout. Blackberry is common in dry areas. Harakeke with raupo forms a reedland in association with <i>Austroderia toetoe</i>, koromiko (<i>Hebe stricta</i> var. <i>stricta</i>), <i>Coprosma propinqua</i>, karamu, and kiokio. <i>Carex secta</i>, <i>Carex virgata</i>, <i>Schoenoplectus tabernaemontani</i>, <i>Baumea rubiginosa</i>, and <i>Baumea juncea</i> dominate the sedgeland, in association with rushes and <i>Eleocharis acuta</i>.</p> <p>Geothermal activity is evident in areas throughout this vegetation type with occasional <i>Cyclosorus interruptus</i> present.</p>	Wetland	c.2.4 ha
22.01 22.01.01	<p>Geothermal water Geothermal water</p> <p>Geothermally influenced pools and lakes.</p>	Open water	c.20.4 ha
22.01.02	<p>Mud pools</p>	Mud pools, craters	c.0.1 ha
28.01 28.01.01	<p>Nonvegetated raw-soilfield Nonvegetated raw-soilfield</p> <p>Includes craters, steaming ground, boiling mud, hot pools, and sinter terraces.</p>	Flat, gently rolling	c.8.0 ha

Geophysical Assessment¹

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.

¹ Geophysical assessment undertaken by Julian McDowell and reviewed by Juliet Newson, 2010.



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 at 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.

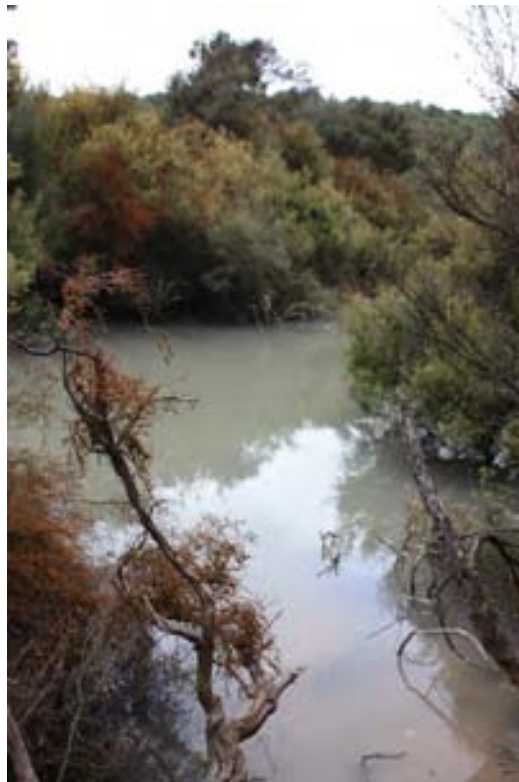


Plate 43: View from northern end of lake. Degassing was noted in middle ground of photo, Feature 2, Waiotapu South.

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/sec. The pH was found to be 7.6 in the pools in this area. There was significant steam discharging from the area and a moderate H₂S 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, Waitapu 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, Waitapu South.

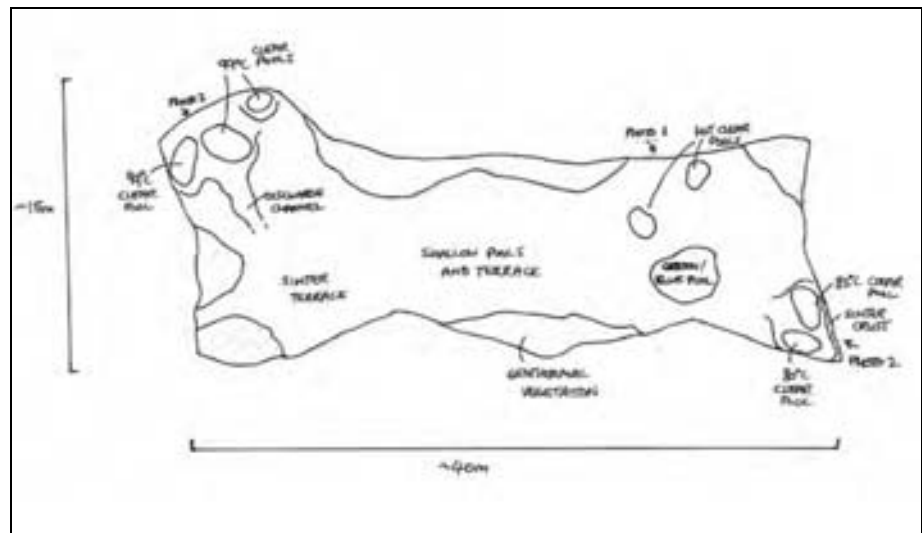


Figure A1-8: Field sketch of area of hot pools and sinter terrace, Feature 3, Waitapu South.

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, Waiotapu 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 was infrequent bubbling 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 noted to be 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 <0.1L/sec.

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 which 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 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 150-200L/sec.

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 at this location 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) and as such an upwelling of hotter

fluid is suggested. There is an outflow from the lake at its southern margin which had a temperature of 21°C, pH of 4.8 and a flow of approximately 5-6L/sec. 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 south-eastern part of the site were around 32°C, while the majority 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, Waiotapu 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 of 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, Waiotapu South.



Plate 55: Small 90°C clear grey pool, Feature 16, Waiotapu South.

Indigenous Flora: Prostrate kanuka (classed as „At Risk-Naturally Uncommon’ in de Lange *et al.* 2009), which is endemic and restricted to geothermal areas, occurs here.

A large population of *Cyclosorus interruptus* (classed as „At Risk-Declining’ in de Lange *et al.* 2009), is present in the wetland to the south of the reserve. Hobbs (2002) recorded 329 plants in Orutu Wetland to the south part of this site in 2002. The population is likely to be considerably larger than this, as much of this part of the site is inaccessible. One frond of *Dicranopteris linearis* (classed as „At Risk-Naturally Uncommon’ and known from only *c.*24 sites in New Zealand) has been recorded near „Twin Rivers’ geothermal stream (Paul Cashmore pers. comm. 2007).

Fauna: Two threatened bird species (spotless crane and North Island fernbird) classed as „At Risk-Relict’ and „At Risk-Declining’ respectively (in Miskelly *et al.* 2008) are present in the wetland at the southern end of the site. New Zealand dabchick (Threatened-Nationally Vulnerable in Miskelly *et al.* 2008) are present on Lake Orutu. Other species present include shining cuckoo, grey warbler, bellbird, tui, fantail, Australasian shoveler, grey duck, mallard, pied tit, North Island robin, greenfinch, house sparrow, and Australasian magpie.

Current Condition (2004 Assessment): In the tourist area, areas around the key geothermal features are well maintained for public viewing; however the vegetation is modified by the presence of maritime pine. Few other invasive exotic plants are present and overall this site is in good condition, particularly at the southern end. Some management of wilding pines has taken place in recent years, improving the quality of the site. Exotic pines continue to be a major threat, particularly in the area between Waiotapu Loop Road and State Highway 5. 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 pest plants, 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 (2011 Assessment): 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 strobus pine. However, the density of pines in the northern part of the site has been significantly reduced through control since the 2004 survey. 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 was mapped and described in Wildland Consultants (1998).

Human impacts (2011 Assessment): 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. In most other areas human impacts are low as they are rarely visited.

Grazing (2011 Assessment): Livestock have no access to most of this site, although sheep have had access to the wetland to the south-western portion of the site due to broken

fences. These have recently been replaced. Feral pigs have done a lot of damage in the southern and western wetlands, with tracks crossed every few metres when walking through wetland. Possum sign was also abundant. Deer are also likely to graze the site. The small area amongst Ngapouri Station is grazed by stock.

*Adjoining land use
(2011 Assessment):*

Plantation forests, farming, road, tourism land use.

Site Change:

Recent change:

Most of the changes in site mapping since 2004 is related to new parts of the site only becoming known to the authors recently, and improved quality of aerial photographs. 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, particularly its indigenous character. Overall, the extent of geothermal habitat at Waiotapu South is considered to be similar to the 2004 study.

Historical:

An assessment was made comparing 1941 (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) to 2007 aerial photographs. The most significant change in historical photographs from 1941 is the lack of wilding pines and trees in 1941. In the south of the site, the wetland extended most of the way to State Highway 5 and the wetland may have been one-third larger than it is today. However, most of this wetland would not have been geothermal. There was also a greater buffer between geothermal features and plantation forests 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 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 may have been lost since 1941, and wilding pines may have caused degradation to 25% of the site. Some of these pines have been controlled in recent years.

**Management
Requirements:**

Weed spread should continue to be controlled, particularly within the main area of geothermal activity within the reserve. Given (1995) recommended a 50 m buffer zone of indigenous forest should be established around the major geothermal area to counter pine invasion. This should be implemented. An area of high priority for exotic tree control is between Waiotapu Loop Road and State Highway 5.

Significance Level:

A: International (Table 1 - Criteria 1, 3, 5, 9, 10; Table 2 - Factor 5).
B: Regional (Table 1 - Criteria 1, 5; Table 2 - Factor 9).
C: Local (Table 1 - Criterion 5; Table 2 - Factor 19).

**Significance
Justification:**

This site has been divided into three parts, A, B, and C (see site map).

A: This part of the site (which includes most of Waiotapu South) contains the best representative example of geothermal wetland and one of the best areas of terrestrial geothermal vegetation in New Zealand.

B: The remaining parts of this site are of regional significance because they are within a scenic reserve protected under the Reserves Act (1977), or are relatively large good quality examples of geothermal vegetation and habitats (e.g. Whangioterangi South).

C: This area is of local significance because it contains a small degraded example 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 and this site was classed as Category A - the highest category.

Because of the size of this site, very broad classes of vegetation are described. While small areas of most parts of the site have been visited in 2004 and 2011, some parts are too dangerous to access. Areas where most doubt exists to exact boundary of geothermal habitat are the wetland to the south near Lake Orutu, and in the area between Waitapu Loop Road and State Highway 5. There is no clear cut boundary between geothermal wetland and non-geothermal wetland in the south and southwest of this site.

Parts of the geothermal vegetation and habitats that are not protected are subject to grazing and extensive areas are dominated by pest plants. These unprotected areas are 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 regularly monitored for management issues and formal protection and a restoration plan for these areas would enhance and/or protect the highly significant ecological values of this field.

References:

Beadel & Bill 2000; Clarkson 1982; Given 1995 & 1996; Hobbs 2002; Miller & Miller 1983; Rasch 1989; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 1998 & 2004.