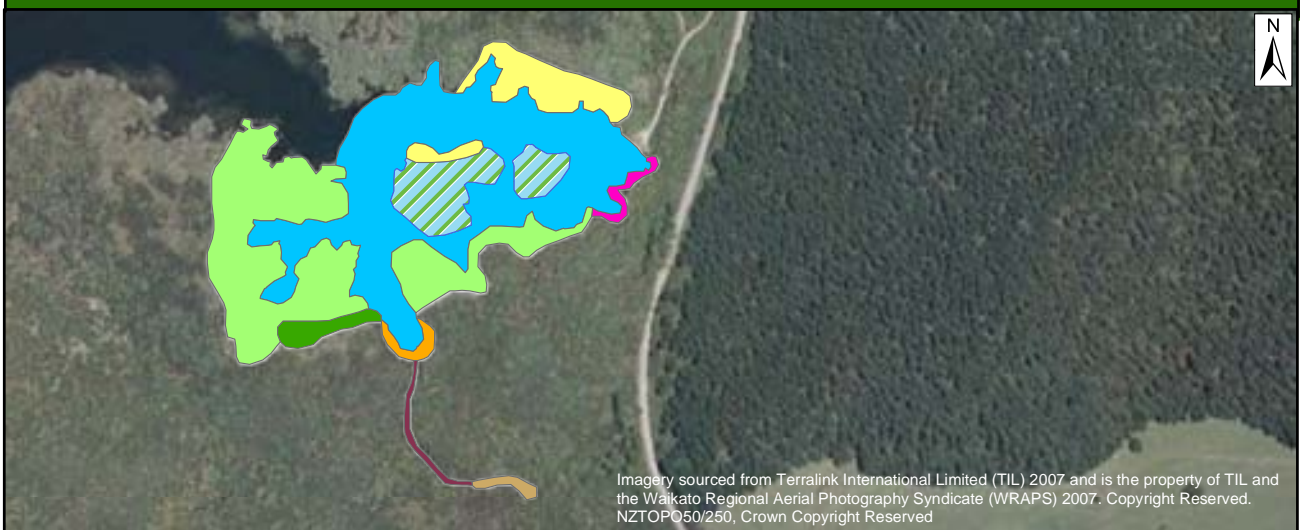
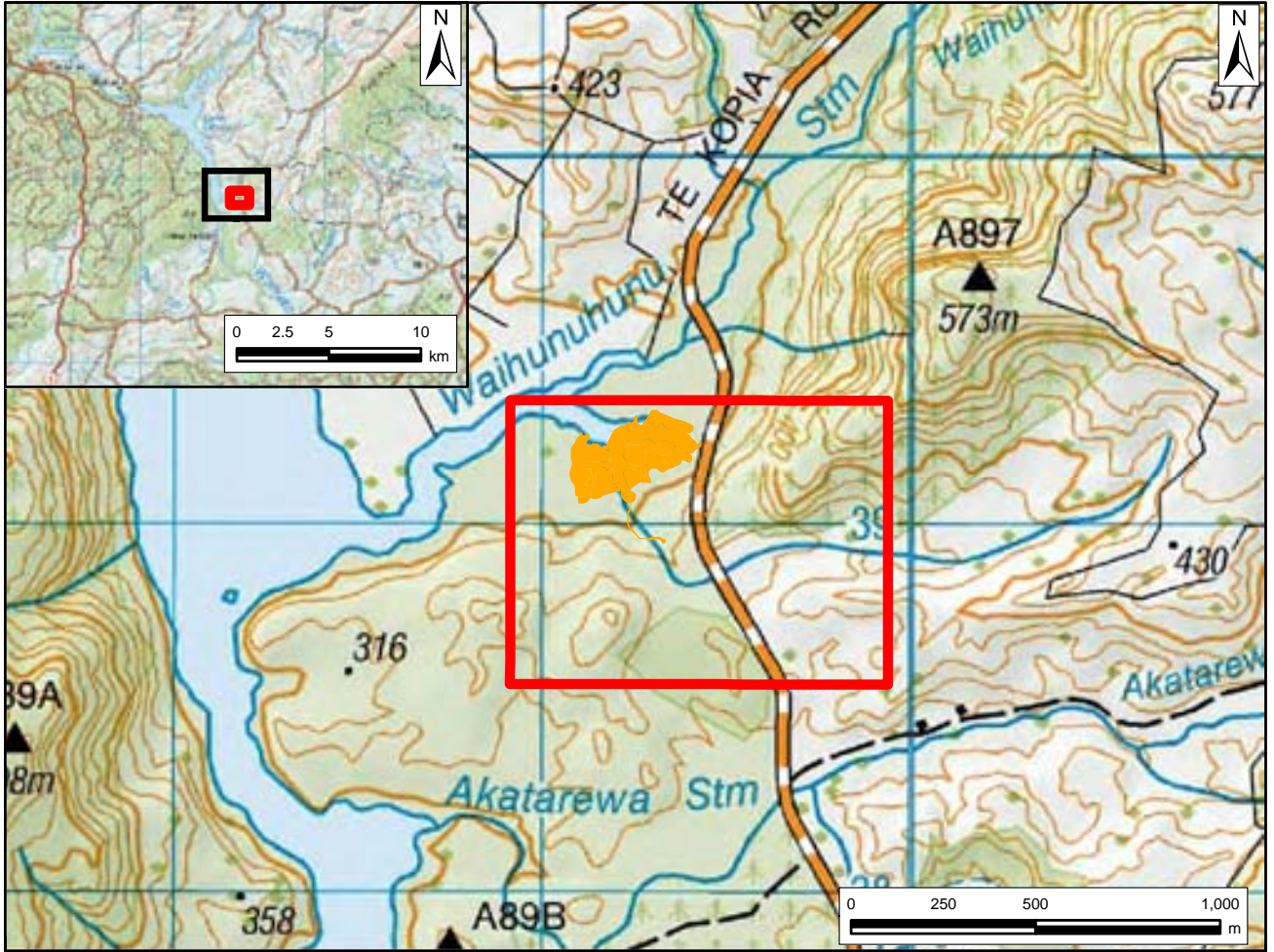


1.7 ORAKEIKORAKO GEOTHERMAL FIELD

List of Geothermal Sites

OKV01	Waihunuhunu
OKV02	Akaterewa Stream
OKV03	Orakeikorako
OKV04	Red Hills
OKV05	Akatarewa East



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Legend

- (Ti kouka)-(manuka)/raupo-*Cyperus ustulatus*-*Schoenoplectus tabernaemontani* reedland
- Christella* aff. *dentata* ("thermal")-*Nephrolepis flexuosa*-blackberry-rank exotic grasses fernland
- Nephrolepis flexuosa* fernland
- Nephrolepis flexuosa*-bracken-*Christella* aff. *dentata* ("thermal")-blackberry fernland
- Bracken-mingimingi-blackberry fernland
- Geothermal water
- Grey willow/raupo reedland
- Mercer grass-*Cyclosorus interruptus*-*Hypolepis ambigua* grassland
- Raupo reedland

1:6,000

WAIHUNUHUNU

Site Number: OKV01¹
Grid Reference: NZTopo50 BF36 752 390
GPS Reference: NZTM E1875248 N5738978
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Lowland - Submontane
Tenure: Unprotected private land
Altitude: 300 m
Extent of Geothermal Habitat: c.5.3 ha
Extent of Geothermal Vegetation: c.3.1 ha
Date of Field Survey: 8 March 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
07.03 07.03.05	Bracken-dominant fernland Bracken-mingimingi-blackberry fernland Scattered emergent karamu, kohuhu, mamaku (<i>Cyathea medullaris</i>), and wheki are present over bracken, mingimingi, and blackberry. On lake margins patches of <i>Baumea articulata</i> , <i>Schoenoplectus tabernaemontani</i> , <i>Baumea rubiginosa</i> , swamp kiokio, <i>Christella</i> aff. <i>dentata</i> (“thermal”), <i>Carex virgata</i> , and kiokio are common. A geothermal stream flows though this vegetation type.	Wetland, terrace	<0.1 ha
07.06 07.06.03	<i>Christella</i> aff. <i>dentata</i> (“thermal”)-dominant fernland <i>Christella</i> aff. <i>dentata</i> (“thermal”)-<i>Nephrolepis flexuosa</i>-blackberry fernland Narrow band of vegetation on each side of an unnamed hot water stream which flows into the Waihunuhunu Arm of Lake Ohakuri. The stream is fed by hot springs upstream of this vegetation type, but hot water seepages were also present within the stream bed. The banks of the stream are dominated by <i>Christella</i> aff. <i>dentata</i> (“thermal”) and <i>Nephrolepis flexuosa</i> . <i>Cyperus ustulatus</i> is also common along stream margins. Blackberry and bracken shrubland occurs upslope of these species. Planted radiata pine plantation surrounds this vegetation type. Along small parts of the stream, indigenous species form a canopy above this geothermal vegetation type, often comprising karamu, kohuhu, and wheki. The stream was viewed at several points along its length, although access into the stream is very difficult due to the steep sides and very hot stream temperatures.	Stream margins	c.0.1 ha
07.08 07.08.01	<i>Nephrolepis flexuosa</i>-dominant fernland <i>Nephrolepis flexuosa</i> fernland The upstream part of the unnamed hot water stream, where the margins of hot springs and a hot water stream are dominated by <i>Nephrolepis flexuosa</i> fernland. Several patches of <i>Dicranopteris linearis</i> are also present. There is	River margins	<0.1 ha

¹ Previously identified as U17/31 in Wildland Consultants (2004 and 2007b).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
	scattered <i>Carex virgata</i> , blackberry, mingimingi, <i>Hypolepis ambigua</i> , wheki, fleabane, buddleia, <i>Christella</i> aff. <i>dentata</i> (“thermal”), Spanish heath, Scotch thistle, bracken, ti kouka, Yorkshire fog, and <i>Cyperus ustulatus</i> .		
07.08.03	<i>Nephrolepis flexuosa</i>-bracken-<i>Christella</i> aff. <i>dentata</i> (“thermal”)-blackberry fernland This type is located on the banks above Lake Ohakuri where hot geothermal water from a geothermal stream discharges into the lake. Patches of <i>Nephrolepis flexuosa</i> and bracken are common. Plants of <i>Christella</i> aff. <i>dentata</i> (“thermal”), blackberry, and mingimingi are also common with scattered <i>Dicranopteris linearis</i> , Spanish heath, wheki, karamu, kohuhu, and swamp kiokio.	Lake margins	c.0.1 ha
08.04 08.04.04	Mercer grass-dominant grassland Mercer grass-<i>Cyclosorus interruptus</i>-<i>Hypolepis ambigua</i> grassland A Mercer grass dominated grassland with common <i>Cyclosorus interruptus</i> and <i>Hypolepis ambigua</i> . Narrow-leaved plantain (<i>Plantago lanceolatum</i>), blackberry, lotus, Spanish heath, Scotch thistle, fleabane, kohuhu, <i>Histiopteris incisa</i> , <i>Cyperus ustulatus</i> , manuka, and bracken are scattered through this area. Several hot springs are present.	Ephemeral wetland	c.0.1 ha
11.01 11.01.01	Raupo-dominant reedland Raupo reedland Raupo reedland with common patches of <i>Carex virgata</i> and <i>Carex secta</i> and occasional grey willow, cleavers (<i>Galium aparine</i>), <i>Centella uniflora</i> , <i>Carex maorica</i> , lotus, <i>Carex virgata</i> , <i>Eleocharis acuta</i> , wheki, swamp kiokio, <i>Juncus edgariae</i> , and <i>Baumea articulata</i> .	Wetland	c.0.5 ha
11.01 11.01.14	Raupo-dominant reedland (Ti kouka)-(manuka)/raupo-<i>Cyperus ustulatus</i>-<i>Schoenoplectus tabernaemontani</i> reedland Scattered ti kouka and manuka are present over raupo reedland, with other areas dominated by <i>Cyperus ustulatus</i> sedgeland, <i>Schoenoplectus tabernaemontani</i> reedland, and several patches of <i>Eleocharis acuta</i> . Some small areas of bare soil around hot springs are present. Other common species include <i>Carex virgata</i> , wheki, swamp kiokio, and <i>Baumea articulata</i> .	Wetland	c.1.7 ha
11.01 11.01.15	Raupo-dominant reedland Grey willow/raupo reedland Grey willow is common over raupo.	Wetland	c.0.4 ha
22.01 22.01.01	Geothermal water Geothermal water Geothermally heated waters of Waihunuhunu Arm of Lake Ohakuri. Includes several hot springs, as well as inputs from several hot streams.	Open water	c.2.3 ha

Indigenous Flora: *Christella* aff. *dentata* (“thermal”) and *Nephrolepis flexuosa* (both classed as „At Risk-Declining’ in de Lange *et al.* 2009) are scattered alongside stream margins throughout this site, and alongside lake margins.

One large population of *Cyclosorus interruptus* (classed as 'At Risk-Declining' in de Lange *et al.* 2009) is present. This population comprises 52 large patches over a 60 m² area.

Two small populations of *Dicranopteris linearis* (classed as 'At Risk-Naturally Uncommon' in de Lange *et al.* 2009, and known from only c.24 sites in New Zealand) were present near the hot springs along the unnamed hot water stream, and another population occurs near the outlet of this stream into Lake Ohakuri.

Other species present that are typical of geothermal habitat include *Cyperus ustulatus*, turutu, *Histiopteris incisa*, raupo, mingimingi, and manuka.

Thelypteris confluens has been recorded from this site in the past (E. Miller pers. comm. in Hobbs 2002) but was not recorded during this survey or by Hobbs. *T. confluens* is classed as an 'At Risk-Declining' fern in de Lange *et al.* (2009).

Fauna:

North Island fernbird, spotless crane, grey warbler, bellbird, spur-winged plover, tui, pukeko, and little shag were present. Other common indigenous and introduced bird species typical of the habitat are likely to be present.

Spotless crane and North Island fernbird are classed as 'At Risk-Declining' and 'At Risk-Relict' respectively in Miskelly *et al.* 2008.

Current Condition (2007 Assessment):

This site is mainly in good ecological condition providing good habitat for four threatened fern species. However, pest plants (e.g. grey willow and crack willow) are common in the wetland. Blackberry scrub and exotic plantation trees are common around the geothermal streams.

Threats/Modification/Vulnerability:

Invasive pest plants (2007 Assessment):

Blackberry (5-25% cover), grey willow (1-5% cover), crack willow (1-5% cover), and buddleia (<1% cover).

Human impacts (2007 Assessment):

Litter is common near hot springs near road entrance. Exotic plantations are near the hot geothermal stream at this site.

Grazing (2007 Assessment):

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

Adjoining land use (2007 Assessment):

Plantation forest, farmland, recreation area.

Site Change:

Recent change:

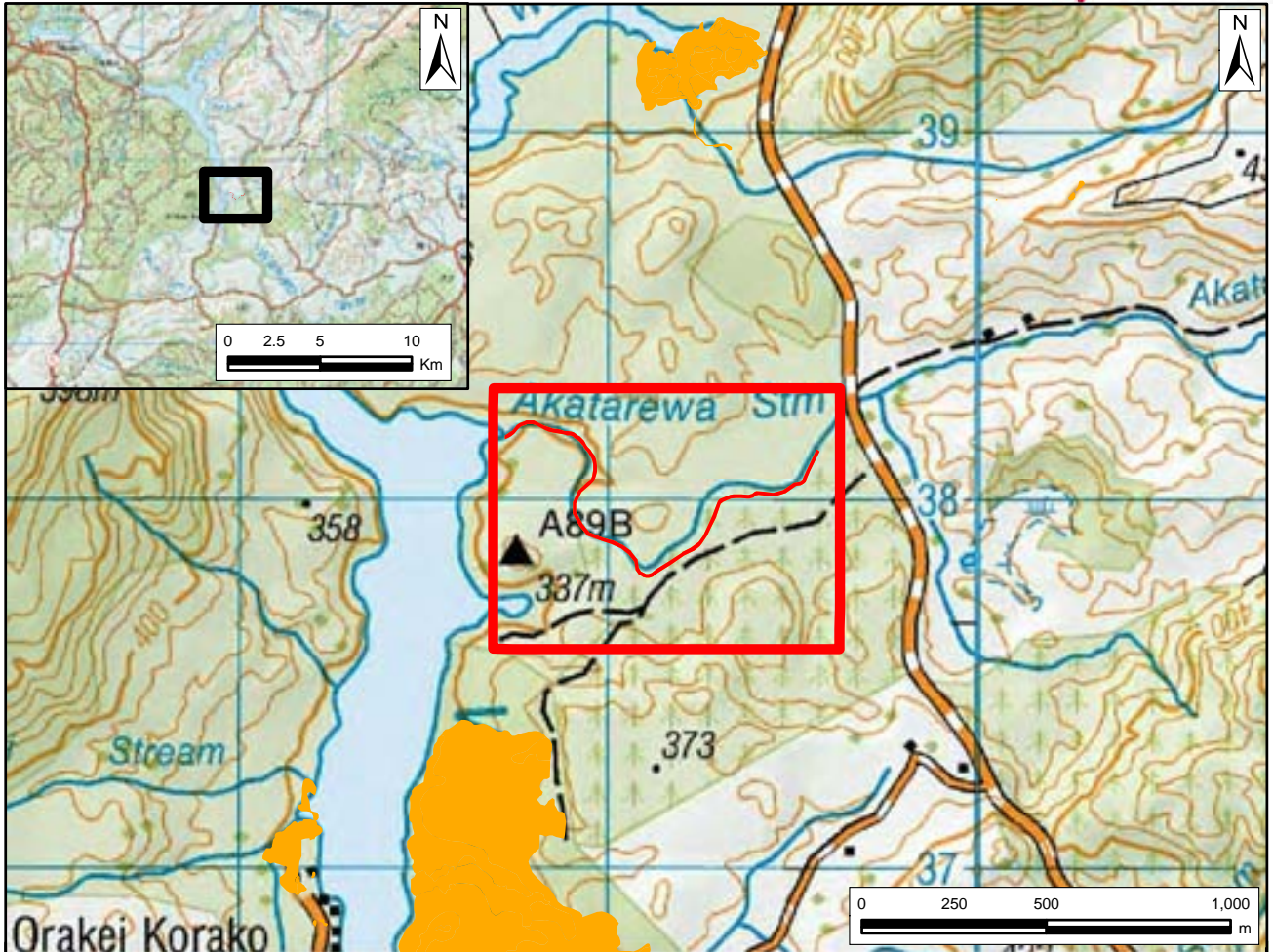
Not assessed prior to 2007, unlikely to be significant change since that field survey.

Historical:

The lower parts of the site were flooded when the Waikato River was dammed to form Lake Ohakuri in 1961, and features were destroyed by flooding. The loss of terrestrial geothermal vegetation and habitats at this site since the raising of Lake Ohakuri is likely to have been substantial. The

geothermal activity in Waihunuhunu is now in a head of a bay that was previously a long valley (c.1 km in length) (Historical photo: SN358 run 1074 1944-49). Heated water in this arm of the lake indicates that there is considerable geothermal activity beneath the lake here. The higher lake level has however 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. Based on the above assumptions we could presume that a loss of c.75% of terrestrial geothermal habitats has occurred with the raising of Lake Ohakuri. About 25% of this has since become geothermal wetland, indicating a total vegetation loss of c.50% since 1961.

Management Requirements:	This site has great potential for ecological restoration through management of pest plants (e.g. willow trees in wetland).
Significance Level:	National (Table 1 - Criteria 3, 5, 6, 7, 9; Table 2 - Factor 8).
Significance Justification:	This site is of national significance because it is a very good quality example of a habitat that is nationally uncommon. It also contains good populations of four 'At Risk' species: <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> and <i>C. interruptus</i> in New Zealand.
Notes:	Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region and this site was classed as Category B - the second highest category.
References:	Beadel & Bill 2000; Given 1989, 1995 & 1996; Hobbs 2002; Merrett & Burns 1999; Smith-Dodsworth 1993; Wildland Consultants 2004 & 2007b.

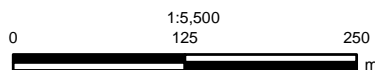


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Legend

 (Maritime pine)/kiokio-blackberry-bracken-buddleia shrubland



AKATAREWA STREAM

Site Number: OKV02¹
Grid Reference: NZTopo50 BF36 751 378
GPS Reference: NZTM E1875142 N5737819
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Lowland Submontane
Tenure: Unprotected private land
Altitude: c.300 m
Extent of Geothermal Habitat: c.1.4 ha
Extent of Geothermal Vegetation: c.1.4 ha
Date of Field Survey: 28 May 2007

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
05.08 05.08.04	<p>Mixed indigenous shrubland (Maritime pine)/kiokio-blackberry-bracken-buddleia shrubland</p> <p>Kiokio, blackberry, bracken, and <i>Cyperus ustulatus</i> are common along stream margins, with scattered maritime pine, ti kouka, whauwhaupaku, kohuhu, buddleia, harakeke, karamu, and wheki. Creeping bent, Yorkshire fog, <i>Deparia petersenii</i>, <i>Histiopteris incisa</i>, <i>Paesia scaberula</i>, <i>Hypolepis ambigua</i>, creeping buttercup, paku (<i>Pneumatopteris pennigera</i>), <i>Carex secta</i>, and lotus are also common. Several patches of <i>Gleichenia microphylla</i> are present. There are scattered <i>Christella</i> aff. <i>dentata</i> (“thermal”) plants (47 mature plants recorded). These are more common along the lower reaches of the Akatarewa Stream, however plants are less common below the waterfall at the bathing pool closest to the lake. Seepages of hot water and occasional sinter are present along the entire length of stream. A eucalyptus plantation borders the margins of this vegetation type.</p>	Stream margins	c.1.4 ha

Indigenous Flora: *Christella* aff. *dentata* (“thermal”) (classified as an „At Risk-Declining’ species in de Lange *et al.* 2009) is scattered alongside stream margins throughout this site. Forty-seven mature plants were recorded.

Cyclosorus interruptus was recorded at this site in 2002 (Hobbs 2002). In 2007 the stream was inspected 50 m upstream and downstream of the location of the 2002 sighting, but no plants of *C. interruptus* were found. *C. interruptus* is an „At Risk-Declining’ species (in de Lange *et al.* 2009). *C. interruptus* appears to be a seasonal species in the Bay of Plenty/Waikato and is not always visible at a site during all seasons, so this species could still be present at this site.

Dicranopteris linearis (classified as an „At Risk-Naturally Uncommon’ species in de Lange *et al.* 2009, and known from only c.24 sites in New

¹ Previously identified as U17/30 in Wildland Consultants (2004). This site was also updated in 2007 (Wildland Consultants 2007b).

Zealand) was also been recorded from this site in 2002 (Hobbs 2002), but was not recorded in the 2007 survey.

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

Fauna: North Island robin, grey warbler, North Island fantail, bellbird, pied tit, and tui. Other common indigenous and introduced bird species typical of the habitat are likely to be present.

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 'At Risk' fern species.

**Threats/Modification/
Vulnerability:**

*Invasive pest plants
(2007 Assessment):* Blackberry (5-25%), pampas (<1%), grey willow (<1%), buddleia (1-5%), Himalayan honeysuckle (<1%).

*Human impacts
(2007 Assessment):* Several bridges and culverts. Bathing pools. Plantation forest harvesting operations nearby.

*Grazing
(2007 Assessment):* Livestock have no access to the area

*Adjoining land use
(2007 Assessment):* Camping ground, and plantation forestry.

Site Change:

Recent change: This site has not been revisited by the authors since 2007, but is unlikely to have undergone significant change over this timeframe.

Historical: We compared 2007 aerial photographs with those from 1949 (Historical photos: SN 358 Run 1074 Photos 92-94, 1949). It appears that the lower portion of the stream (in the order of c.50 m) was inundated when Lake Ohakuri was raised. This is likely to have reduced habitat for fern species such as *Christella* aff. *dentata* ("thermal"). An area of raw-soilfield appears to be present in the upper stream catchment in the 1949 photo. This area is now in plantation forest. Overall, there has been at least a 25% loss of geothermal vegetation and habitats at this site since 1949.

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

Significance Level: Regional (Table 1 - Criteria 3, 5, 6; Table 2 - Factor 12).

Significance Justification: This site is of regional significance because it contains an important population of an 'At Risk' species *Christella* aff. *dentata* ("thermal"). This is one of only 14 known sites of *Christella* aff. *dentata* ("thermal") in the

North Island.

Notes:

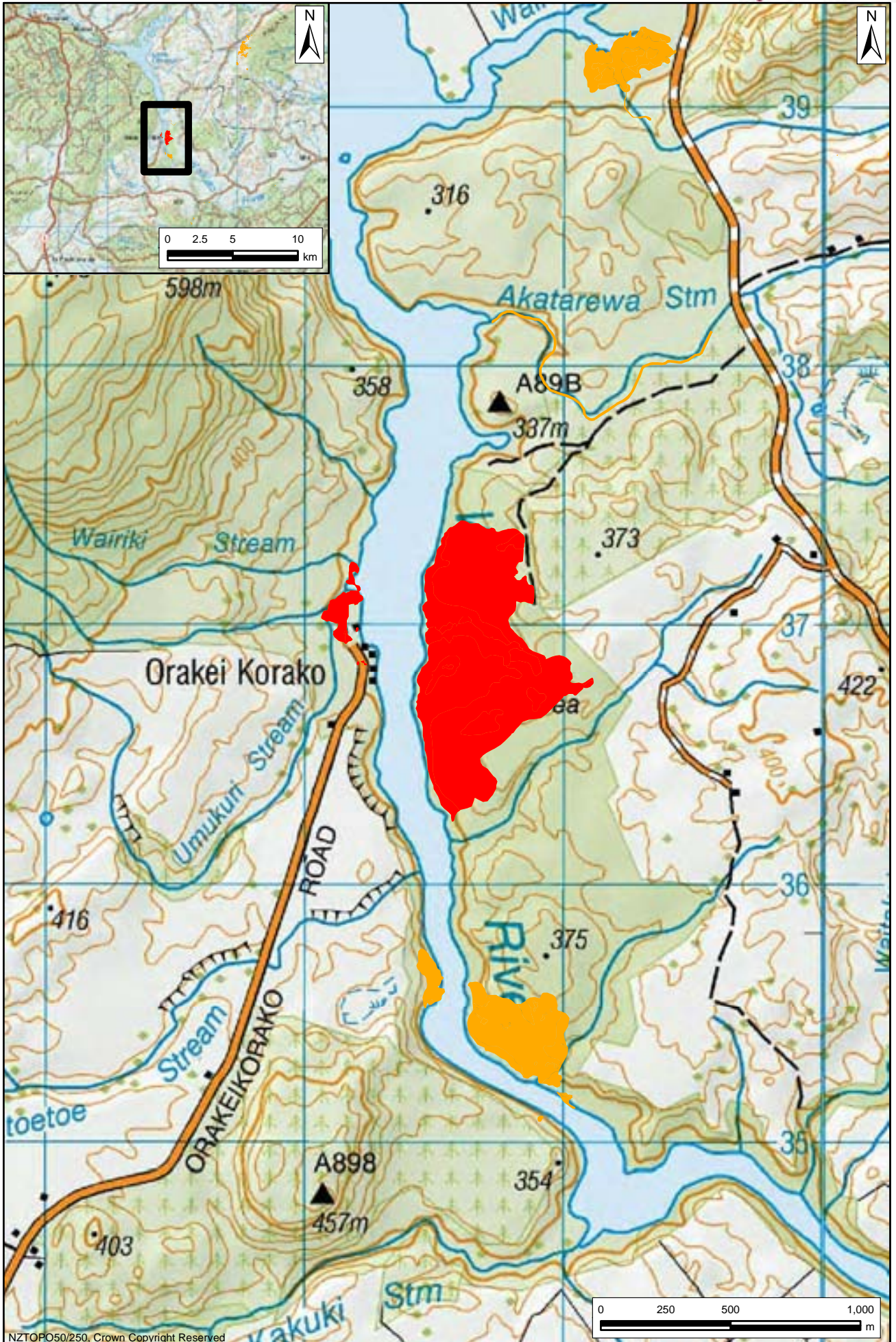
Given (1996) assessed the botanical value of many of the geothermal sites in the Waikato Region, and in this study this site was classed as Category C - the third highest category.

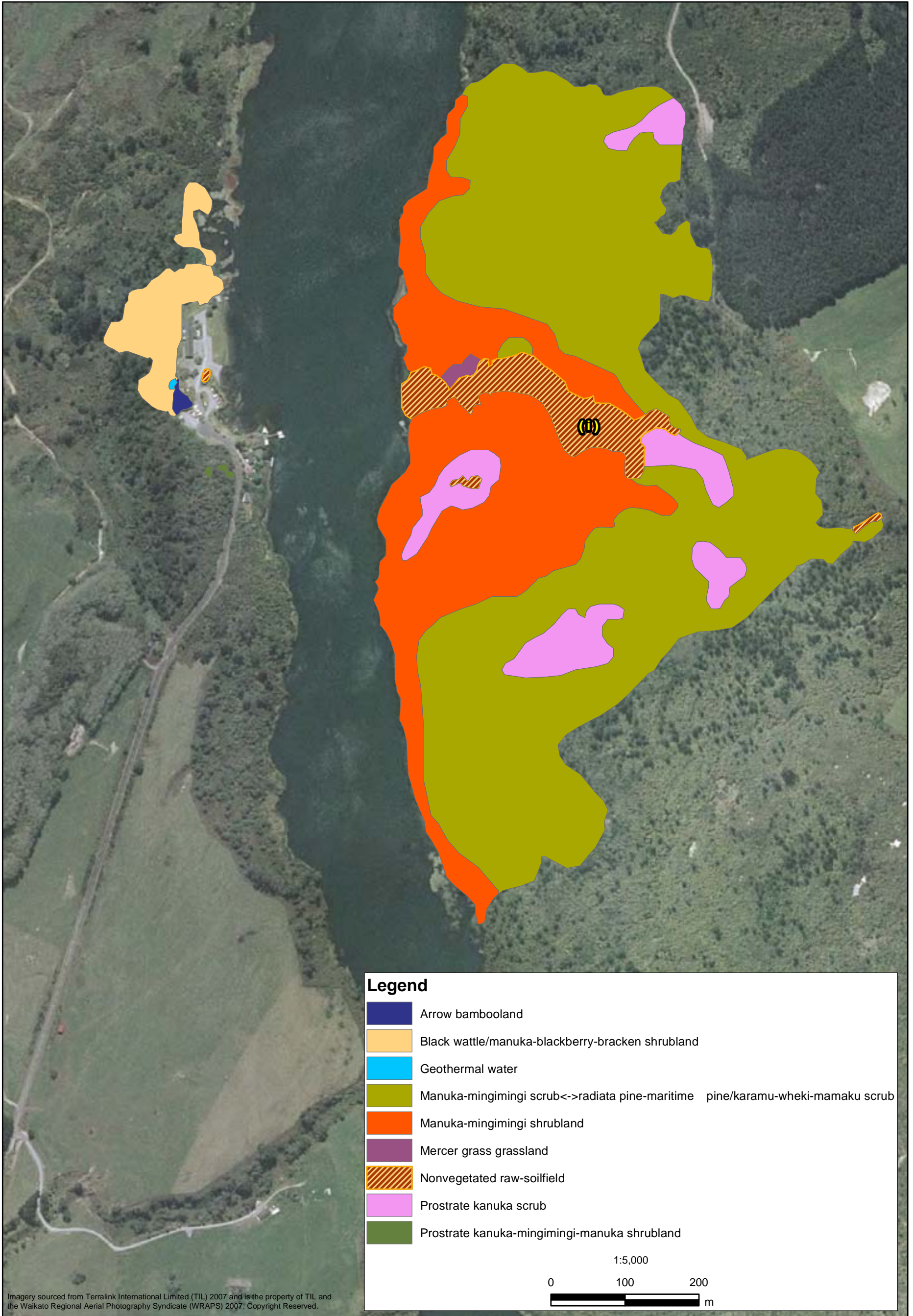
Some of the *Christella* aff. *dentata* (“thermal”) plants may have been damaged during recent harvesting operations - hence the lower number of plants recorded here than by Merrett & Burns (1999) who recorded 96 plants at the site before harvesting was undertaken in 1999.

This site was formerly identified as being of national significance (Wildland Consultants 2007b) due to the presence of *Christella* aff. *dentata* (“thermal”) which, at that time, was classified as ‘Chronically Threatened’ (de Lange *et al.* 2004).

References:

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





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ORAKEIKORAKO

Site Number: OKV03¹
Grid Reference: NZTopo50 BF36 747 369
GPS Reference: NZTM E1874726 N5736937
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Submontane
Tenure: Protected (Lake Ohakuri Stewardship Area administered by DOC) and unprotected private land
Altitude: c.300-340m
Extent of Geothermal Habitat: c.42.4 ha
Extent of Geothermal Vegetation: c.42.4 ha
Date of Field Survey: 1 August 2010 (east side of Lake Ohakuri)
 2 February 2011 (west side of Lake Ohakuri)

Code	Type	Landform	Extent
04.01 04.01.01	Prostrate kanuka-dominant scrub Prostrate kanuka scrub Prostrate kanuka (1-3 m high) forms a dense canopy with mingimingi and manuka scattered throughout. Prickly mingimingi and karamu are also present. The groundcover comprises local <i>Lycopodiella cernua</i> , <i>Dicranopteris linearis</i> , Indian doab and bracken, with turutu and <i>Dicranoloma</i> sp. scattered throughout. Fumaroles occur throughout. Wilding pine control has recently been carried out in most of this area and some felled pine trees were observed.	Hillslopes	c.3.0 ha
04.03 04.03.16	Manuka dominant scrub Manuka-mingimingi scrub ↔ (radiata pine)-(maritime pine)/karamu-wheki-mamaku scrub This area comprises a mosaic of manuka-mingimingi scrub and karamu-wheki-mamaku scrub, where manuka-mingimingi scrub is the predominant vegetation type. Occasional rimu are present. Broadleaved species and tree ferns are common including rewarewa, kohuhu, ponga (<i>Cyathea dealbata</i>), and <i>Cyathea smithii</i> . <i>Morelotia affinis</i> , kiokio, and turutu are common in the understory. Fumaroles occur throughout, and prostrate kanuka is associated with areas of heated soil. Mingimingi, prostrate kanuka, <i>Histiopteris incisa</i> , kiokio and wheki are common around mud pools. Pampas has expanded its range in this vegetation type following pine control. Patches of wilding pine still remain at some localities, but the cover is greatly reduced from the 2004 and 2007 surveys.	Hillslopes and alluvial terraces	c.24.7 ha
05.01 05.01.01 ²	Prostrate kanuka-dominant shrubland Prostrate kanuka shrubland (not mapped) Low prostrate kanuka (<0.5 m) forms a sparse canopy in local areas around the margin of the sinter terrace and other		

¹ Previously identified as U17/11 in Wildland Consultants (2004 and 2007).

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

Code	Type	Landform	Extent
	areas of nonvegetated raw-soilfield. Mingimingi becomes more common on margins, and manuka becomes more common in poorly drained areas. <i>Baumea juncea</i> , sea rush, and oioi occur occasionally in cooler wet areas.		
05.01.15	Prostrate kanuka-dominant shrubland Prostrate kanuka-mingimingi-manuka shrubland Small areas of heated soils (up to 30°C) with prostrate kanuka, mingimingi and manuka occur nearby the road. Other species in this area include bracken, maritime pine, fleabane, Japanese honeysuckle, silver birch, and Spanish heath.	Hillslope	<0.1 ha
05.03 05.03.04	Manuka dominant shrubland Manuka-mingimingi shrubland Manuka and mingimingi in association with scattered kanuka and prostrate kanuka and occasional karamu and kohuhu. <i>Gleichenia microphylla</i> , bracken, <i>Paesia scaberula</i> , <i>Histiopteris incisa</i> , kiokio, and turutu. These are large local patches of <i>Dicranopteris linearis</i> , and small local patches of Indian doab. Fumaroles are scattered throughout and there are seepages adjacent to Lake Ohakuri. Scattered populations of <i>Christella</i> aff. <i>dentata</i> (“thermal”) occur near heated water on lake margins.	Hillslopes and alluvial terrace	c.10.7 ha
05.03.23	Manuka dominant shrubland Black wattle/manuka-blackberry-bracken shrubland Emergent black wattle and maritime pine occur in association with manuka, blackberry, bracken and Japanese honeysuckle with small patches of raupo, mingimingi, and prostrate kanuka (up to c.3 m tall). Blackberry occurs in large swaths and in places is the dominant canopy cover. Other common species include mingimingi, bracken, <i>Lycopodiella cernua</i> , <i>Paesia scaberula</i> , swamp millet, <i>Baumea rubiginosa</i> , Mercer grass, karamu, wheki, turutu, <i>Gleichenia microphylla</i> , greater bindweed, <i>Cyperus ustulatus</i> , buddleia, and <i>Hypolepis</i> sp. 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 also present. Mud pools occur throughout this type.	Wetland, gently sloping.	c.1.7 ha
07.01 07.01.01 ¹	Dicranopteris-dominant fernland Dicranopteris fernland (not mapped) Small areas dominated by <i>Dicranopteris linearis</i> occur locally. These areas were too small to identify on the aerial photograph, but are scattered amongst prostrate kanuka scrub and shrubland.	Hillslope	
08.04 08.04.03	Mercer grass-dominant grassland Mercer grass grassland A small area of grassland dominated by Mercer grass with local <i>Gleichenia microphylla</i> , <i>Histiopteris incisa</i> and <i>Paesia scaberula</i> . <i>Cyperus ustulatus</i> and <i>Baumea juncea</i> occur around a small thermal seepage.	Alluvial terrace	c.0.1 ha
22.01 22.01.01	Geothermal water Geothermal water Hot seepage and hot springs with blackberry. <i>Cyclosorus</i>	Alluvial terrace	<0.1 ha

Code	Type	Landform	Extent
	<i>interruptus</i> and <i>Christella</i> aff. <i>dentata</i> (“thermal”) are present in small numbers (c. <5 plant of each) along the warm margins.		
28.01 28.01.01	Nonvegetated raw-soilfield Nonvegetated raw-soilfield The large sinter deposit terrace on the eastern side of the river is the most prominent geothermal feature of the site (mapped as (i) on vegetation map). Mineral pools and hot springs occur throughout this feature, with some geysers along its edge. There are also patches of bare ground, steaming fumaroles, and mud pools throughout this site, but these were too small to map within the context of this project. Occasional sea rush and manuka, and patches of exotic grasses, are present.	Hillslopes and alluvial terrace	c.2.1 ha
30.01 30.01.01	Bamboo-dominant bambooland Arrow bambooland Near the visitor car park an area of arrow bamboo (<i>Pseudosasa japonica</i>) with occasional maritime pine, black wattle, <i>Cotoneaster glaucophyllus</i> , and Japanese honeysuckle occurs.	Hillslope	c.0.1 ha

Geophysical Assessment:¹

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, Orakeikarako. Note the *Dicranopteris linearis* in photo.

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

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 50-60°C. At one point the thickness of the sinter was observed through a break in the crust to be about 10 cm thick.



Plate 66: Heavily vegetated sinter scarp. Feature 2, Orakeikorako.



Plate 67: Sinter structure on scarp. Note silicified organic material. Feature 2, Orakeikorako.

Feature 3: Relic discharging pool/Geyser
Grid Reference: E1874554 N5736837

Above the scarp and sinter deposition channels a relic sinter depositing pool/geyser was identified. 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/geyser with east west fissure and sinter terrace in background, Feature 3, Orakeikorako.

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). Luckily, during the monitoring round, the geyser did play at 11.55 a.m. for approximately 30 seconds - 1 minute. There is a main central fissure (again 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, Orakeikorako.



Plate 70: Geyser. View looking northeast. Note drainage channel back into crater, Feature 5, Orakeikorako.



Plate 71: Area of steaming ground with red altered clay and sinter to the north of the geyser. Feature 5, Orakeikorako.

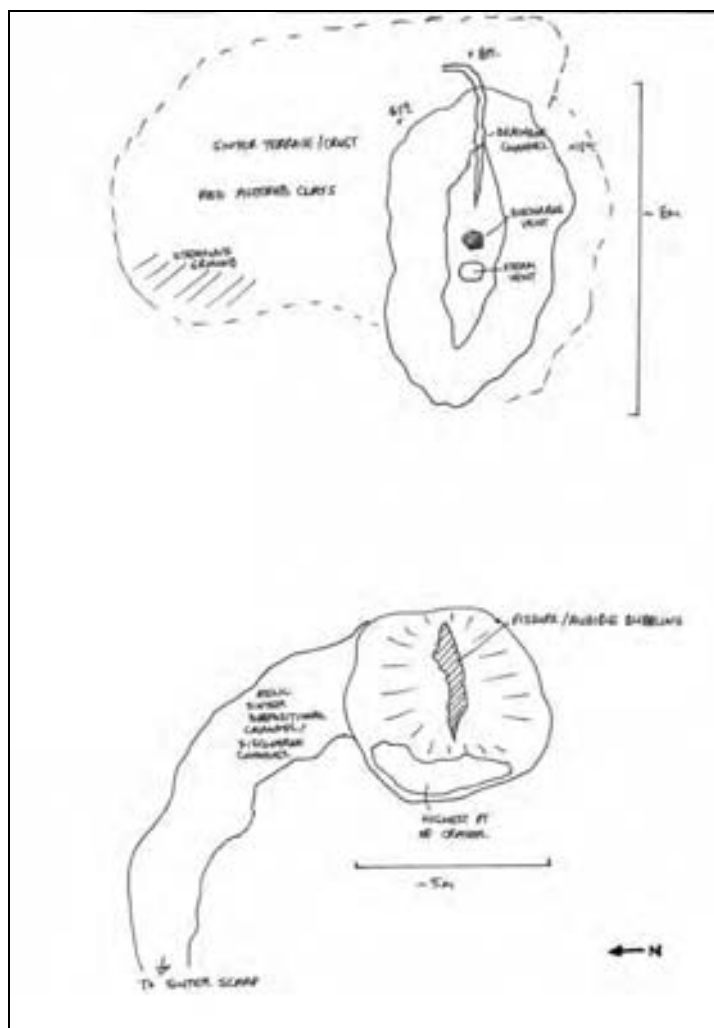


Figure A1-20: Field Sketch of Relic Pool/Geyser of Feature 4 (bottom) and Active Geyser of Feature 5 (top) at Orakeikorako.

Feature 6: Steaming ground
Grid Reference: E1874546 N5737104

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.

Feature 7: Mud pool
Grid Reference: E1874593 N5737122

This feature was a small mud pool with viscous mud and vigorous bubbling. Thick vegetation prevented access.

Feature 8: Mud Pool and Volcano
Grid Reference: E1874607 N5737129

This feature is a mud pool with a less viscous mud and minor steam discharge. A mud volcano approximately 30 cm high lies adjacent to it. Thick vegetation prevented access for temperature measurement.



Plate 72: Mud Volcano

Feature 9: Artistes Palette Hot Clear Pool

The main pool in the Artistes 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 its discharge channels.



Plate 73: Pool at Artistes Palette July 2010 on left,
July 2009 on right.

Indigenous Flora:

Prostrate kanuka and *Dicranopteris linearis*, which are both classed as ‚At Risk-Naturally Uncommon’ (in de Lange *et al.* 2009) and characteristic of geothermal areas, are present. *D. linearis* is known from only *c.*24 sites in New Zealand.

At least 50 plants of *Christella* aff. *dentata* (“thermal”) (classed as ‚At Risk-Declining’, in de Lange *et al.* 2009) are located on the eastern margins of Lake Ohakuri. None are known inland of the lake edge on the eastern side. At least another 40 plants are located in the wetland behind the accommodation facilities on the western side of the lake, along with several small populations of *Cyclosorus interruptus* („At Risk-Declining’ in de Lange *et al.* 2009), some of which are immature and are not expected to survive.

Schizaea dichotoma (classed as ‚At Risk-Naturally Uncommon’; in New Zealand, restricted to kauri forests of Northland and South Auckland, and locally at geothermal sites), *Calochilus robertsonii* (classed as ‚At Risk-Naturally Uncommon’), *Psilotum nudum* (restricted to geothermal and northern coastal areas), *Lycopodiella cernua*, arrow grass, *Schizaea bifida*, sea rush, manuka, turutu, and *Campylopus capillaceus*, which are characteristic of geothermal areas, are also present.

Species recorded from previous surveys at the site, but not during the 2004 survey or the current survey are: *Nephrolepis flexuosa* (in New Zealand, this species is confined to geothermal areas in the North Island) (classed as ‚At Risk-Declining’ in de Lange *et al.* 2009), and *Corunastylis pumila* (both classed as ‚At Risk-Naturally Uncommon’).

Other species of interest which occur at Orakeikorako include *Microtis parviflora*, *Thelymitra carnea* (Bellingham 1985), sea rush, *Limosella lineata*, and *Drosera binata* (Wildland Consultants 2009a).

Fauna:

Common indigenous and introduced bird species typical of the habitat are present, including grey warbler, silvereye, Australasian coot, fantail, Australasian harrier, tui, New Zealand scaup, North Island robin, spur-winged plover, mallard, yellowhammer, and magpie. One New Zealand

bush falcon (classed as 'Threatened-Nationally Vulnerable' in Miskelly *et al.* 2008) was recorded flying over the eastern side of the site on 2 February 2011. Grey duck classed as 'Threatened-Nationally Critical', and black shag 'At Risk-Naturally Uncommon', in Miskelly *et al.* (2008) have also been recorded on geothermal waters of Lake Ohakuri near this site. Wasps were recorded from the western wetland.

A small population of Long tailed bats (classed as 'Threatened-Nationally Vulnerable' in Miskelly *et al.* 2008) 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-sjZ12WehC4>: accessed 12 September 2011).

**Current Condition
(2011 Assessment):**

Overall, the site is in an excellent ecological condition. Recent removal (2008/2009) of wilding pines has improved the quality of the geothermal vegetation on the western side of this site markedly since 2004, with most tree stumps not visible to the naked eye from the car park on the eastern side. However, pampas has become established in places following pine control. Some small areas of wilding pines on the site are still to be controlled.

Vegetation on the western side of the river has localised patches of adventive weed species, and control of maritime pine, black wattle, blackberry, Japanese honeysuckle and bamboo should be undertaken.

**Threats/Modification/
Vulnerability:**

*Invasive pest plants
(2011 Assessment):*

Recent removal of wilding pines (maritime pine and radiata pine) has improved the ecological condition of this site. Several patches of wilding maritime pines remain, e.g. at E1874602 N3736832. Wilding pines are still present although at a lower, 1-5%, cover. Spanish heath (1-5 % cover), blackberry (1-5 % cover), bamboo (<1% cover), black wattle (1-5% cover), broom (<1% cover), Montpellier broom (<1% cover), and Japanese honeysuckle (1-5 % cover) are also present. Pampas has increased in cover and is now present at 1-5% cover. Arrow bamboo and blackberry was only recorded as common on the western side of the river. The eastern side of the river is unusual in that blackberry is extremely rare. Wildland Consultants (2008) only reported one plant from the eastern side of the river.

In April 2011, subsequent to the field component of this project, Waikato Regional Council funded the aerial control of pampas at this site.

*Human impacts
(2011 Assessment):*

Two royal fern plants were recorded at Orakeikorako on 11 March 2009 (Wildland Consultants 2009), which were removed. 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.

*Grazing
(2011 Assessment):*

The site is not farmed and stock do not have access to the site. Pig and possum sign were noted. Deer are also likely to utilise this site.

*Adjoining land use
(2011 Assessment):*

Pine plantation; Waikato River (Lake Ohakuri); accommodation facilities; tourist use; and nearby farmland.

Site Change:**Recent change:**

The boundaries of the site have been updated following pine control, and better quality aerial photographs provided in 2007. The most significant real change to the site is the management of pine trees on the eastern side of the river/lake. Otherwise, change is considered to be minimal compared with 2004 and 2007 surveys.

Historical:

In 1961 the Waikato River was artificially dammed to form Lake Ohakuri and c.75% of the geothermal features were destroyed by flooding (Lloyd 1972 in Given 1989a).

The reduction of the extent of geothermal vegetation and habitats is marked from the historical photos (Historical photos: SN 358 Run 1074 Photos 92-94, 1949), particularly on the western side of Lake Ohakuri, when compared with 2007 aerial photographs. Extensive areas of raw-soilfield were evident, presumably a large portion of it being geothermal, however this 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. A considerable loss of habitat with the construction of Lake Ohakuri is evident. Due to the steep nature of the landforms present an accurate measure of loss of geothermal is impossible; however, the previous estimates of 75% loss by Lloyd (1972) (particularly with the losses on the western side of the river) seem reasonable. In the areas that were not flooded by 1961, a greater extent of bare ground is visible in the historical photos (i.e. there is an increase in vegetation cover between 1961 and 2007). Increased vegetation could be due to a number of factors including reduced heat from geothermal systems. Development since the 1949 photos also includes a tourist operation and associated tracks.

Management Requirements:

Ongoing wilding pine and black wattle control work on the western side of the site will further enhance biodiversity values. Blackberry, Japanese honeysuckle and bamboo control here would allow geothermal species such as prostrate kanuka, mingimingi, *Cyclosorus interruptus*, and *Christella* aff. *dentata* (“thermal”) populations to expand their range. On the eastern side of the river the impacts of pampas expanding its density following pine control should be monitored and managed as necessary. Follow-up control of pines should be undertaken on a regular basis. The site should be regularly checked for new pest plant invasions, and when rare weeds such as royal fern are found, they should be removed.

Significance Level:

National (Table 1 - Criteria 1, 2, 3, 5, 7, 9; Table 2 - Factor 8).

Significance Justification:

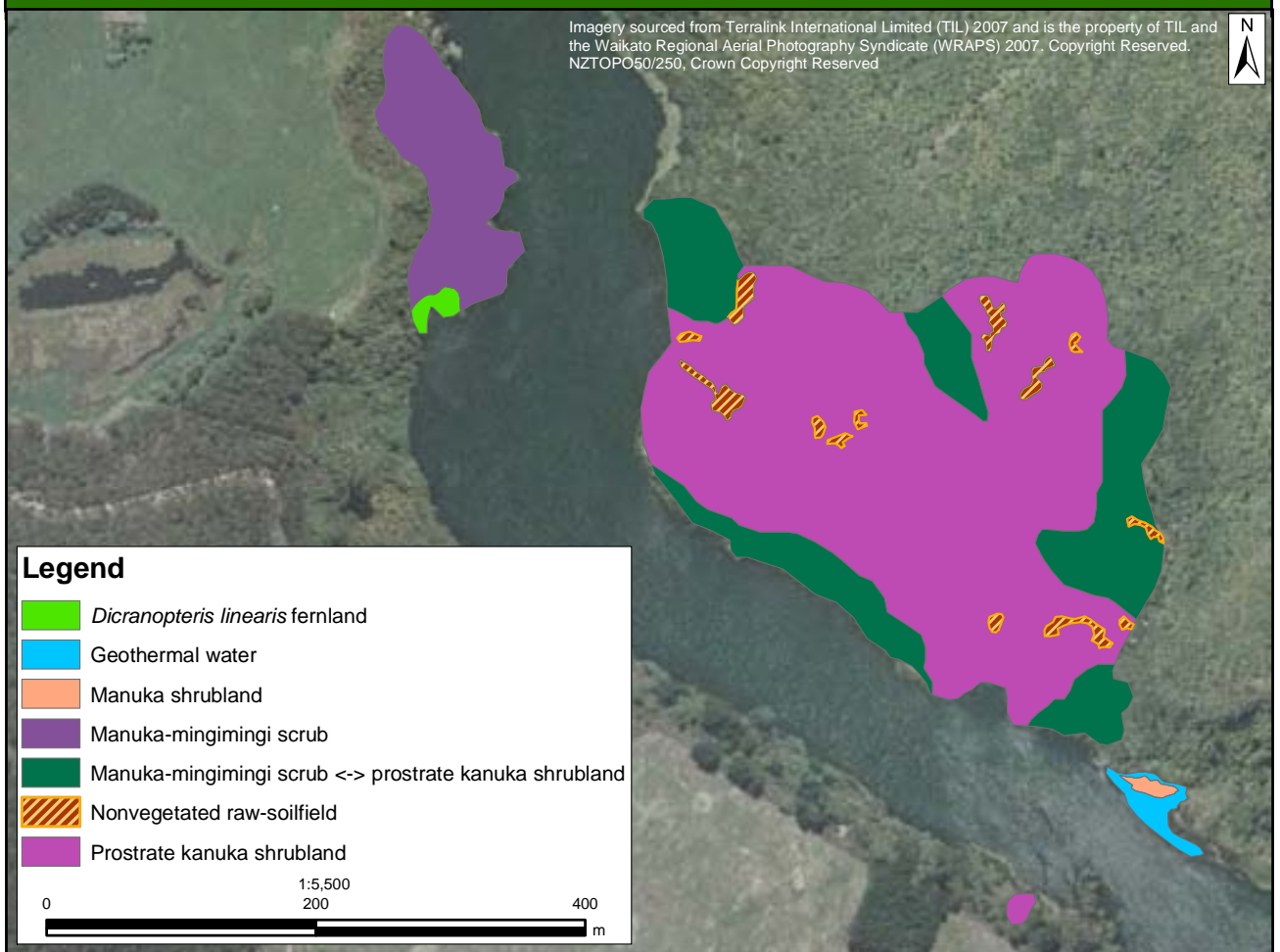
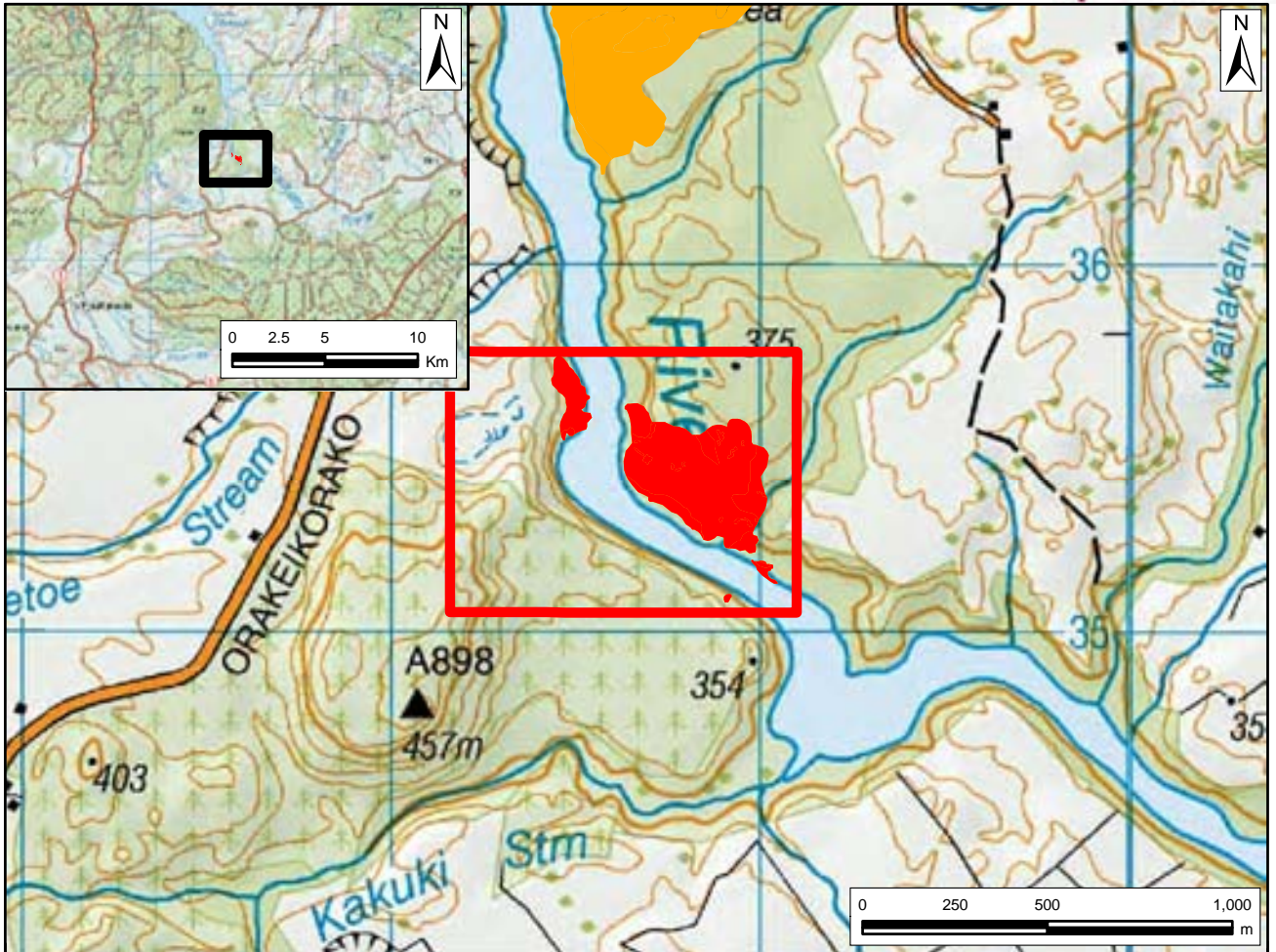
This site is of national significance because it is a good quality example of geothermal vegetation, a nationally uncommon habitat type, and one of the best examples in the Waikato Region. It includes populations of eight ‘At Risk’ species including: prostrate kanuka, *Christella* aff. *dentata* (“thermal”) 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 *Psilotum nudum*, and has a high diversity of geothermal features, including steamfields, mud pools, fumaroles, geysers, hot springs, and sinter terraces. Grey duck (classed as ‘Threatened-Nationally Critical’ in Miskelly *et al.* 2008) and black shag (‘At Risk-Naturally Uncommon’) have been recorded at the site.

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 A - the highest category.

References:

Beadel 1995b; Beadel & Bill 2000; Ecroyd 1986; Given 1989a & 1995; Smith-Dodsworth 1993; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004, 2007b, & 2009a&b.



RED HILLS

Site Number: OKV04¹
Grid Reference: NZTopo50 BF36 748 354
GPS Reference: NZTM E1874822 N5735404
Local Authority: Rotorua/Taupo
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Submontane
Tenure: Protected (Lake Ohakuri Conservation Area administered by DOC)
Altitude: c.300-340 m
Extent of Geothermal Habitat: c.11.6 ha
Extent of Geothermal Vegetation: c.11.5 ha
Date of Field Survey: 16 June 2004 (part of site field surveyed on 8 March 2007)

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
04.03 04.03.02	<p>Manuka-dominant scrub</p> <p>Manuka-mingimingi scrub Manuka and mingimingi are dominant, with scattered kanuka and prostrate kanuka, as well as occasional karamu and kohuhu. Emergent wilding pines (maritime pine and radiata pine) are scattered throughout. The groundcover comprises <i>Gleichenia microphylla</i>, bracken, <i>Paesia scaberula</i>, <i>Histiopteris incisa</i>, kiokio, and turutu with large local patches of <i>Dicranopteris linearis</i>. <i>Dicranoloma</i> sp. (a moss) is also abundant. Fumaroles are scattered throughout and there are a number of seepages which flow directly into Lake Ohakuri. Occasional Spanish heath and Chinese privet plants are present on the margins.</p>	Hillslopes and alluvial terraces	c. 1.3 ha
04.03.12	<p>Manuka-mingimingi scrub ↔ prostrate kanuka shrubland A mosaic of predominantly manuka-mingimingi scrub (refer to 04.03.02) with local prostrate kanuka shrubland (refer to 05.01.01) 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 maritime pines are present with occasional <i>Christella</i> aff. <i>dentata</i> ("thermal") on lake margins.</p>	Alluvial terrace, hillslopes	c.2.5 ha
05.01 05.01.01	<p>Prostrate kanuka-dominant shrubland</p> <p>Prostrate kanuka shrubland This type comprises a low discontinuous canopy of prostrate kanuka (c.0.5 m high) with mingimingi and monoao scattered throughout. The groundcover comprises local patches of moss, most notably <i>Dicranoloma</i> sp., <i>Campylopus capillaceus</i> and <i>Lycopodiella cernua</i>. Local patches of mature wilding pines (mainly maritime pine) are present.</p>	Hillslopes	c.7.3 ha

¹ Previously identified as U17/10 in Wildland Consultants (2004).

VEGETATION		LANDFORM	EXTENT
CODE	TYPE		
05.03 05.03.01 ¹	Manuka-dominant shrubland Manuka shrubland Scattered manuka over rank exotic grassland species (e.g. tall fescue, creeping bent, and ragwort - <i>Jacobaea vulgaris</i>), as well as occasional Spanish heath and prostrate kanuka. Several areas of geothermal sandfield. Water temperatures were recorded up to 69 °C on lake margins.	Lake margins	<0.1 ha
07.01 07.01.01	Dicranopteris-dominant fernland Dicranopteris fernland A small south-facing section on the western bank of the lake with a steaming fumarole. <i>Dicranopteris linearis</i> forms the cover.	Alluvial terrace	c.0.1 ha
07.01.01 ²	Dicranopteris fernland (not mapped) Many small areas are almost completely dominated by <i>Dicranopteris linearis</i> .	Hillslopes	
22.01 22.01.01	Geothermal water Geothermal water	Open water	c.0.1 ha
28.01 28.01.01	Nonvegetated raw-soilfield Nonvegetated raw-soilfield Sinter deposits and mineral pools occur throughout this feature, with some geysers along the lake edge. There are patches of bare ground, craters, steaming fumaroles, and mud pools.	Flat, hillslopes	c. 0.3 ha

Indigenous Flora: Extensive areas of prostrate kanuka and *Dicranopteris linearis* (both classed as „At Risk-Naturally Uncommon’ in de Lange *et al.* 2009), are present at this site. *D. linearis* is known from only c.24 sites in New Zealand. Fifty mature plants of *Christella* aff. *dentata* (“thermal”) (classed as „At Risk-Declining’ in de Lange *et al.* 2009) were recorded in March 2007; most of these were present near a hot stream in the south of the site (GPS reference: E1874474 N5735523). *Campylopus capillaceus*, a characteristic feature of geothermal areas, is also present.

Fauna: Common indigenous and introduced bird species typical of the habitat are present including grey warbler, silveryeye, North Island fantail, Australasian harrier, spur-winged plover and Australian magpie.

Current Condition (2007 Assessment): Generally the site is in excellent condition with large areas of geothermal vegetation with no pest plants. Whilst wilding pines are locally prominent, few other pest plant species are present.

**Threats/Modification/
Vulnerability:**

Invasive pest plants (2007 Assessment): Wilding pines (maritime pine and radiata pine) are the main invasive exotic plant species, forming a c.6-25% cover. There has been extensive control of wilding pines at the site. Chinese privet (currently <1% cover) is present

¹ Field survey 2007.

² Areas of this vegetation type occur within the area mapped as 04.03, however were too small to be mapped separately.

at the camp/picnic area adjacent to the southern side of the site, and is beginning to invade the manuka-mingimingi scrub. It could spread rapidly if it is not controlled.

Human impacts
(2007 Assessment):

Direct human impact is low, as the site is relatively inaccessible and appears dangerous. A bath has been constructed near the south end of the site. Some control of wilding pines has been undertaken at the site. The vegetation of the site is very susceptible to damage by trampling.

Grazing
(2007 Assessment):

Livestock do not have access to this area.

Adjoining land use
(2007 Assessment):

Pine plantations and the Waikato River.

Site Change:

Recent change:

No known changes to the extent and quality of geothermal activity at this site. Any changes made to site boundaries are based on higher quality aerial photographs, rather than any real change to geothermal extent.

Historical:

The site has become considerably reduced in size since dam construction on the Waikato River in 1961 resulted in the formation of Lake Ohakuri. An assessment of aerial photographs taken in 1949 (Historical photos: SN 358 Run 1074 Photos 92-94, 1949) shows extensively 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:
Significance Level:

Wilding pines and Chinese privet should be controlled.

National (Table 12 - Criteria 1, 3, 5, 7, 9; Table 2 - Factors 8).

Significance Justification:

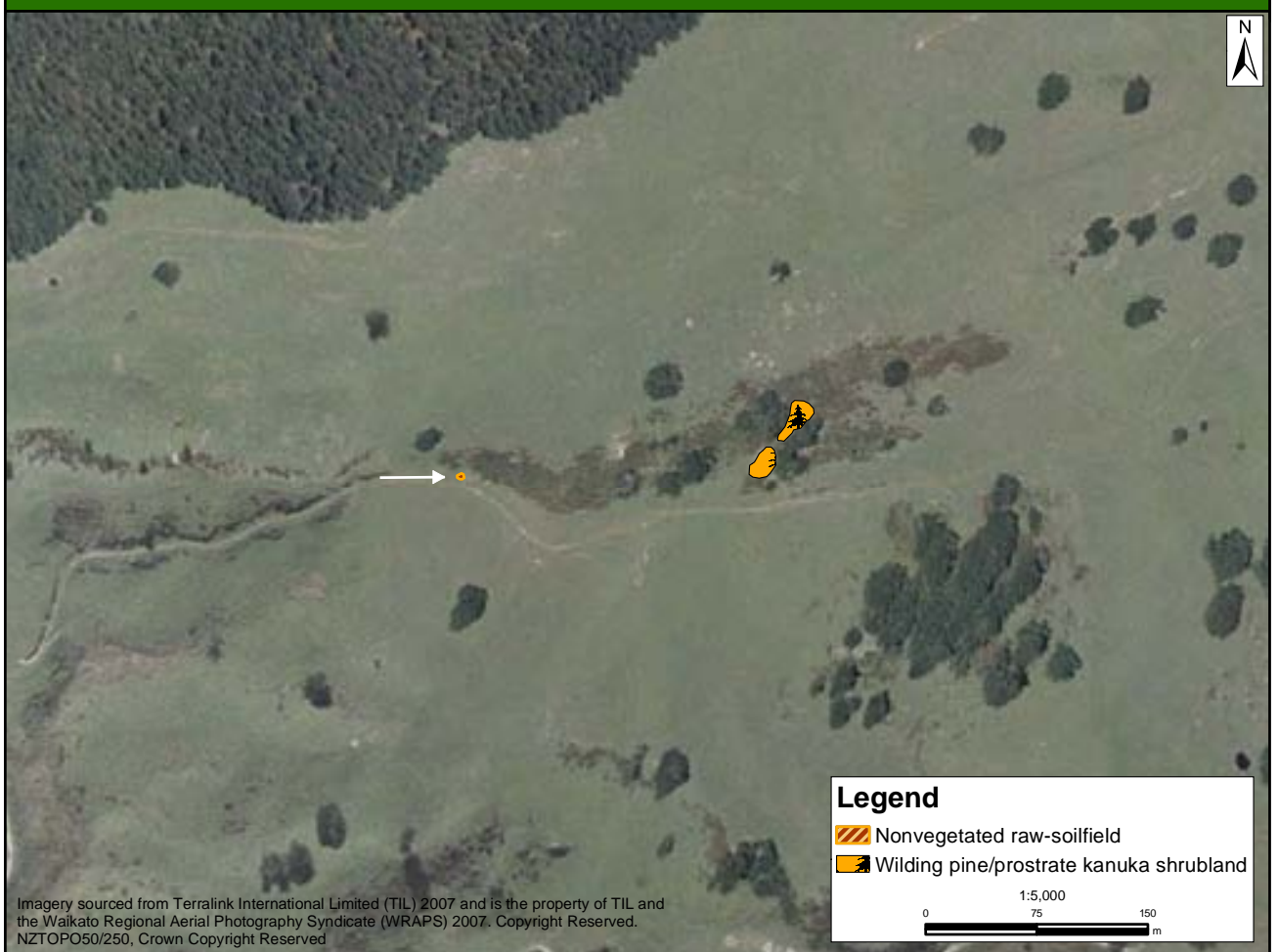
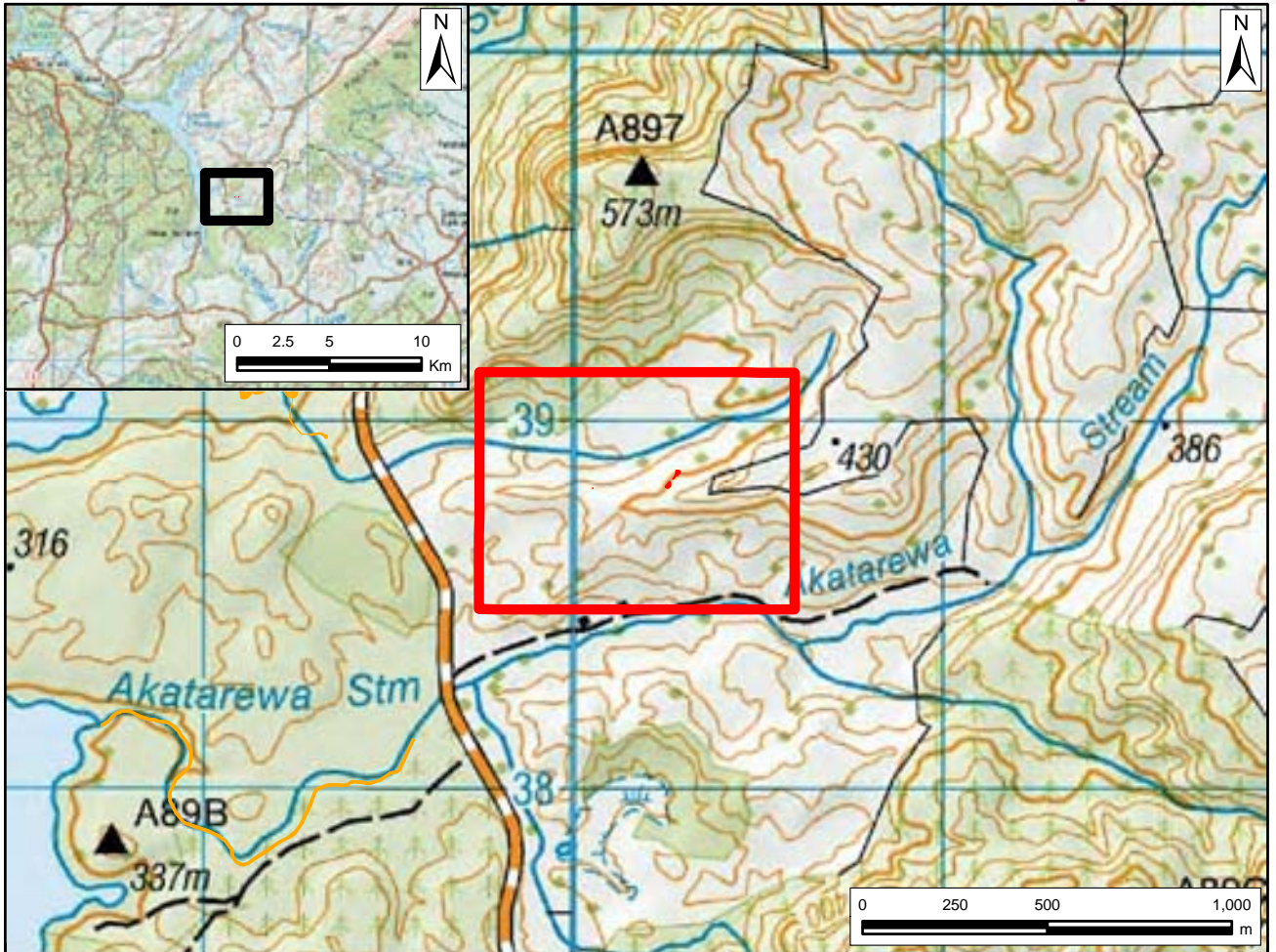
This site is nationally significant because it is a very good quality example of a habitat type that is nationally uncommon (i.e. geothermal). Together with Orakeikorako (site OKV03, c.1 km to the north) it comprises one of the best examples of geothermal vegetation in the Waikato Region. Red Hills has an extensive area of prostrate kanuka shrubland, and stable, relatively large, populations of *Christella* aff. *dentata* ("thermal"), and *Dicranopteris linearis* (all 'At Risk' species).

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 A - the highest category.

References:

Beadel 1995b; Beadel & Bill 2000; Given 1996; Unpublished Atiamuri PNAP data 1995; Wildland Consultants 2004 & 2007b.



AKATAREWA EAST

Site Number: OKV05
Grid Reference: NZTopo50 BF37 763 389
GPS Reference: NZTM E1876276 N5738860
Local Authority: Rotorua
Ecological District: Atiamuri
Geothermal Field: Orakeikorako
Bioclimatic Zone: Submontane
Tenure: Unprotected private land
Altitude: 390 m
Extent of Geothermal Habitat: <0.1 ha
Extent of Geothermal Vegetation: <0.1 ha
Date of Field Survey: 3 February 2011

Code	Type	Landform	Extent
05.01 05.01.14	Prostrate kanuka-dominant shrubland Exotic pine/prostrate kanuka shrubland One tall (c.20 m) radiata pine is emergent over prostrate kanuka, with scattered Spanish heath, buddleia, paspalum and sweet vernal. Other species include blackberry, bracken, manuka, <i>Cheilanthes sieberi</i> and occasional patches of <i>Dicranopteris linearis</i> .	Steep hillslope	<0.1 ha
28.01 28.01.01	Nonvegetated raw-soilfield Nonvegetated raw-soilfield A small (c.0.5 × 0.2 m) fumarole alongside the cattle race is surrounded by pasture which is dominated by sweet vernal and browntop. <i>Paesia scaberula</i> and Spanish heath seedlings are also present.	Hillslope	<0.1 ha

Indigenous Flora: Prostrate kanuka and *Dicranopteris linearis*, which are both classified as „At Risk-Naturally Uncommon’ (de Lange *et al.* 2009) and are characteristic of geothermal vegetation, are present. *Dicranopteris linearis* is present in small patches but is known from only c.24 sites in New Zealand.

Fauna: Greenfinch and yellowhammer were recorded. Other common pasture birds are likely to be present.

Current Condition (2011 Assessment): This site comprises geothermal features and vegetation surrounded by farmland and pine plantations. Domestic stock has access to this site but parts of the site are on a steep hill-face that is largely inaccessible to stock.

Threats/Modification/Vulnerability:

Invasive pest plants (2011 Assessment): Radiata pine (5-25% of cover) is present on the geothermal margins and Spanish heath (1-5% cover) is scattered throughout. Buddleia (1-5% cover) and blackberry (<1% cover) are also present.

<i>Human impacts (2011 Assessment):</i>	Site adjacent to farmland.
<i>Grazing (2011 Assessment):</i>	This site is unfenced and grazed. Some parts of the site are steep and stock are unlikely to be a threat in these areas.
<i>Adjoining land use (2011 Assessment):</i>	Farming and pine plantation.
Site Change:	
<i>Recent change:</i>	Not assessed. There is no known ecological information for this site prior to the current study.
<i>Historical:</i>	Site not assessed, no historical aerial photos found. However, since the site is small and is in a gully it is unlikely that change would be able to be identified between historic and recent aerial photographs for this site.
Management Requirements:	The radiata pine should be removed, and the site fenced and retired from grazing. The <i>Dicranopteris linearis</i> population should be monitored.
Significance Level:	Local (Table 1 - Criteria 3, 5; Table 2- Factor 19)
Significance Justification:	Akatarewa East is locally significant because it comprises a small example of geothermal vegetation, which is a nationally uncommon habitat type. It also provides habitat for two „At Risk’ plant species: prostrate kanuka and <i>Dicranopteris linearis</i> .
Notes:	There may be more features and small geothermal areas on the vertical face but access is an issue. This site was identified for this study based on a summary of known geothermal features in Hochstein (2007 Figure 4.1, Page 92). The Hochstein study was based on summaries of geothermal features in the Orakeikorako and Te Kopia geothermal fields from Lloyd (1974) and Bignell (1994).
References:	Bignell 1994; Hochstein 2007; Lloyd 1974.