Geothermal vegetation of the Waikato Region: 2023 update

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ABSTRACT

We present the findings from our 2022-2023 update to the inventory of geothermal habitats in the Waikato Region. This is an updated inventory of the current distribution, condition, and extent of geothermal vegetation and habitats in the Waikato Region, where almost 74% of New Zealand's geothermal systems occur. Forty-six sites with geothermal vegetation, within 14 Geothermal Systems were identified, mapped, described, and assessed for significance. For each site, the vegetation, site boundaries, and location relative to other sites were mapped. Changes in site condition, management actions, and threats were all considered. Since the last inventory study in 2014, an additional 142.8 hectares of geothermal vegetation has been mapped, however most of this area is the result of discovery of additional areas of existing habitat as the quality of aerial photography continues to improve. Real increase in vegetation extent was noted for two sites covering only relatively small areas. Overall, the extent of geothermal vegetation across the Waikato Region has been relatively stable in the last ten years. Minor reductions have occurred at some sites due to increases in pest plant cover and, in some cases, from herbicide use on site margins. The condition of many sites has improved as a result of ecological restoration effort. However, some sites are in poorer condition since the last survey, mainly as a result of the expansion of pest plant infestations. Many geothermal areas have been fenced in the past 10+ years, but in many cases where no other restoration effort has taken place this has resulted in a significant increase in blackberry.

1. INTRODUCTION

Waikato Regional Council (WRC) has engaged Wildland Consultants to undertake inventory studies of geothermal vegetation in the Waikato Region on multiple occasions since 2000. Major inventory updates have occurred in 2004, 2012, and 2014 (Wildland Consultants 2000, 2004, 2012, 2014). In 2022-2023, an update was undertaken (Wildland Consultants 2023a), using the most recently-available aerial photographs. The total area of geothermal vegetation mapped has increased in each study, and over time additional sites have been incorporated based on new information. This paper provides an overview of the latest inventory study of the current distribution, extent, and character of geothermal vegetation in the Waikato Region, and includes an assessment of the relative significance of each site based on criteria defined in the Waikato Regional Policy Statement (WRC 2016). This study updates the 2014 geothermal inventory report (Wildland Consultants 2014), and will facilitate management of the varied geothermal resources, as required by the Waikato Regional Policy Statement.

Most of the geothermal vegetation in Aotearoa New Zealand occurs in the Taupō Volcanic Zone (TVZ), with *c.*75% of the geothermal vegetation within the TVZ located in the Waikato Region (Figure 1). Waikato Regional Council therefore has significant responsibilities for the management of geothermal systems and associated habitats.

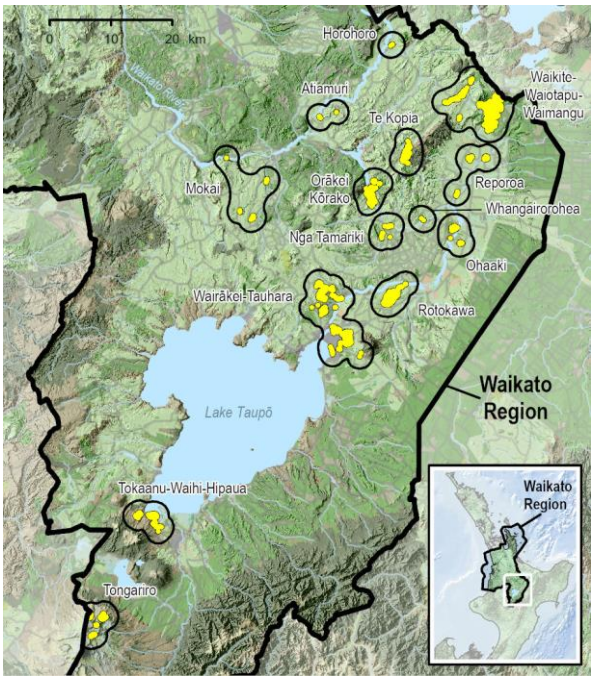

Figure 1: Location of geothermal vegetation by geothermal systems in the Waikato Region. The areas of geothermal vegetation are shown in yellow.

Geothermal activity is associated with the surface release of geothermal heat. This heat release is a significant environmental stressor, as it is associated with elevated subsurface soil temperatures, boiling groundwater and surface water, and the emission of steam and gases, including carbon dioxide and hydrogen sulphide. These environmental stressors limit the survivorship and growth of most plants and animals. As a result, geothermal habitats are occupied by a unique assemblage of plants and animals that are tolerant of the heat and chemical induced stress, particularly the subsurface soil temperature. Geothermal vegetation is defined as "…terrestrial and emergent vegetation… communities that have compositional, structural, and/or growth rate characteristics determined by current and former inputs of geothermally derived energy (heat) or material (solid, fluid or gas)" (Merrett and Clarkson 1999). These assemblages include species normally found in tropical and subtropical climates, and species capable of surviving high soil temperatures or hydrothermally altered soils (Given 1980). Geothermal vegetation is naturally rare in Aotearoa New Zealand (Williams et al. 2007) and internationally.

Most of the Waikato Region's geothermal resources are located in 15 discrete areas of geothermal activity known as geothermal systems (Luketina 2022). Site information and

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inventory assessments are presented according to their geothermal systems and fields in this paper. The terms geothermal system and geothermal field have most recently been defined by (Cody et al. 2021). A geothermal system (GS) is 'an individual body of geothermal energy (including geothermal water), material containing heat or energy surrounding any geothermal water, and all plants, animals, micro-organisms and other characteristics dependent on the geothermal energy'. A geothermal system may contain more than one geothermal field. A geothermal field (GF) is 'an area of separate upflow with its own set of surface features'. The following three Geothermal Systems have been subdivided into Geothermal Fields for this inventory: Wairākei-Tauhara, Tokaanu-Waihi-Hipau, and Waikite-Waiotapu-Waimangu. Geothermal fields and systems are more relevant to the character of geothermal ecosystems than some other measures often used in ecological surveys such as ecological districts and district boundaries, and avoids splitting sites within geothermal systems that span two ecological districts.

2. METHODS

2.1 Site review and amalgamation

Since the 2014 geothermal inventory report (Wildland Consultants 2014), the names and groupings of geothermal sites in the Waikato Region have been updated. The groupings of geothermal sites are somewhat arbitrary; however, groupings in the 2023 assessment (Wildland Consultants 2023a) are generally based on geothermal surface manifestations that are located adjacent to each other, where it is easy to assess geothermal vegetation as single unit during fieldwork, and where sites are clearly differentiated from each other. Many new areas of geothermal vegetation have been identified during the series of inventory surveys between 2000 and 2023. Over time, this has caused a substantial increase of sites. Some of the smaller sites that were identified individually in 2014 occur near a much larger site, and are part of the wider geothermal activity of the neighbouring site (e.g. several small sites near Te Kopia). Meanwhile, other large sites are semi-continuous areas of geothermal habitat that means there is no clear boundary between the sites (e.g. Orākei Korako-Red Hills). For these reasons, the boundaries of sites have been reviewed and many sites have been amalgamated. As a result of this process the number of sites was reduced from 64 sites in 2014, to 46 sites in 2023 (Wildland Consultant 2014, 2023a). Names of sites have been updated to reflect updated site boundaries, and sometimes have changed based on advice on appropriate spelling. One new area found since the 2014 inventory was determined to be isolated enough to be assessed as a new site: Rotopaunga in Tongariro GS. See Figure 1 for the locations and Table 1 for site names by geothermal system and geothermal field.

2.2 Field survey and assessment

For the 2022-23 study, field surveys of 28 sites (or parts of sites) were undertaken between 2022 and 2023. For an additional 10 sites, site visits were also made between 2018 and 2021, and data from these visits were determined to be recent enough removing the need for a field visit in 2022-23. Two sites have not been visited at all in this inventory study since 2000 due to lack of landowner permission. For the remainder of sites, the information is based on field surveys between 2004 and 2014.

For all sites (including those not visited during the 2022-23 survey), the extent of geothermal vegetation and habitat types were mapped onto the most recently-available aerial photography. Most of the Waikato Region north of Lake Taupō is covered by 2021 WRAPS photography, but sites to the south were mapped using a combination of 2021 WRAPS, 2021 Urban, 2019 Western Settlements, and 2019 Waikato 0.3 m Rural aerial photographic series. Geothermal vegetation types present were described for each site, and the extent of each type was mapped onto colour printouts of digital aerial photographs at A3 size and scale of 1:1,000. The extent (in hectares) of each geothermal vegetation and habitat type in each site was calculated using mapped polygon size.

Field assessments addressed the following components for each site: indigenous flora and fauna (including threatened species); current condition of vegetation and habitats; key geothermal ecosystems present; invasive exotic plants; human impacts; grazing; adjoining land use, and management requirements.

Site information sheets were prepared and included: information on the extent and composition of vegetation and habitat types present; the presence of threatened plant or animal species within a site; and threats to the vegetation and habitats at the site:

The relative significance of each geothermal site was assessed as part of the current study using the criteria specified in the Waikato Regional Policy Statement (WRC 2016). Using these criteria, each site was assigned to one of four levels of relative significance: Internationally Significant, Nationally Significant, Regionally Significant, or Locally Significant.

We also followed the WRC system for classification of geothermal resources, and determined the extent to which the mapped areas fell into the categories: development; limited development; research; protected, and small (WRC 2016).

Only sites with terrestrial or emergent wetland vegetation were assessed as part of this study. Horomatangi Geothermal System was not included in the study as all surface manifestations are present entirely on the Taupō lake bed. Terrestrial habitats include geothermal vegetation dominated by vascular and non-vascular plants, and geothermally-influenced bare ground (unvegetated or with a very low vegetation cover). Wetland habitats include emergent wetland vegetation and open geothermal water. Geothermal water was only mapped if it was an integral part of a geothermal site; geothermal streams flowing from a site without associated geothermal vegetation are not typically mapped.

3. NATURAL DYNAMICS

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

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Table 1: Geothermal sites in the Waikato Region by geothermal system and geothermal field, 2023 inventory.

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

4. GEOTHERMAL VEGETATION - OVERVIEW

Forty-six sites with geothermal vegetation, within 14 geothermal systems and 17 geothermal fields were identified, mapped, and described, and their significance assessed in the 2023 geothermal inventory report for Waikato Region (Wildland Consultants 2023a). The 46 sites contained c.1,016 hectares **(ha)** of geothermal habitat, which comprises c.894 ha of geothermal vegetation (including geothermally-influenced bare ground) and c.123 ha of geothermal water. Broad groupings of geothermal vegetation and habitats within the Waikato Region include geothermally-influenced bare ground (c.97 ha), emergent wetland vegetation (c.114 ha), and terrestrial vegetation (c.683 ha) (see Appendix 1). Terrestrial vegetation includes all vegetation that was not mapped as geothermal wetland and geothermally-influenced bare ground; for example, forest, scrub, shrubland, fernland, and mossfield etc.

5. CHANGES IN EXTENT AND CONDITION OF GEOTHERMAL VEGETATION

A total of 750 ha of geothermal vegetation were mapped in 2014, compared to 894 ha in 2023. Since the last inventory study in 2014, an additional 142.8 ha of geothermal vegetation has been mapped, however most of this area is the result of discovery of additional areas of existing habitat as the quality and resolution of aerial photography continues to improve. Waikato Regional Council obtained very high-resolution images (0.06 metres resolution) of some geothermal sites in the Region in 2021, and these have contributed to more accurate mapping and identify areas not

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mapped previously. Pine plantation harvest has also resulted in additional areas being mapped, as these areas were previously obscured. Indigenous forest also obscures geothermal habitat at some sites, such as Maunga Kākaramea (Rainbow Mountain), Te Kopia, and Orākei Kōrako and Red Hills, and additional geothermal features are likely to be present in these areas.

Overall, the extent of geothermal vegetation across the Waikato Region has been relatively stable in the last ten years. Real changes in mapped area of geothermal vegetation between 2014 and 2023 are summarised in Table 2. Real increase in vegetation extent was noted for only two sites. At Waikite Valley this increase was due to restoration effort in the wetland area. The increase at Te Maari Craters is because of the 2012 eruptions which resulted in an expansion of geothermal habitat.

Table 2: Changes in mapped area (hectares) of geothermal vegetation by geothermal system and geothermal field in the Waikato Region between 2014 and 2023.

Geothermal System	Geothermal Field	No of Sites	Area of Mapped Geothermal Vegetation (hectares)		Overall Extent of Change (hectares)
			2014	2023	
Atiamuri	Atiamuri	2	0.1	0.2	0.07
Horohoro	Horohoro	1	<0.1	<0.1	0
Mokai	Mokai	4	3.1	2.9	-0.2
Nga Tamariki	Nga Tamariki	2	1.3	5.1	3.8
Ohaaki	Ohaaki	2	18.0	18.4	0.4
Orākei Kōrako	Orākei Kōrako	4	64.2	74.7	10.5
Reporoa	Reporoa	3	10.0	11.1	1.1
Rotokawa	Rotokawa	1	114.8	144.8	30.0
Te Kopia	Te Kopia	2	65.1	68.5	3.4
Tokaanu-Waihi-Hipaua	Hipaua	1	12.1	12.7	0.6
	Tokaanu	3	47.1	53.2	6.1
	System Subtotal	4	59.2	65.9	6.7
Tongariro	Tongaririo	4	28.6	49.8	21.2
Waikite-Waiotapu-Waimangu	Waikite	2	20.2	22.8	2.6
	Waiotapu	3	221.1	265.0	43.9
	System Subtotal	5	241.3	287.9	46.6
Wairākei-Tauhara	Tauhara	5	55.6	66.1	10.5
	Wairakei	6	89.2	97.9	8.7
	System Subtotal	11	144.8	164.0	19.2
Whangairorohea	Whangairorohea	1	<0.1	<0.1	0
Grand Total		**46**	**750.5**	**893.3**	**142.8**

Minor real reductions have occurred at some sites since 2014 due to increases in pest plant cover and, in some cases, from herbicide use on site margins. Small losses of geothermal vegetation were evident at some sites, due to conversion to farming, industrial development, or plantation forestry, e.g. Tauhara South, East Taupō, Te Kopia, Waiotapu, and Ohaaki Steamfield East. However, decreases in vegetation extent that are large enough to be clearly identified, against changes that are a result of more accurate mapping (i.e. true decreases), have not occurred.

Recent changes have been occurring since the inventory was completed at the Otumuheke site, though we have not detailed this due to a lack of recent aerial photographs. At this site, the geothermal spring at the upper end of the Otumuheke Stream valley has reduced in flow over the last 10 years, and has retreated at least 350 metres down the valley. This has resulted in a reduction in geothermal wetland extent, and loss of steamy habitat for threatened fern populations (Bycroft *et al*. In press).

There have also been changes in condition of geothermal sites (improving and declining) rather than changes in extent. New local geothermal features and decline of nearby features were noted at a few sites. In farm paddocks and fenced features at Waiotapu and Te Kopia there were localised movements of some features, rather than increases or decreases in extent.

The condition of many sites has changed positively as a result of ecological restoration effort. However, some sites are in poorer condition since the last survey, mainly as a result of pest plant expansion. It was noted in particular that many geothermal areas have been fenced in the past 10+ years, but that in some cases, this has resulted in a significant increase in blackberry (Rubus fruticosus agg.), pampas (Cortaderia selloana), and other pest plants where no other restoration effort such as planting of indigenous species has taken place.

6. ASSESSMENT BY WRC CLASSIFICATION FOR RESOURCE USE

The WRC has classified the geothermal resources of the Waikato Region into five categories:

- Development
- Limited Development
- Research
- Protected
- Small

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A total of c.335.3 ha of geothermal vegetation was mapped in fields classified as Development Geothermal Systems, comprising c.37% of the mapped geothermal vegetation in the Waikato Region. Development Systems allow for large-scale use of the geothermal resources as long as they are undertaken in a sustainable and environmentally-responsible manner.

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

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

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

7. ECOLOGICAL SIGNIFICANCE

Each of the 46 sites meets one or more of the criteria for ecological significance in the Waikato Regional Policy Statement (WRC 2016). Six entire sites, and part of three other sites encompassing c.446 ha or 44% of geothermal habitat in the Waikato Region, were identified as being of International significance. Ten entire sites, and part of three other sites encompassing c.434 ha or 43% of geothermal habitat in the Waikato Region, were identified as being of National significance. Eight entire sites, and part of seven other sites encompassing c.122.2 ha or 12% of geothermal habitat in the Waikato Region, were identified as being of Regional significance. The remainder of the sites (12 entire sites, and parts of nine other sites encompassing c.17 ha, or c.2% of geothermal habitat in the Waikato Region) were identified as being of Local significance. Ranking of areas of geothermal vegetation by system and field are presented in Table 3.

Table 3: Significance ranking (International, National, Regional, and Local) of geothermal vegetation and habitat (hectares) by geothermal system and geothermal field in the Waikato Region.

Geothermal System	Geothermal Field	No. of Sites	Ecological Significance Ranking			
			International	National	Regional	Local
Atiamuri	Atiamuri	2		0.2		<0.1
Horohoro	Horohoro	1				<0.1
Mokai	Mokai	4		1.2		2.2
Nga Tamariki	Nga Tamariki	2			5.9	
Ohaaki	Ohaaki	2			19.7	0.6
Orākei Kōrako	Orākei Kōrako	4		81.1		0.1
Reporoa	Reporoa	3			6.4	5.2
Rotokawa	Rotokawa	1		217.8		
Te Kopia	Te Kopia	2	68.5		0.1	0.8
Tokaanu-Waihi-Hipaua	Hipaua	1		12.8		
	Tokaanu	3	47.5	7.8	2.1	<0.1
	System Subtotal	4	47.5	20.6	2.1	<0.1
Tongariro	Tongariro	4	52.9			
Waikite-Waiotapu-Waimangu	Waikite	2		25.1		0.4
	Waiotapu	3	276.6	9.2	10.2	
	System Subtotal	5	276.6	34.3	10.2	0.4
Wairākei-Tauhara	Tauhara	5		3.8	56.2	6.4
	Wairākei	6		75.9	21.6	0.9
	System Subtotal	11	0	79.7	77.8	7.3
Whangairorohea	Whangairorohea	1				0.2
Grand Total		**46**	**445.5**	**434.9**	**122.2**	**16.8**

8. CONCLUSION

Inventories of geothermal sites in the Waikato Region provide an ongoing record of change in a Nationally rare ecosystem. As the quality of aerial photography and site knowledge has improved, the extent of areas mapped in these surveys has increased. Some changes have been readily identified as being real changes, and other monitoring such as transect monitoring at sites (e.g. in the Wairākei-Tauhara, Rotokawa, Nga Tamariki, and Ohaaki Geothermal Systems) has enabled the identification of local changes in vegetation condition (Wildland Consultants 2021a, 2021b, 2022a, 2022b, 2022c, 2022d). Real change has been identified in

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relation to natural events, such as the 2012 eruptions, as well as through the loss of parts of sites for developments like roads, farming, residential and industrial developments. The information collected in these inventory surveys, particularly on ecological threats and changes to extent, has been used to provide management recommendation advice on pest plant control, pest animal control, and fencing to exclude farm animals from sites (Wildland Consultants 2023b). Regular updates to these inventories (e.g. every five years) are recommended, as many changes are only evident when viewed during field surveys and/or on high-quality aerial photographs. Sites of highest priority for future field surveys, if resources are limited, are those of highest ecological value (International, National, Regional) and those where no other formal monitoring is being undertaken.

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Appendix 1: Area (ha) of each habitat type within geothermal systems and fields in the Waikato Region.

Geothermal System	Geothermal Field	Geothermal Habitats (ha)					Total Site Area (ha) (including water)
		Geothermal Water (ha)	Geothermal Vegetation (ha)				
			Terrestrial Vegetation (including bare ground)	Geothermally-Influenced Bare Ground	Emergent Wetland	Total Geothermal Vegetation	
Atiamuri	Atiamuri	<0.1	0.2	0.1	0.0	0.2	0.2
Horohoro	Horohoro	<0.1	<0.1	<0.1	<0.1	0.1	0.1
Mokai	Mokai	0.4	2.7	0.5	0.3	3.0	3.3
Nga Tamariki	Nga Tamariki	0.9	1.4	0.2	3.7	5.1	5.9
Ohaaki	Ohaaki	1.9	17.2	2.3	1.2	18.4	20.3
Orākei Kōrako	Orākei Kōrako	4.4	70.9	2.4	3.8	74.7	79.1
Reporoa	Reporoa	0.5	8.97	2.1	2.1	11.1	11.54
Rotokawa	Rotokawa	72.9	135.2	11.0	9.7	144.8	217.8
Te Kopia	Te Kopia	0.9	66.2	4.7	2.4	68.6	69.5
Tokaanu-Waihi-Hipaua	Hipaua	0.0	12.7	0.7	0.0	12.7	12.7
	Tokaanu	4.2	5.8	0.2	47.4	53.2	70.9
	System Subtotal	4.2	18.5	0.9	47.4	65.9	83.6
Tongariro	Tongariro	2.4	49.59	48.7	0.2	49.8	52.2
Waikite-Waiotapu-Waimangu	Waikite	2.7	12.4	0.7	10.4	22.8	25.5
	Waiotapu	30.9	234.1	11.9	31.2	265.3	296.0
	System Subtotal	33.7	246.5	12.7	41.6	288.1	321.6
Wairākei-Tauhara	Tauhara	0.3	65.0	7.3	1.1	66.1	66.4
	Wairākei	0.5	97.8	3.8	<0.1	97.9	98.4
	System Subtotal	0.8	162.8	11.1	1.2	164.0	164.8
Whangairorohea	Whangairorohea	0.1	0.1	0.0	0.0	0.1	0.2
Grand Total		**123.0**	**780.1**	**96.7**	**113.6**	**893.7**	**1016.5**

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