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Report: 4363
 Client: WRC
 Ref: 01 1769
 Path: E:\gis\EW_Geothermal_Sites_2003\2017\mxd\June2017\Te_Maari_Craters.mxd
 File: Te_Maari_Craters.mxd

Te Maari Craters

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Scale: 1:7,500
 Date: 21/06/2017
 Cartographer: JO
 Format: A4

TE MAARI CRATERS

Area:	Geothermal Habitat: c.9.5 ha Geothermal Vegetation: c.8.4 ha
Geothermal Field:	Tongariro
Site Description:	<p>Te Maari Craters are located within the Tongariro Geothermal Field on the northern slopes of the Mt Tongariro National Park. The park is also a World Heritage Site. Geothermal features comprise vents on the edge of Te Maari Crater, geothermal lake/water in the base of craters, geothermal soils, and steaming ground. This site is c.1.5 km to the east of an internationally recognised walking track (Tongariro Alpine Crossing). The vegetation has a low diversity of plant species, but it is habitat of exceptional quality, with no recorded pest plant species and few human-induced impacts. The area of geothermal activity has increased markedly at the site following two eruptions of the Upper Te Maari Crater on 6 August and 21 November 2012. The geothermal activity is now visible from tens of kilometres from the volcano including from Taupō Township, and is considerably more visible from the Tongariro Alpine Crossing. An interesting feature of the geothermal vegetation is the presence of species at much higher altitude than would normally be expected (e.g. <i>Lycopodiella cernua</i>). While there are usually no restrictions on public access to the craters, it is not actively encouraged, and it occurs in a remote experience zone within Tongariro National Park.</p> <p>Wildland Consultants (2014a) ranked the ecological values of the site as being of international significance due to it being in the part of Tongariro National Park that is listed as a World Heritage Site. The vegetation is of considerable scientific interest, and interest in following plant succession has been enhanced by the 2012 eruptions.</p>
Ecosystem Services:	<p>There are no provisioning services at this site due to the low diversity of plant species at this site, and because the site is located within a World Heritage Site, all features are protected from development.</p> <p>Regulation and maintenance services at this site are difficult to quantify as there is limited vegetation on the scree slopes.</p> <p>The site provides a number of cultural services. The geothermal features are now visible from a considerable distance, with steam visible from Taupō Township, c.60 km to the north of the site. It is also a major feature of the Tongariro Alpine Crossing that attracts 109,000 visitors annually (Mitchell 2016). The site is of considerable scientific interest, with 250 research papers published on the geophysical characteristics of the site, its geothermal field and other scientific values (Google Scholar search). Monitoring equipment including seismographs are present around the Craters, and the site is regularly visited by volcanologists. Following the 2012 eruption, a rahui was placed over the area restricting access to the craters. The significance of the volcanic landscape in Tongariro National Park has been recognised in its designation as a World Heritage Site, and the Waikato Regional Council Policy Statement recognises Tongariro National Park for its outstanding landscape values.</p>



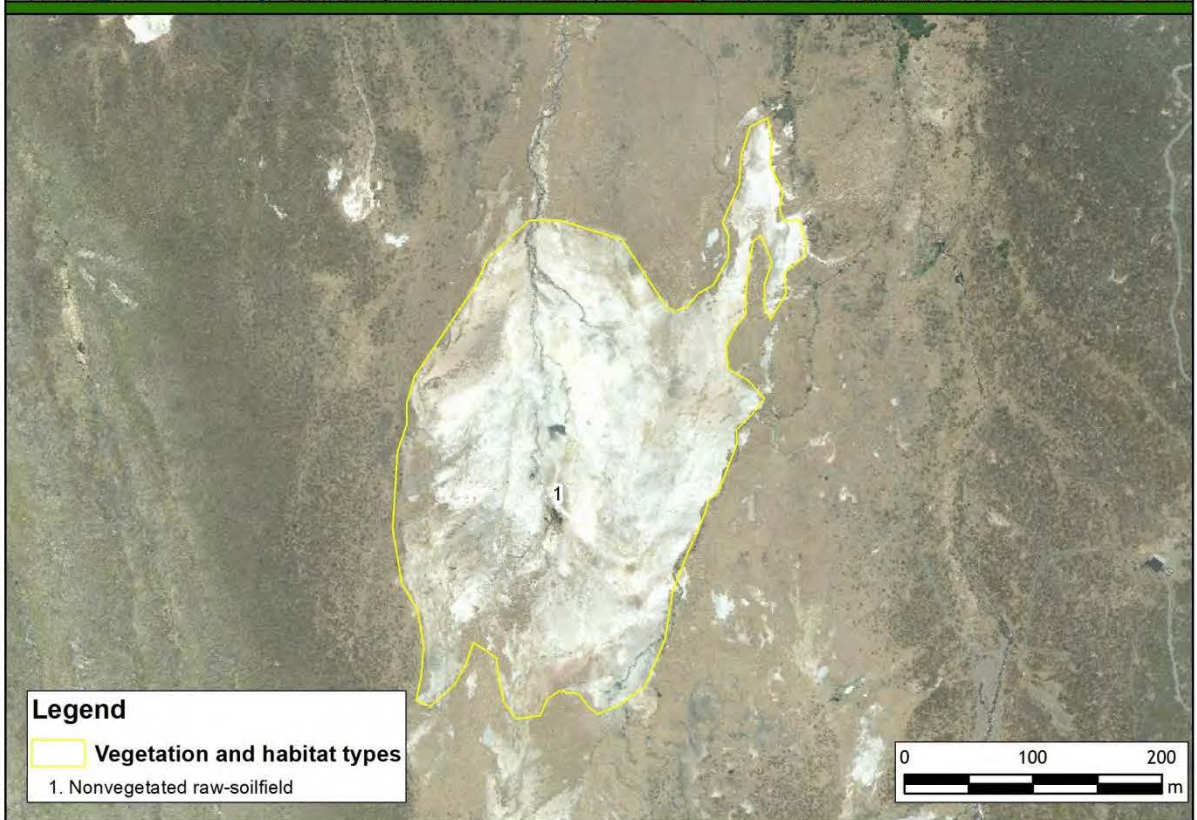
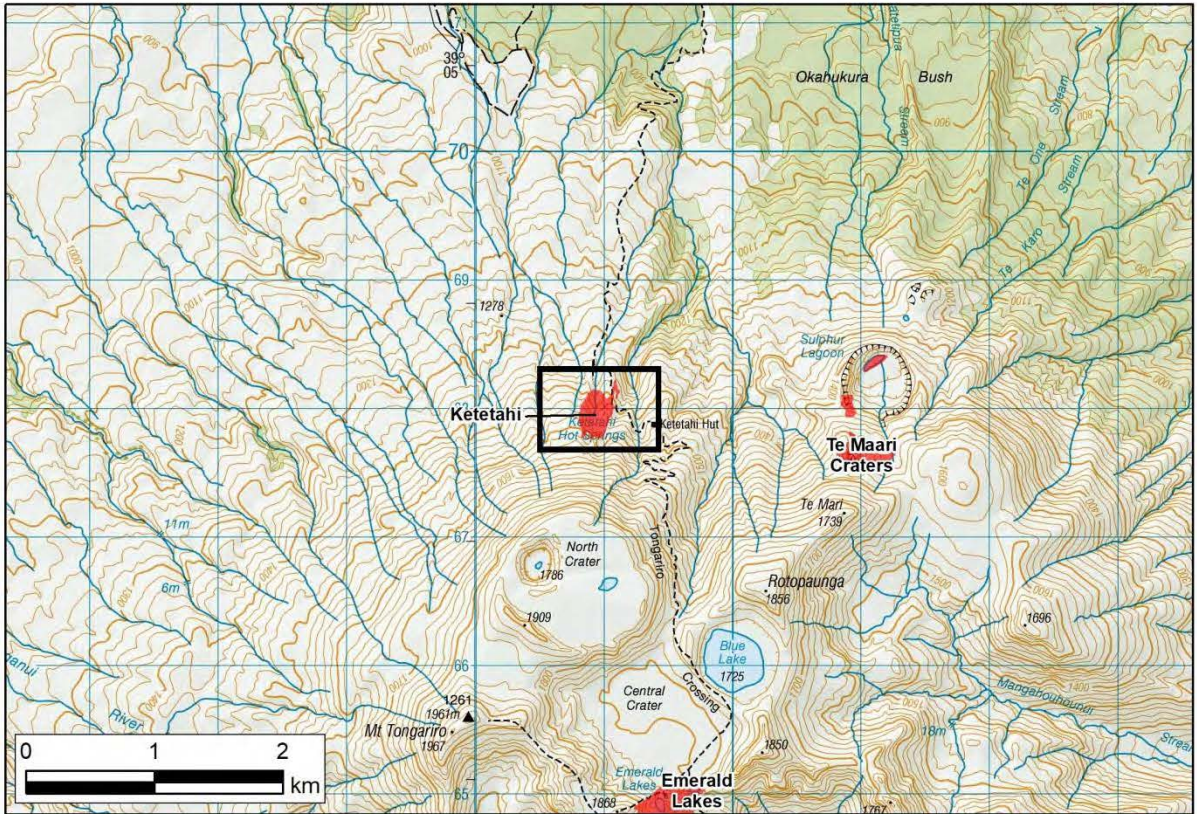
A small population of *Lycopodiella cernua* present in Te Maari Crater (just below upper Te Maari Crater) prior to the 2012 eruption. This population was destroyed in the eruption, but others survived elsewhere on the mountain. (June 2011)



Te Maari Craters. (June 2011)



Partly frozen lake with geothermal influence known as Sulphur Lagoon. (June 2011)



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 Ref: 01 1769
 Path: E:\gis\EW_Geothermal_Sites_2003\2017\mxd\June2017\
 File: Ketetahi.mxd

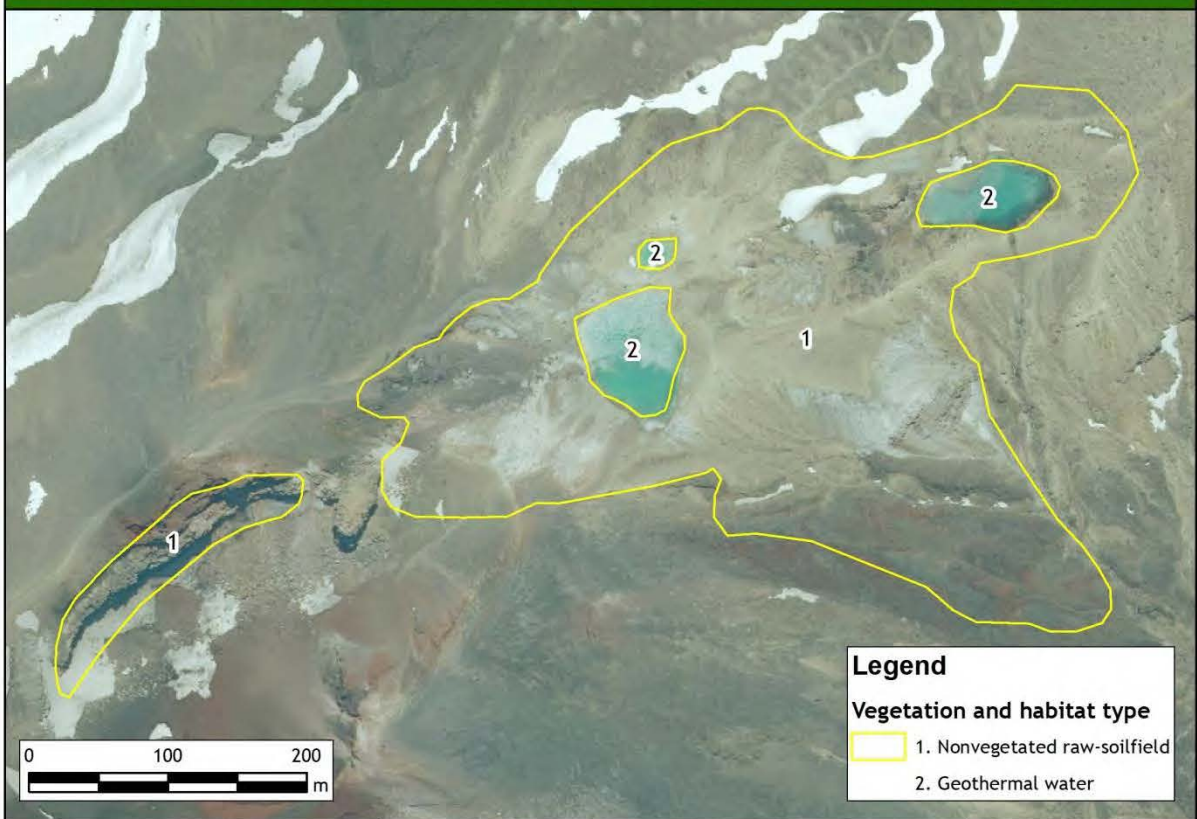
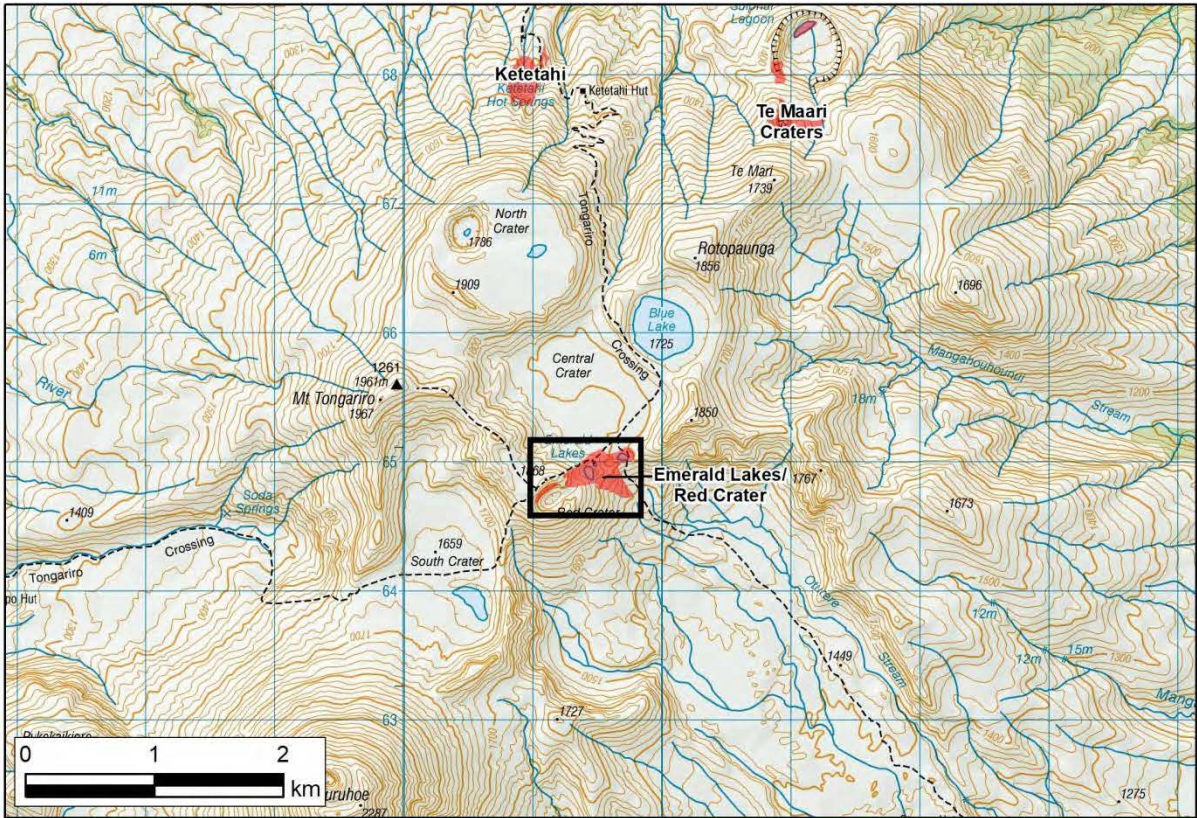
Ketetahi

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KETETAHI

Area:	Geothermal Habitat: c.8.2 ha Geothermal Vegetation: c.8.2 ha
Geothermal Field:	Tongariro
Site Description:	<p>Ketetahi is an area of high cultural importance within the Tongariro Geothermal Field on the northern slopes of the Tongariro Complex. The site is surrounded by Tongariro National Park and the Tongariro Alpine Crossing walking track passes nearby, giving tourists the opportunity to view the site from a distance. The site is of exceptional quality with few human impacts. Features include hot springs, silica crusts and fumaroles. Ketetahi is known to be a very good quality example of a nationally uncommon habitat type: geothermally heated dry ground (Williams <i>et al.</i> 2007, Holdaway <i>et al.</i> 2012).</p> <p>No field visit of this site has been undertaken by Wildland Consultants (or others) due to the special significance of this site to local iwi.</p>
Ecosystem Services:	Many ecosystem services provided by other nearby geothermal sites are also likely to be provided by this site. However, given the significance of the site to iwi, it is not appropriate for a full assessment of these to be made without appropriate consultation.



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Report: 4363
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 Path: E:\gis\EW_Geothermal_Sites_2003\2017\mxd\June2017\
 File: Emerald_Lakes_Red_Crater.mxd

Emerald Lakes/Red Crater

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Scale: 1:4,641
 Date: 21/06/2017
 Cartographer: JO
 Format: A4

EMERALD LAKES/RED CRATER

Area:	Geothermal Habitat: c.12.9 has Geothermal Vegetation: c.12.0 ha
Geothermal Field:	Tongariro
Site Description:	<p>Emerald Lakes/Red Crater is an amalgamation of two sites assessed in Wildland Consultants (2014a): Emerald Lakes and Red Crater.</p> <p>The Emerald Lakes/Red Crater site is within the Tongariro National Park. It comprises three geothermally influenced lakelets (three explosion pits) located downslope of Red Crater. Red Crater comprises bare heated scoria and soils, and a fumarole. The Tongariro Alpine Crossing passes close to the site and track users have access to the Emerald Lakes. While not botanically diverse, the lakes, Red Crater and surrounding geothermal habitat are of exceptional ecological quality, of high scientific value, and high ecological and geodiversity interest. The site is located within the part of Tongariro National Park that is listed as a UNESCO World Heritage Site. An exotic weed, <i>Juncus bulbosus</i>, is detracting from the natural character of the lower Emerald Lake and is of conservation concern. Several pest animal species utilise the site, but their densities are likely to be low. Cody (2007) lists three features and geothermal characteristics present at or near this site with two of these being of national significance. In terms of ecological values this site is ranked as being of international significance (Wildland Consultants 2014a).</p>
Ecosystem Services:	<p>Provisioning services are low due to the low diversity of the vegetation at this site. As the site is located within a World Heritage Site, all features are protected from development. The site provides regulation and maintenance services of bioremediation in streams that flow off the eastern slopes of Tongariro, although levels of this service can be considered low in the context of the surrounding vegetation and landscape. The vegetation provides some mass stabilisation and control of erosion rates, and probably very low rates of sequestration of carbon and potentially other climate change gases.</p> <p>The site provides a broad range of cultural services. The geothermal area and lakes are a major feature on the Tongariro Alpine Crossing that attracts 109,000 visitors annually (Mitchell 2016). People occasionally swim in the lakes, although this is not encouraged. The site is of considerable scientific interest, with 222 research papers published on the geophysical characteristics of the site, its geothermal field and other scientific values (Google Scholar search). The site is regularly visited by volcanologists.</p>



Emerald Lakes has a population of *Juncus bulbosus* which is of conservation concern. (June 2011)



Lower Emerald Lake with Red Crater in the background. (June 2011)

ECOSYSTEM SERVICES PROVIDED BY GEOTHERMAL ECOSYSTEMS INCLUDING DESCRIPTION AND INDICATORS FOR QUANTIFICATION

MEA Classification	Division	Group/ Product	Class	Geothermal Sites - Indicators of Data to be Collected	Ecosystem Service Indicator	Description
Provisioning	Nutrition	Biomass	Cultivated crops	Wet weight of crop harvested	Crop harvested	Volume of crop harvested (kg)
			Wild plants, algae and their outputs	Wild plants used in gastronomy, cosmetic, pharmaceutical uses (data on industries collecting the plants)	Unknown.	Harvested wild plants.
			Wild animals and their outputs	Honey	Honey production (food)	Area of plants within site which are used for honey production (ha).
				Number of wild animals killed annually (pigs, pheasants, quail)	Animals harvested	Parts of the site may be used for game mammal hunting, duck shooting in ponds and wetlands, game bird (e.g. California quail, pheasants).
			Reared animals and their outputs	Fresh weight of crop harvested (tonnes)	Domestic stock present	Areas of unfenced geothermal in farm paddocks (ha).
			Area of plants that mānuka honey can be produced from	Honey production (volume)	Area of plants within site which are used for honey production (ha).	
	Materials	Water		Geothermal water abstracted	Geothermal surface water draw off	Volume of water drawn (L).
			Biomass	Fibres and other materials from plant, algae and animals for direct use or processing	Wood produced (tons or volume) by forest and area of exploited forests, including flax	Cover of harakeke and raupō.
	Energy	Biomass based energy sources	Plant based resources	Firewood produced by forests	Firewood	Area of tree and shrub cover that could be removed for firewood (ha).
			Heat from ground	Heat exchangers on ground within sites	Heat exchange at site.	Presence/absence
	Materials	Biomass	Genetic materials from all biota	Number of known thermophilic organisms from each site	Thermophilic organisms present	Number of Phylotypes detected in Stott (2011)
				Extraction of clays for various use	Clay extraction	Extraction of clay (volume).
Harvesting of chemicals from the system, e.g. sulphur				Sulphur and other mineral mining	Extraction of sulphur and other minerals (volume).	
Regulation and Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals		Bioremediation	Extent of vegetation with bioremediation potential (ha).
				Nutrient load - and whether this is different from that expected for this geothermal system		Nutrient load - not yet able to be quantified

MEA Classification	Division	Group/ Product	Class	Geothermal Sites - Indicators of Data to be Collected	Ecosystem Service Indicator	Description
				Area occupied by riparian forests	Riparian forest.	Length of waterways in geothermal site (m).
				Potential mineralization or decomposition	Landform change due to presence of geothermal activity.	Examples include silica terraces, mud pools, fumaroles, geothermal clays and others. (Extent of geothermal habitat - ha)
				Nutrient retention		Nutrient retention - not yet able to be quantified.
		Mediation by ecosystem		Sequestration of toxic chemicals by biota	For example thermophiles.	Number of Phylotypes detected in Stott (2011)
				Waste treated		Waste treated - not yet able to be quantified.
	Mediation of flows	Mass flows	Buffering and attenuation of mass flows	Sediment retention		Sediment retention - not yet able to be quantified.
			Mass stabilisation and control of erosion rates	Area of geothermal site covered in vegetation	Vegetation cover	Area of vegetation mapped in Wildland Consultants (2014) excluding water and bare ground (ha).
		Liquid flow		Water holding capacity of soils	Water holding.	Ability of soil to hold water - not yet able to be quantified.
				Area of geothermal sites located in flood risk zones	Flood risk	Hectares of geothermal site within flood risk zone.
		Gaseous/air flows		Number of frost days in geothermal sites vs surrounding area	Climate regulation	Ventilation and transpiration, storm protection, frost free days, moisture contributed to atmosphere.
				Area of geothermal vegetation	Air purification	Air purification function - not yet able to be quantified.
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and dispersal	Bee keeping value of geothermal systems	Honey production (pollination).	Parts of site may contain plants which benefit from bee pollination.
				Ecological connectivity value of geothermal sites	Connectivity to indigenous habitat.	Percent of indigenous habitat within 1 km of site boundary, based on New Zealand Landcover Database.
			Maintaining nursery populations and habitats	Biodiversity value (species diversity or abundance, endemic species, Threatened and At Risk species)	Number of At Risk and Threatened species recorded at site since 2002	List of species.
				Diversity of indigenous species characteristic of geothermal sites	Non-threatened species typical of geothermal habitat.	Number of key non-threatened species typical of geothermal habitat.
				Number of geothermal habitat types	Broad geothermal habitat types.	Number of broad geothermal habitat types.
		Pest and disease control	Pest control	Number of beneficial predatory species (especially invertebrates)	Beneficial predatory species.	Number of beneficial predatory species.
				Effectiveness of geothermal system to prevent or reduce spread of alien species		Not yet able to be quantified.
			Disease control	Resistance of geothermal biota to disease (e.g. is geothermal kākūka resistant to myrtle rust?)		Disease resistance - not yet able to be quantified.

MEA Classification	Division	Group/ Product	Class	Geothermal Sites - Indicators of Data to be Collected	Ecosystem Service Indicator	Description	
				Do any geothermal flora have specific disease control characteristics		Disease control - not yet able to be quantified.	
		Soil formation and composition		Change in soil surface height relative to fixed geodata point (accumulating or losing material?)		Accumulation or loss of material - not yet able to be quantified.	
			Decomposition and fixing processes	Rate of mineralization, decomposition		Rate of mineralisation - not yet able to be quantified.	
		Water conditions	Chemical condition of freshwaters	Chemical status of geothermal water	Condition of water	Water chemistry information.	
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	Annual C sequestration by vegetation	Carbon sequestration	Tonnes of carbon	
				Rate of sequestration of other climate change gasses			Tonnes of other gases
				Annual C sequestration by soil processes			Tonnes of carbon
			Micro and regional climate regulation	Temperature gradients from geothermal to non-geothermal sites		Temperature range.	
				Contribution to cloud or fog formation processes	Cloud or fog formation	Steam and cloud cover over site.	
				Rate and type of geothermal gas emissions (e.g. H2S)	Gas emissions	Amount of gas released at site.	
Cultural	Physical and intellectual interactions with biota, ecosystems, and land/ seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land/ seascapes in different environmental settings	Number of people who live in/around the geothermal area (permanent or seasonal residents, not tourists)	Number of people living nearby.	Estimated by number of buildings within one km.	
				Annual number of visitors to view geothermal areas	Visitors to geothermal area.	Number of visitors.	
				Annual number of visitors to geothermal areas for bathing/swimming purposes	Visitors who swim at site.	Number of visitors.	
				Visitors pay an entry fee to enter site	Visitors pay to visit site.	Entrance fee is charged.	
		Physical use of land/ seascapes in different environmental settings		Number of hunters	Hunting experience.	Number of hunters that seek permission to hunt at the site.	
				Number of bird or fauna watching sites	Bird watching values	Number of records on eBird website	
				Annual number of other visitors (trampers, boating, etc)	Other visitors.	Number of visitors to site for other purposes.	
		Scientific		number of monitoring sites present (by scientists), number of scientific projects, articles, classified sites (world heritage)	Research	Search Google Scholar using key words.	

MEA Classification	Division	Group/ Product	Class	Geothermal Sites - Indicators of Data to be Collected	Ecosystem Service Indicator	Description
				International and national geopreservation classification (geodiversity)	Geodiversity of site.	Number of features and geothermal characteristics listed in Cody (2007)
				Entry restrictions due to sensitive environment	Entry restrictions	Number of features listed in Cody (2007) of being of National significance of higher.
				Protection status of the site	Site protection	Presence/absence of fencing, restricted access, permits.
			Educational	Number of visitors, national parks		Percent of site legally protected
				Number of schools groups to visit	Educational use	Number of visits.
				Number of educational displays/signage	Educational display	Number of school/education group visits
			Heritage, cultural	Number of visitors, number natural heritage and cultural sites, number of annual cultural activities organised	Needs consultation with iwi	Information building, number of signs, number of guides employed.
				Number of legends for the site/area	Needs consultation with iwi	Number of legends
				Current Maori and cultural use	Needs consultation with iwi	Use occurs.
				Number of displays explaining heritage and cultural values	Education of cultural information.	number of displays
				Traditional cooking site	Needs consultation with iwi	Signs with cultural information. Staff employed providing cultural information.
				Traditional bathing site	Needs consultation with iwi	
				Known historical Maori use	Needs consultation with iwi	
				Entertainment	Number of visitors (or number of sites located next to cycle path)	Cycle path
			Number of photos of the site in the internet		Number of times site is photographed	Number of photographs on Flickr
			Number of times a site has featured in a film/TV programme, or documentary			Number of times the site is tagged in Te Taonga - the New Zealand film archive.
			Aesthetic	Number of visitors	Visitors for aesthetics	Number of visitors
				Landscape values	Landscape values	Values as listed in WRC Regional Plan
				Contrasting landscapes (e.g. geothermal area and lake)	Contrasting landscape values	Author assessment (outstanding, high, moderate, low)
				Proximity to urban areas or habitation	Number of people living in close proximity	Number of buildings within 1 km
				Number of roads or paths that look out over/in to the geothermal site	Roads in proximity	Number of roads or paths that look out/over/in to the geothermal site.

MEA Classification	Division	Group/ Product	Class	Geothermal Sites - Indicators of Data to be Collected	Ecosystem Service Indicator	Description
				Number of roads or paths created to access or view the geothermal site	Access to site.	Number of roads or paths created to access or view geothermal site.
	Spiritual, symbolic and other interactions with biota, ecosystems, and land/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	Number of iconic species or landscape elements (national species or habitat types)	Consultation required with iwi.	Number of species.
Direct selling of geothermal products as souvenir items				Direct selling of geothermal products	Number of geothermal products sold on site.	
Name of the site is synonymous with geothermal or iconic site (e.g. Wairakei)				Site name	Name of the site is synonymous with geothermal or iconic site (e.g. Wairakei).	
Sacred and/or religious			Number and importance of sacred/religious sites	Consultation required with iwi.	Number of important sites	
			Number of wai tapu or rahui sites	Consultation required with iwi.	Number of wai tapu or rahui sites	
			Number of catastrophic or historic events	Number of catastrophic or historic events.	Number of events.	
Other cultural outputs		Existence	Number of visitors	Spiritual visitors.	Number of visitors.	
			Degree of appreciation by locals and tourists	Appreciation	Number of visitors.	
			Range of activities that take place	Other activities.	Pest control, tourism, hunting, protection of site from overuse, e.g. fencing.	
		Bequest	Number of people or community groups working to maintain or restore a geothermal site	Restoration.	Number of groups or people.	
	Expenditure to maintain geothermal site in good condition		Expenditure to maintain geothermal site in good condition	Amount spent on maintenance.		
	Expenditure to ensure people are safe (reflection of visitor numbers)		Site safety.	Expenditure on fencing, signs.		

COMMON PLANT NAMES USED IN TEXT

Common Name	Scientific Name
Arrow grass	<i>Triglochin striata</i>
Blackberry	<i>Rubus fruticosus</i> agg.
Crack willow	<i>Salix × fragilis</i>
Geothermal kānuka	<i>Kunzea tenuicaulis</i>
Harakeke	<i>Phormium tenax</i>
Japanese honeysuckle	<i>Lonicera japonica</i>
Kohūhū	<i>Pittosporum tenuifolium</i>
Mānuka	<i>Leptospermum scoparium</i>
Mingimingi	<i>Leucopogon fasciculatus</i>
Oioi	<i>Apodasmia similis</i>
Raupō	<i>Typha orientalis</i>
Reed sweetgrass	<i>Glyceria maxima</i>
Ti kōuka	<i>Cordyline australis</i>
Whekī	<i>Dicksonia squarrosa</i>



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