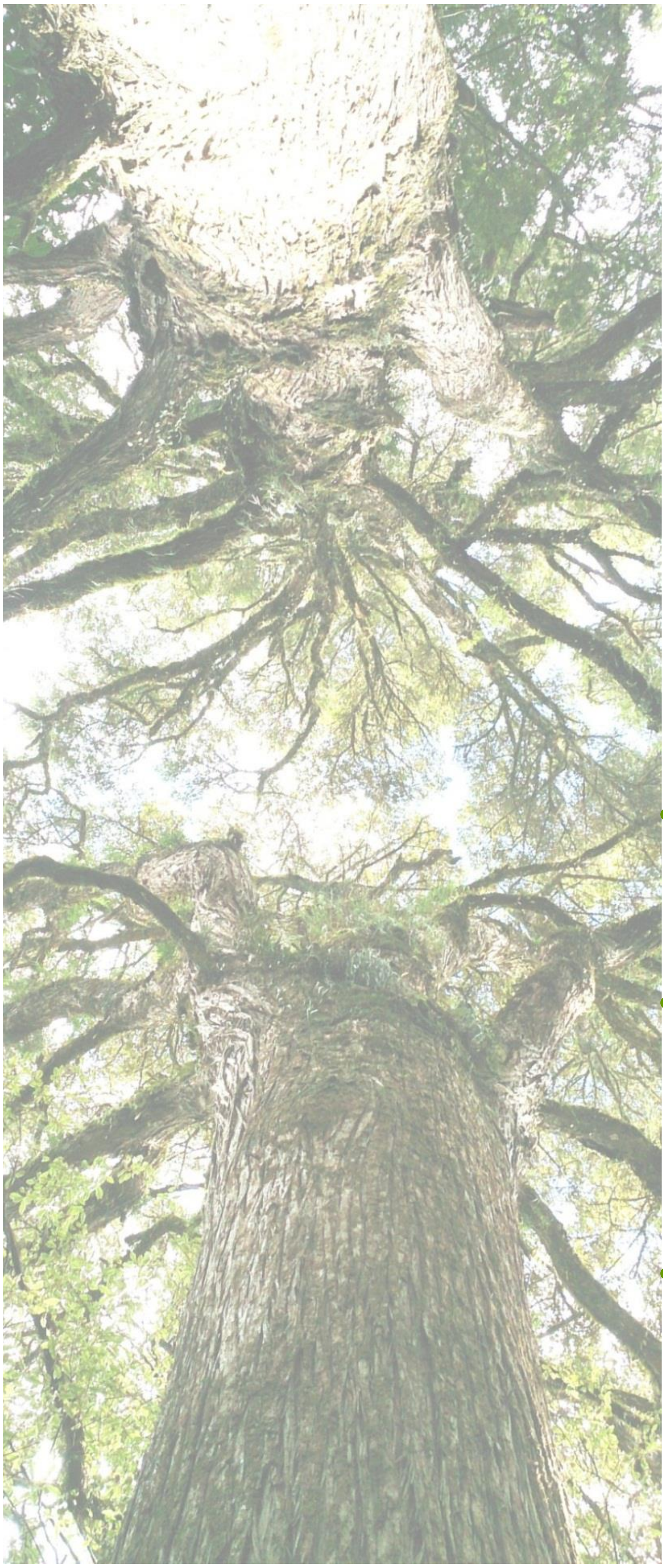

A potential Ecosystem map of the Bay of Plenty Region

Explanatory information to accompany the map

Compiled by Nicholas Singers Ecological Solutions Limited for the Bay of Plenty Region

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1. Background

The ecosystem classification used to map potential ecosystems of the Bay of Plenty Region was developed by the Department of Conservation, as a tool for prioritising ecosystem management (Singers & Rogers 2014). This classification is a synthesis that amalgamates previous classifications and ecological studies aligned to an abiotic framework. It describes a full range of ecosystem types at a variety of scales in a natural or potential state as they potentially existed if people arrived today in New Zealand. The classification system has two tables that describe ecosystem drivers of the abiotic environment (Appendix 1) and biotic compositional description which further includes ecosystem distribution and relevant source references (Appendix 2). The data contained within these two tables have been used as the fundamental basis for mapping ecosystem types, supported by other readily available ecological descriptions, vegetation maps and relevant GIS layers such as soil maps of the region.

Vegetation has been previously mapped for parts of the Bay of Plenty Region at a variety of scales and accuracy for multiple purposes. All of these examples have used various classification systems or methodologies for describing vegetation, some of which have a strong equivalency with Singers and Rogers (2014), while others less so.

The process of creating the potential vegetation map was relatively straight forward in places where intact forest remains and have been described and mapped. In this situation, mapping involved identifying equivalencies, from one classification or vegetation type to the equivalent ecosystem unit of Singers and Rogers (2014). Mapping potential ecosystems in areas without indigenous vegetation used a variety of data sources to make informed decisions, and because of these assumptions should be seen as a working hypothesis.

2. Mapping process

The most comprehensive and accurate source of information used to construct the potential ecosystem map were the forest type maps of Nicholls (1964 – 1969). Forest types recognised within these maps used the "Classification of indigenous Forests for the North Island" (McKelvey & Nicholls 1976) or predecessor draft classification systems contained on the maps. For North Island forest ecosystem units the Singers and Rogers (2014) classification system used Nicholls forest types as a fundamental basis for unit formation. Usually this involved combining several similar types within a single ecosystem unit — resulting in direct equivalencies between ecosystem units and forest types. Where forest type maps were available these were simply digitised and types converted to ecosystem units. Forest type maps were however not comprehensive for the whole Bay of Plenty region though covered most land within Kaimai—Mamaku, Rotorua Lakes, Whakatane and Te Urewera conservation lands. Where forest type maps were not available, forest class maps were used instead.

Forest classes (NZFM MS6) are a broader classification unit which group many similar forest types. Though the forest class maps are comprehensive and cover most indigenous vegetation that was present at the time of the New Zealand Forest Survey (post World War II), the broader classification groupings meant that fewer direct comparisons between an ecosystem unit of Singers & Rogers (2014) and a forest class can be made. The forest class C "Kauri-Softwoods-Hardwoods-Beeches" is a direct equivalent to WF12: Kauri, podocarp, broadleaved, beech forest. Where forest class mapping was used other pertinent information such as ecological reports (e.g. Vegetation of Te Urewera National Park (McKelvey 1973)), vegetation maps and species distributions of diagnostically important species were used. Often ecological descriptions within these publications enabled direct equivalencies to be made with ecosystem units of Singers and Rogers (2014).

The Land Cover Database (LCDB2) Sub-alpine shrubland (Class 55) is essentially an ecological equivalent to ecosystem unit CF13 of Singers and Rogers (2014). An attempt was made to use the LCDII polygons, however due to the difference with real ecological boundaries such as the treeline which could be seen on aerial imagery and the LCDB2 layer (which is derived from a raster dataset), this ecosystem type was hand digitised from Imagery instead, though referring to LCDB2 layer for guidance.

3. Information Used

All mapping work was done using ArcGIS for Desktop v 10.2.1 unless stated otherwise.

3.1 Developing the feature-class and Ecosystem Unit layer

Three principal datasets were used for the ecosystem unit mapping were:

(1) The New Zealand Fundamental Soil Layer from Landcare Research, fsl – north-island-all-attr.shp. This layer originates from a join of the NZ LRI and the national soils database. "Data reproduced with the permission of Landcare Research New Zealand Limited"

(2) Forest Service Mapping Series 6 (FSMS6), nz-fsms6-north-island.shp. These maps provide the distribution of indigenous forest vegetation at a scale of 1:250,000. The North Island maps were primarily compiled by John Nicholls. License is Public Domain.

(3) S-map from Landcare Research. This layer derives depth, drainage and texture from fundamental soil properties, sample information and expert knowledge. "Data reproduced with the permission of Landcare Research New Zealand Limited". The drainage layer was of most use

These three datasets were merged together using the Union tool.

Source feature	Field Name
NZ FSMS6	DESC FOREST_CL
NZ FSL	DOMNZSC SOILTYPE NZSOILGRP PHASE
s-map	DrainDom

Unfortunately this process can produce many small slivers. An effort was made to reduce these without interfering with the integrity of the data. The minimum polygon size was chosen as 0.5 Ha, however subsequent mapping produced many more small polygons. There is also a significant difference in the scalability of the above datasets, e.g. 1:250,000 paper maps for the fsms6 data and 1:1000 – 1:5000 Orthophoto Aerial images 2011 provided by Bay of Plenty Regional Council. The result is large areas of apparent inaccuracy if viewed at a scale of 1:5000. The optimal scale for this work is about 1:10,000. To overcome this significant remapping was undertaken particularly along the coast line, rivers and lake margins using the most recent orthophotos. It was also apparent from the orthophotos that there are inaccuracies in the soil layers. Wetlands from BOP data and swamps from NZ Topo50 were added to the feature-class and often required remapping, usually in relation to landform boundaries e.g. removing a valley floor wetland from the adjoining hill-slope.

3.2 Species distributions of diagnostically significant species

Species distributional information of diagnostically significant species was also examined and used were appropriate to assist with ecosystem unit boundary determinations. Distributional information was obtained for hard beech (*Fuscospora truncata*), pohutukawa (*Metrosideros exselsa*), mangeao (*Litsea calicaris*), kohekohe (*Dysoxylum spectabile*), kauri (*Agathis australis*), tawa (*Beilschmedia tawa*), taraire (*Beilschmedia tarairi*), puriri (*Vitex lucens*) and pukatea (*Laurelia novae-zelandiae*), sourced from the NZ Plant Conservation Network (NZPCN). Maximum altitudinal limit for totara was also calculated on the central volcanic plateau using the remnants that contain these species.

The distribution of kohekohe was used as a surrogate to divide warm and mild forest ecosystem units of Singers and Rogers (2014), which have the same NZMS FS6 forest class e.g. Rimu-tawa (D). The distribution of kohekohe was developed using NZPCN point locations, forest types that contained kohekohe and a hand drawn boundary provided by Paul Cashmore from the Department of Conservation (Rotorua) for the old Bay of Plenty Conservancy. McKelvey (1973) observed that kohekohe occurs below 1400 ft., (426 m). Our boundary manually digitised a line using the above data sources as a guide and generally following the 400 m contour on northern aspects and lower elevation on southerly aspects.

In the Opotiki District an approximate distribution of hard beech was created to define the boundary between ecosystem units of Singers and Rogers (2014) that have partial equivalency with the forest classes Rimu-tawa (D) and Rimu-tawa-beeches (H), or their logged counterparts. This distributional boundary was created with the support of the forest class maps and was located in the east between the Waiotahi Valley and Opape.

3.3 Influence of recent volcanism (post Taupo 232 A.D.) and the distribution of ecosystem types — understanding landscape history

Volcanism has had a significant effect on the distribution of ecosystems within the Bay of Plenty Region. This effect has been recognised by McKelvey (1973) in the vegetation pattern of the Urewera and Whirinaki Ranges and Rotorua Lakes by Nicholls (1959). The most recent eruptions were from Mt Tarawera in 1886AD and the Kaharoa eruption in 1315AD both of which caused vegetation damage. The Taupo 232AD eruption comparatively had a much greater influence, especially on the Kaingaroa Plateau and Whirinaki Basin. These volcanic events destroyed and damaged vegetation, greatly influence soils composition and structure which has influenced vegetation succession and ecosystem composition.

3.3.1 Tarawera eruptions

The ecosystem map has been influenced by the landscape forming patterns of both the Tarawera 1886AD and the Kaharoa 1315AD volcanic activity. The Kaharoa eruption was larger and consequently caused greater destruction which included a massive lahar that flowed at >100,000m^3/sec down the Tarawera River and onto the Rangitaiki Plains (Hodgson & Nairn 2005). This lahar devastated the vulnerable riparian areas adjacent to the Tarawera River. Further, it substantially influenced riparian terrace formation downstream and deposited deep layers of free draining volcanic derived alluvial sands over these flood prone terraces — as a result MF10 Totara, matai, kahikatea forest have been mapped on these land systems instead of the predicted alluvial forest ecosystems such as WF2: Totara, matai, ribbonwood forest

The Tarawera eruption was considerably smaller and occurred at a time when Maori had already burnt large parts of the landscape within the eruption affected area. Determining natural versus human induced vegetation successions has required interpretation of quantitative and qualitative evidence.

Areas significantly affected by the eruption, resulting in near complete destruction of vegetation have been mapped as vegetation succession ecosystem units. Outside of this destruction zone a much larger area of vegetation would have been partially impacted by the eruption, though have been mapped as the potential ecosystem units.

The extent of this vegetation succession area was derived from Smith and Percy (1886) which includes a map of the area affected; Nicholls (1959), Timmins (1983) and Clarkson (1986) which describe post-eruptive vegetation succession patterns and with the use of orthophotos were primarily used to map its distribution. Smith and Percy's (1886) map was geo-referenced and compared to NZMS FS 6 vegetation mapping. The map shows areas of native vegetation which is assumed to have existed prior to the eruption and some of which were "*covered with deep mud*".

The text within the document contains the following pertinent information that relates to the forests of the area.

"*The forest around the seat of eruption presents the most deplorable and desolate aspect. Wherever the mud has fallen it has completely stripped off the leaves, and in the deeper parts the weight of mud has broken off' branches, leaving jagged stumps and stems, thickly bespattered with mud. On the north side of Tarawera the forest is on fire in several places; but, on account of the mud, this cannot extend far. The violent wind which accompanied the outburst, especially near the Wairoa, has prostrated considerable areas of forest, leaving a tangled mass of mud-covered logs. The beautiful forest on the road from Rotorua to Wairoa, near Tikitapu Lake, is a complete ruin, and, together with the village of Wairoa, presents a scene of utter desolation beyond all description. The beautiful clear waters of the lakes are now turbid with mud, and must continue so for a long time to come, as the first heavy rains will bring down vast quantities of fresh mud to add to them. Even Rotorua is discoloured over its whole area*"

Nicholls, 1959, "*concluded that severe damage was very limited and recovery is now far advanced, with new associations destined scarcely to differ from the old*". Nicholls references Hill (1910) who in 1887 "viewed the Tikitapu-Rotomahana country from the hills behind Whakarewarewa—"*all dull grey, not a trace of grass or fern or bush was to be seen*". However, in 1910 he observed that "*the Tikitapu Bush that was destroyed has in a large measure reappeared*". Other references were given for a recovery of the bush that existed at the time e.g. Thomas (1888) and (Turner 1928). He notes a permanent disappearance of "rimu and rata from the Tikitapu forest which blew over during the eruption".

For the reasons outlined above we took a conservative approach to mapping the vegetation succession types around Mt Tarawera. The aerial imagery was useful in determining that VS2 and VS5 were best mapped as a mosaic except on the western edge of Lake Rotomahana where VS2 was dominant.

3.3.2 Taupo 232AD eruption

As a result of post eruption erosion processes Taupo pumice (232AD) deposits are now thickest on flat or shallow sloping land, especially on alluvial terraces, in comparison to steeper land. Cold air temperature inversion also occurs on the Kaingaroa Plateau which prevents the establishment of forest trees and enables scrub (frost flat) ecosystems to occur. This zone was previously mapped by Mark Smale for the Bay of Plenty Region and has been refined using GIS slope analysis tools.

Outside of the cold air temperature inversion zone podocarp dominant forests once occurred on the densest deposits of Taupo pumice on flat or shallow sloping land. These forests have been virtually eliminated and now only occur within the Whirinaki basin, being extirpated on the Kaingaroa by Maori fires. Conversely, podocarp broadleaved forests which are equivalent to ecosystem units MF7 and MF8 occur on thinner pumice deposits generally on steeper land (McKelvey 1973).

To reconstruct this ecosystem pattern a zone representing the central volcanic area which has been influenced by recent (since Taupo 232AD) volcanic activity was defined, which included the Kaingaroa Plateau adjoining with the Mt Tarawera destruction zone, Whirinaki basin and Galatea flats. Within this zone the boundary between podocarp and podocarp broadleaved forests was arbitrarily defined as 8°, to represent the forest pattern related to slope and pumice thickness described by McKelvey (1973). Areas below <600 m and less than 8° slope were classified as MF10, Totara, matai, kahikatea forest while areas on slopes >8° were classified as MF7, Tawa, kamahi, podocarp forest. As MF10 is now extremely scarce on the entire Central Volcanic Plateau, its distributional limits are not known and assumptions were required to map its distribution. At Kuratau (S.W. Taupo) on the Moerangi Plateau which likely receives similar cold air temperature inversion, totara is replaced by matai and rimu as the canopy dominant at approximately 600m. In the Urewera Forest the upper altitude of rimu is recorded at approximately 945m, though on steeper land not prone to cold air inversion (McKelvey 1973). In comparison the small forest remnants at Rangitaiki that surround cold air temperature inversion basins with non-forest monoao scrub, matai is the dominant canopy tree, likely due to having a lower temperature tolerance than rimu (Sakai & Wardle 1978). To recognise this pattern the cool forest type CLF5, Matai, Halls totara, kamahi forest was mapped above 600m in the southern Kaingaroa Plateau.

3.3.3 Wetlands

Wetlands were mapped using a variety of data sources of which the primary source was the historical wetland layer developed by Beverly Clarkson and staff from Landcare Research — Hamilton. In addition to this layer, additional wetlands were identified from the NZ Topo, NZMS 1 maps and using organic and gley soil layers.

Most wetlands include a number of different ecosystem units, usually as fine scale mosaics in relation to environmental drivers of which the water table regime and fertility are primary factors. Mapping wetland types to a finer scale is however problematic and generally requires using field descriptions and vegetation maps for specific types. Wetlands were typically mapped as combinations of swamp mosaics, fen mosaics or bog mosaics. Some small and intact wetlands which have been well described were mapped to the ecosystem unit level.

Swamp mosaic wetlands include the three ecosystem units; WL18: Flaxland, WL19: Raupo reedland, WL20: *Coprosma Olearia* scrub. Swamp mosaics were often mapped in association with WF8: Kahikatea, pukatea forest. Fen mosaics include the WL10: Oioi restiad- rushland/ reedland, WL11: *Machaerina* sedgeland, WL12: Manuka, tanglefern scrub/fernland and potentially WL13: *Sphagnum* mossfield.

Organic soil layers are a diagnostic feature of fen and bog wetlands (Johnson & Gerbeaux 2004) and occur at several lowland sites. Very limited information is known about the composition of these wetlands with organic soils, though are thought to have been developed from *Machaerina complanata* (Campbell 1975). Pollen of *Sporadanthus*, a characteristic bog forming species, has been recorded within peat cores from near Papamoa and could have also potentially occurred elsewhere (de Lange et.al 1999). Also Sphagnic Fibric Organic (OFS) soil occurs near the Waihi Estuary (Pukehina Beach). It therefore seems probable that bog ecosystem units may have been present within the Bay of Plenty or at least there were older low fertility fens on the pathway to becoming bogs. To recognise this pattern these older wetlands with organic soil types; Acidic Mesic Organic (OMA) and Sphagnic Fibric Organic (OFS) which occur in wetlands near Kaituna—Waihi Estuary and on the Rangitaiki Plains where mapped as fen or fen—bog mosaics.

3.3.4 Geothermal areas

Geothermal ecosystems contain two ecosystem units; GT1: Geothermal kanuka scrub and GT2: Geothermally heated water and steam. Considerably finer vegetation types have been described and mapped within all Bay of Plenty Region geothermal fields, which are related to changes in soil temperature and acidity. All geothermal habitats were grouped and mapped into "Geothermal" because of the scale of these ecosystems.

4. Explanatory information for mapping each ecosystem unit

Ecosystem Type	Explanation
WF2: Totara, matai, ribbonwood forest	Very little of this ecosystem type remains in the region. It historically occurred on well-drained and moderately fertile alluvium, such as those derived from the greywacke mountains adjacent to the Rangitaiki and Whakatane Rivers. This ecosystem unit was mapped using the well-drained (w) soil drainage class of S-map on young river terraces, predominantly draining from the Urewera mountains.
WF4: Pohutukawa, puriri, karaka, broadleaved forest	Very little of this ecosystem unit remains within the region with the largest area occurring on Mayor Island (Tuhua). What remains is largely secondary and many areas are actively regenerating, such as within Matata and Ohope Scenic Reserves. Colloquially known as “coastal broadleaved forest” it occurs along the coastal fringe generally on seaward facing hill slopes, within 800m – 1km of the coast and up to approximately 150m in a.s.l. that experience regular salt laden winds. It has equivalency with the NZFM MS6 (Nicholls 1976) forest type “P2” of the general hardwoods forest class. As very limited examples of this type exist to today, mapping was largely a subjective process by interpreting the coastal margin, considering the proximity to the coast and exposure to coastal salt-laden winds.
WF5: Totara, kanuka, broadleaved forest	No intact example of this ecosystem unit remains within the region, though small modified examples of kanuka dominant scrub and forest occur in the Thornton area. Colloquially known as “Dune forest” it occurred on stabilised dunes with excessively drained sandy soils. Historically the largest area within the region likely occurred on Matakana Island. Coastal dunes were mapped from digitised soil layers including S-map or Land Resource Inventory (LRI) including UST: Typic Sandy Ultic Soils BST: Typic Sandy Brown Soils. Inland from the current active dunes along the coastal margin, these soil types were used as a surrogate for the extent of this ecosystem unit.
WF7: Puriri forest	Due to the significant human history and forest clearance near the Bay of Plenty coastline very little remains of this ecosystem unit. Puriri forest occurs in warm locations on moderately to highly fertile soils relatively close to the coast. Two variants were identified; WF7.1 Puriri, totara forest and WF7.3 Puriri, kahikatea forest, being restricted to free draining and imperfectly draining soils respectively. Forest types described as “Puriri” or “Tawa — Puriri” dominant occur in the Opotiki District northwards to East Cape (Regnier

	et.al 1988; Shaw et.al 1999). Remaining examples are all small, modified and primarily occur on hillsides especially within gullies. In other regions examples occur on older alluvial terraces and shallow hill slopes. Historically puriri was described as an "important constituent" of the semi-coastal forests (Kirk 1897 cited in Regnier et.al 1988) of the East Cape. Given the limited current extent, all remaining examples were first plotted and from this an approximate upper altitudinal limit was identified as being at 120m a.s.l. Using the remaining examples as a starting point, mapping potential extent was undertaken somewhat subjectively by placing onto appropriate land-systems — fertile soils on older alluvial terraces, up-lifted marine terraces and shallow hill-slopes below 120m a.s.l. Puriri forest usually merged into WF4 Pohutukawa, puriri, karaka, broadleaved forest near the coast and either MF13 or WF14.1 inland on steep hill-slopes. WF7.3 Puriri, kahikatea forest was mapped in the Opotiki District on several alluvial terraces with imperfectly drained soils mapped as Mottled Orthic Recent Soils (ROM) in the LRI. This ecosystem unit was not mapped in the volcanically influenced semi-coastal zone west of Ohiwa Harbour, the soils of which are primarily derived from rhyolitic ash, of lower fertility. Potentially, it may have been present in suitable locations, such as on marine terraces that drain into the Tauranga Harbour, though no evidence could be found for its existence.
WF8: Kahikatea, pukatea forest	Very little of this ecosystem type remains in the region with White Pine Bush one of the last remaining examples in the region. Historically it would have been common on poor draining alluvial terraces and adjoining non-forest wetlands, lakes and estuaries. This type is generally regarded as wetland forest and primarily occurs on poor draining gley soils including; recent gley (RG), acidic gley (AG), sandy gley (GS), orthic gley (GO) soil types. It was mapped using the S-Map drainage classes of i (imperfectly drained) and p (poorly drained), often mapped as a mosaic with swamp wetland ecosystems.
WF11: Kauri, podocarp, broadleaved forest	This type is equivalent to NZFM MS6 (Nicholls 1976) forest class B "Kauri-Softwoods-Hardwoods" and occurs exclusively in the Kaimai Ranges.
WF12: Kauri, podocarp, broadleaved, beech forest	Equivalent to NZFM MS6 (Nicholls 1976) forest class C "Kauri-Softwoods-Hardwoods-Beeches" and occurs exclusively in the Kaimai Ranges.
WF13: Tawa, kohekohe, rewarewa, hinau, podocarp forest	This type occurs in lowland and climatically warm areas, often on moderate to steep hill slopes which experience limited frost. It is partially equivalent to the NZFM MS6 (Nicholls 1976) forest class D "Rimu-tawa".

	The potential distribution of this unit was developed using NZPCN point locations, NZFS MS 2 forest types that contained kohekohe and a hand drawn boundary provided by Paul Cashmore from the Department of Conservation (Rotorua) for the old Bay of Plenty Conservancy. McKelvey (1973) observed that kohekohe occurs below 1400 ft., (426 m). Our boundary manually digitised a line using the above data sources as a guide and generally following the 400 m contour on northern aspects and lower elevation on southerly aspects.
WF14-1: Kamahi, tawa, podocarp, hard beech forest	This ecosystem unit occurs predominantly in the eastern Bay of Plenty steep hill-country within the warm climatic zone (Singers & Rogers 2014). It is partially equivalent to the NZFM MS6 (Nicholls 1976) forest classes H "Rimu-tawa-beeches" and the logged variant class O "Tawa-beeches" and was mapped within the hard beech zone (see above). It usually merges into MF22 and these two types were separated using the distribution of kohekohe as a surrogate for the warm—mild temperature boundary.
MF4: Kahikatea forest	This type occurs on gley soil types similar to WF8: Kahikatea, pukatea (see above), however is restricted to inland cooler and frost prone areas, which are too inhospitable for pukatea and swamp maire. The distributional pattern of pukatea was sourced NZPCN point data, species lists and reviewing ecological descriptions from SNA and PNA reports. Pukatea was chosen as the key diagnostic determinant for constructing the boundary between MF4: Kahikatea forest and WF8: Kahikatea, pukatea forest. MF4: Kahikatea forest was largely only mapped around the margins of Lake Rotorua. It was also mapped as a mosaic with swamp wetland ecosystems.
MF7: Tawa, kamahi, podocarp forest	This type was arguably the most common forest ecosystem unit within the region — despite being displaced from large areas of suitable habitat as a result of Maori fires. It occurs within central and inland areas and merges into WF13: Tawa, kohekohe, rewarewa, hinau, podocarp forest at lower altitude and often MF8: Kamahi broadleaved podocarp forest at higher altitude — often forming the lower and upper distributional limits. It has partial correspondence with NZFS MS6 Rimu – tawa class, though this class is broader and required subdivision to map. It occurs in areas with a mild climate and low soil moisture deficit (<70mm). Two variants were recognised which were mapped (MF7.1: Tawa, mangeao, podocarp forest and MF7.2: Rata, tawa, kamahi, podocarp forest). These two variants were mapped because they occur in geographically distinct parts of the region and have slightly different species compositions.

	These two variants were differentiated by using the presence of mangeao (*Litsea calicaris*). Mangeao is often a canopy dominant species on volcanic derived soils while being virtually absent in the Urewera Ranges and other ranges on soils derived from greywacke. Mangeao's distribution was used to separate these two variants sourced from the New Zealand Plant Conservation Network point locations. MF7.1 was mapped as occurring in the west of the Urewera Ranges while MF7.2 occurs within the Urewera, Whirinaki and Raukumara Ranges.
MF8: Kamahi broadleaved podocarp forest	This type primarily occurs in the southern Ikawhenua and Whirinaki Ranges, with smaller examples elsewhere. It usually occupies a zone above the altitudinal limit of tawa at approximately 700m a.s.l. or in areas where it was extirpated by the Taupo 232AD eruption and has not re-colonised fully (McKelvey 1973). MF8 is equivalent to types within the broader forest class M "Rimu, matai, general hardwoods" e.g. M1 (Nicholls 1969a).
MF9: Tanekaha forest, locally with *Nothofagus*	This ecosystem unit has a very localised distribution being restricted to steep ignimbrite gorges and outcrops on the Mamaku Plateau such as the Mangorewa Ecological Area. It is equivalent to forest types L2–L3 types of Nicholls (1976). It was not mapped as it generally occurs as small areas within a mosaic of other forest types.
MF10: Totara, matai, kahikatea forest	While totara is still present throughout the region, notably with large trees remaining in Whirinaki Forest, this ecosystem unit is functionally extinct. Most of it was likely destroyed initially by Maori fires and what little remained was logged and land often developed for other purposes. It occupied deep Taupo pumice soils on landforms of low relief (McKelvey 1963). The boundaries used to reconstruct its former distribution were: free draining Taupo pumice and recent volcanic soils on the Kaingaroa Plateau on landforms <8° slope to an upper limit of 600m. In Whirinaki and probably on the Kaingaroa Plateau, the boundaries of MF10 and MF11 would have been transitional with broad zone of mixed composition, potentially with all tall podocarp trees present. Locally matai may have been the most abundant tree.
MF11.3: Rimu, matai forest	This forest type is better represented in the reserves network, though much of it was logged. It occurs on shallow Taupo pumice soils on landforms of low relief predominantly in Whirinaki Forest Park (McKelvey 1973). We have mapped MF11 variant 3 Rimu, matai forest in Whirinaki to recognise the abundance of matai.

	It is partially equivalent to NZFS MS 6 softwoods (L) class in the area identified below. The boundaries used to reconstruct its former distribution are: Softwoods class between 600m and 800m on land <8° slope. In Whirinaki and probably on the Kaingaroa Plateau, the boundaries of MF10 and MF11 would have been transitional with a broad zone of mixed composition, potentially with all tall podocarp trees present. Locally matai may have been the most abundant tree.
MF20: Hard beech forest	This ecosystem unit was likely always uncommon in the region and hard beech (the ecosystem dominant) is usually within a mosaic with other broadleaved, beech and podocarp trees (e.g. WF14: Kamahi, tawa, podocarp, hard beech forest). Several small areas draining from the Mamaku Plateau, were mapped on the NZFS MS1 N67 Te Puke e.g. type K5. (Nicholls 1965c).
MF22: Tawa, rimu, northern rata, beech forest	This ecosystem unit occurs predominantly in the eastern Bay of Plenty steep hill-country within the mild climatic zone (Singers & Rogers 2014). It is partially equivalent to the NZFM MS6 (Nicholls 1976) forest classes H "Rimu-tawa-beeches" and the logged variant class O "Tawa-beeches". It usually merges into WF14-1 in the warm climatic zone. These two types were separated using the distribution of kohekohe as a surrogate for the warm—mild temperature boundary.
CLF5: Matai, Hall's totara, kamahi forest	Very little of this type remains in the region, having been lost as a result of Maori fires and European logging. Even prior to human arrival it was likely restricted by climatic conditions. Small scattered remnants remain in the upper Rangitaiki River catchment, with the best examples occurring within the Rangitaiki Conservation Area. These remnants occur on the margins of cold air inversion basins and small hills, likely in areas unsuitable for rimu. It is partially equivalent to NZFS MS 6 softwoods (L) class e.g. type L7 and occurs on free draining pumice and allophanic (ash) soils. In the southern frost flat zone (see TI3 below), it was mapped up-slope from TI3: Monoao scrub/lichenfield within the Rangitaiki catchment, on areas with slopes >3° on small hills and ridges.
CLF9: Red beech, podocarp forest	This type occurs in the main axil ranges from the Ahimanawa in the south to the Raukumara in the north. Typically it occurs above (in altitude) MF8: Kamahi broadleaved podocarp forest and below pure beech forest. Depending on altitude and landform it has a variable abundance of podocarp trees and locally, such as on steep ridge lines is dominated by red beech. Throughout its range red beech is always present though in some locations silver beech also occurs. It is equivalent to NZFS MS 6 forest class I "Rimu General Hardwoods Beeches" and especially NZFS MS 2 types I1, I2 & I4 and K3 (Nicholls 1966b, 1969a 1969b) which were primarily used

	to map its distribution.
CLF10: Red, silver beech forest	This type occurs in the Urewera and Raukumara Ranges, usually above (in altitude) CLF9: Red beech, podocarp forest and below CLF11: Silver beech forest. It is equivalent to NZFS MS 6 forest class K and NZFS MS 2 type K6 (Nicholls 1966b, 1969a 1969b) which were primarily used to map its distribution. The maximum altitude which red beech occurs is 1100m a.s.l (McKelvey 1973) and this elevation was used to map its upper extent.
CLF11: Silver beech forest	This type occurs in the Urewera and Raukumara Ranges and Kaimai Ranges (Jane & Green 1983). It has partial equivalency with NZFS MS 6 "Beeches" class. Typically it is situated above (in altitude) CLF10: Red, silver beech forest and on the highest mountains below CDF6: *Olearia*, *Pseudopanax*, *Dracophyllum* scrub [sub-alpine scrub]. In the Urewera and Raukumara Ranges it was mapped as occurring within the Beeches K class above 1100m a.s.l. — the maximum altitude of red beech (McKelvey 1973). In the Kaimai Ranges (where red beech is absent) it occurs on the summits of Mt's Te Aroha, Te Rere and Te Hunga, which have been mapped NZFS MS6 Beeches K class, occurring approximately above 720m (Jane and Green 1983).
CLF12: Silver beech, mountain beech forest	Small areas of this type occur on mountain summits of the Urewera Ranges though were too small to map.
CDF4: Halls totara, pahautea, kamahi forest	This ecosystem unit has always had a narrow extent in the Bay of Plenty, being restricted the tops of mountains. One location on the Makatiti Dome occurs west of Lake Okataina and on the northern Kaimai Range. It is partially equivalent to NZFS MS6 G "Lowland Steepland and Highland Softwoods Hardwoods" class. Two variants occur; NZFS MS 2 type GI "Hall's totara, kamahi, broadleaf is equivalent to CDF4.1 on the Makatiti Dome (Nicholls, 1967). On the northern Kaimai Range forest class G is mapped within NZFS MS6 which relates to type G17 (Nicholls 1976). With time and volcanic stability, vegetation succession on the summit area of Mt Tarawera will probably develop into this ecosystem unit (Clarkson 1986).
CDF6: *Olearia*, *Pseudopanax*, *Dracophyllum* scrub [sub-alpine scrub]	This ecosystem unit primarily occurs in the Urewera and Raukumara Ranges. It is most extensive where mountain beech is absent and generally sits altitudinally above CLF11: Silver beech forest. It is equivalent to LCDB2 as "sub–alpine shrub land, class 55". An attempt was made to use the LCDB2 polygons, however due to the difference with real ecological boundaries such as the treeline which could be seen on aerial imagery and the LCDB2 layer (which is derived from a raster dataset), this ecosystem type was hand digitised from Imagery instead, though referring to LCDB2 layer for guidance.
CDF7: Mountain beech, silver beech, montane podocarp	This ecosystem unit only occurs on the Raukumara Ranges. It is equivalent to the mapped unit NZFS M6 "Highland Softwoods-

forest	Hardwoods-Beeches", class J which was used to map it.
AL4: Mid-ribbed and broad-leaved snow tussock tussockland/ shrubland	Not mapped as only very small areas of tussock occur on some mountains e.g. Te Rangaakapua in Te Urewera and Pott's Peak, Arowhana in the Raukumara Range.
TI3: Monoao scrub/ lichenfield	This ecosystem unit occurs only in cold air temperature inversion basins unsuitable for the growth of tall forest trees. The broad extent of the cold temperature inversion basin or "frost flat" zone was previously mapped by Mark Smale (Landcare Research — Hamilton) and was used as a starting point. This zone included two Singers and Rogers 2014 ecosystem types; TI3: Monoao scrub/ lichenfield and TI4: *Coprosma*, *Olearia* scrub [grey scrub]. Within this frost flat zone these two ecosystems were mapped where slope was less than 2-3°. Slope was derived from a 15 m DEM created by University of Otago, National School of Surveying using QGIS software tools version 2.2.0. (10-napier-15m-dem-nzsosde - License: Creative Commons Attribution-Share Alike 3.0). Areas with slope greater than this primarily occur on small hills or ridges and were mapped as CLF5: Matai, Hall's totara, kamahi forest. There were some errors noted with the slope and care was taken to avoid errors with mapping. The area classified as frost flat is comparable to Mark Smale's frost flat layer though extends further north. This ecosystem likely included a significant component of bog pine and alpine celery pine though due to fire and vegetation clearance these two trees have almost been locally extirpated.
TI4: *Coprosma*, *Olearia* scrub [grey scrub]	This ecosystem occurs on alluvial terraces within the broad "frost flat zone" (see above) and small examples remain on public conservation land today. Its composition is typically dominated by dense mingimingi, twiggy tree daisy, locally corokia and *Hebe parviflora* and potentially in historic times *Pittosporum turneri*. Very little of this type remains. It was mapped qualitatively with the support of LRI soil polygons locating it on alluvial terraces adjacent to the Rangitaiki River and other major tributaries.
Wetlands	See section 3.3.3 above
WL10: Oioi restiad- rushland/ reedland	Mapped within fen mosaic wetlands
WL11: *Machaerina* sedgeland	Mapped within fen mosaic wetlands
WL12: Manuka, tanglefern scrub/fernland	Mapped within fen mosaic wetlands
WL13: *Sphagnum* mossfield	Mapped within fen mosaic wetlands
WL14: Herbfield [Ephemeral wetland]	This naturally rare ecosystem likely occurred in tephra basins and dune slacks. In general it is too small to map at 1:10,000 scale however two sites, Arahaki Lagoon and Rangitaiki were mapped.
WL15: Herbfield [Lakeshore	Not mapped

turf]	
WL18: Flaxland	Mapped within swamp mosaic wetlands
WL19: Raupo reedland	Mapped within swamp mosaic wetlands
WL20: *Coprosma Olearia* scrub	Mapped within swamp mosaic wetlands
DN2: Spinifex, pingao grassland/ sedgeland	Mapped using LRI soil type layer WS: Raw sandy soils
DN5: Oioi, knobby clubrush sedgeland	Not mapped
CL1: Pohutukawa treeland/ flaxland/rockland	Small areas occur along rocky coastlines, especially on the East Coast and offshore islands. These were mapped using the LRI Rocky Raw Soils (WX) and Topo50 cliff vectors along the coastline.
CL6: *Hebe*, wharariki flaxland/ rockland	Not mapped
CL10: Kiokio fernland/ rockland	Not mapped
CL11: Mountain tutu, *Hebe*, wharariki, *Chionochloa* shrubland/tussockland/rockland	Not mapped, likely to be present on Mt Maungapohatu cliffs
BR2: Scabweed gravelfield/ stonefield	This ecosystem unit occurs adjacent to braided rivers arising from the greywacke mountains from Urewera to Raukumara. In these areas is equivalent to LCDB2 as Class 11 "River and Lakeshore Gravel and Rock" which was used to map it, crossed referenced with the equivalent topo vector layer and aerial imagery.
SA1: Mangrove forest and scrub	This ecosystem unit occurs in the saline hydro-system between the high and low water spring zone. An extent of mangrove forest and scrub was provided by the Bay of Plenty Regional council and this layer was used as the starting point. Using recent orthophotos this layer was investigated and modified where required. Areas of estuarine vegetation have been reclaimed and occur on Fluid-sulphidic Gley Raw Soils (WGFU) or Saline Orthic Gley Soils" (GOQ). Any reclaimed areas with these soil types were included within this ecosystem unit.
SA2: Searush, oioi, glasswort and sea primrose rushland/ herbfield	This ecosystem unit occurs between the high and low water spring zone. Areas equivalent to this ecosystem type were identified with the historical wetland extent developed by Landcare Research. This ecosystem is also equivalent to LCDB2 as Class 46 "Herbaceous Saline Vegetation" and occurring on occurs on Fluid-sulphidic Gley Raw Soils (WGFU). The potential extent was mapped by amalgamating these (above) layers.
SA7: Iceplant, glasswort herbfield/ loamfield	This ecosystem was mapped on several small islands and rock stacks which are known to have populations of breeding sea birds, which are a key ecosystem driver. It likely was much more widespread and present on larger islands and potentially the mainland prior to the arrival of people and rats — the primary agent of decline. Owing to the difficulty of knowing exactly where it once occurred, historic locations have not been mapped.
VS1: Pohutukawa scrub/forest	This ecosystem type is naturally uncommon occurring in coastal and inland areas following recent volcanic activity. It is equivalent to the NZFS MS 2 type P4 (Nicholls 1965) around the Rotorua

	Lakes and is most abundant around Lake Tarawera and downstream along the Tarawera River. Orthophotos were used in conjunction with Clarkson (1986) on White Island.
VS2: Kanuka scrub/forest	See section 3.3.1 above
VS3: Manuka, kanuka scrub/forest	See section 3.3.1 above
VS8: Monoao scrub	See section 3.3.1 above
VS11: Short tussock tussockland	See section 3.3.1 above

References

Beadel, S. (1989). Notes on the vegetation and flora of Tauranga Harbour and Little Waihi estuary, Bay of Plenty. Wildland Consultants Ltd. Report prepared for Department of Conservation, Eastern Region.

Beadel, S.; Townsend, A.J. and Shaw, W. (1996). Natural heritage of the Whakatane District. Wildland Consultants Ltd. Report prepared for Whakatane District Council.

Beadel, S.; Townsend, A.J. and Shaw, W. (1996). Evaluation of natural heritage sites in Whakatane District. Wildland Consultants Ltd. Report prepared for Bay of Plenty Regional Council.

Beadel, S.; Shaw, W. and Nicholls, J. (1999). Rotorua Lakes Ecological District Natural Area Survey. Wildland Consultants Ltd. Survey report for the Protected Natural Areas Programme. Department of Conservation, Rotorua.

Beadel, S.; Shaw, W. and Gosling, D. (1999). Taneatua Ecological District. Wildland Consultants Ltd. Survey report for the Protected Natural Areas Programme. Department of Conservation, Rotorua.

Beadel, S.; Shaw, W. and Gosling, D. (2003). Te Teko Ecological District. Wildland Consultants Ltd. Survey report for the Protected Natural Areas Programme. Department of Conservation, Rotorua.

Beadel, S. (2005). Nationally and regionally significant geothermal wetlands in the Bay of Plenty region. Wildland Consultants Ltd. Report prepared for Environment Bay of Plenty.

Beadel, S.; Lux, J.; Collins, L; Bayfield, M.; Gillies, R.; Shaw, W.; Manning, L. and Bawden, R. (2006). Significant indigenous vegetation and significant habitats of indigenous fauna in the coastal environment of the Bay of Plenty region. Wildland Consultants Ltd. Report prepared for Environment Bay of Plenty.

Beadel, S.; Lux, J.; Collins, L; Bayfield, M.; Gillies, R.; Shaw, W.; Manning, L. and Bawden, R. (2007). Significant indigenous vegetation and significant habitats of indigenous fauna in the coastal environment of the Bay of Plenty region – addendum to 2006 report. Wildland Consultants Ltd. Report prepared for Environment Bay of Plenty.

Campbell, E. O. (1975). Peat deposits of northern New Zealand as based on identification of plant fragments in the peat. In *Proceedings of the New Zealand Ecological Society* (Vol. 22, pp. 57-60).

Clarkson, B.D. 1990 A review of vegetation development following recent (<450 years) volcanic disturbance in North island, New Zealand. *New Zealand Journal of Ecology* 14: 59–71.

De Lange, P. J., Heenan, P. B., Clarkson, B. D., & Clarkson, B. R. (1999). Taxonomy, ecology, and conservation of Sporadanthus (Restionaceae) in New Zealand. *New Zealand Journal of Botany*, *37*(3), 413-431.

Environment Bay of Plenty (2005). Proposed change No. 1 to the Bay of Plenty Regional Policy Statement (Heritage Criteria). User Guide.

Fitzgerald, N.B. and Smale, M.C. (2010). An updated assessment of geothermal vegetation in the Bay of Plenty region based on 2007 aerial photography. Manaaki Whenua Landcare Research. Report prepared for Environment Bay of Plenty.

Hodgson, K. A., & Nairn, I. A. (2005). The c. AD 1315 syn-eruption and AD 1904 post-eruption breakout floods from Lake Tarawera, Haroharo caldera, North Island, New Zealand. *New Zealand Journal of Geology and Geophysics*, *48*(3), 491-506.

Humphreys, E.A. and Tyler, A.M. (1990). Coromandel Ecological Region. Survey Report for the Protected Natural Areas Programme. Department of Conservation, Hamilton.

Jane, G.T., & Green, T.G.A. (1983). Episodic forest mortality in the Kaimai Ranges, North Island, New Zealand. *New Zealand journal of botany*, *21*(1), 21-31.

Johnson, P., & Gerbeaux, P. (2004). *Wetland types in New Zealand*. Department of Conservation.

Lucas, D.; Head, J; Gray, N.; Riley, A.; Day, A.; Lynn, I.; Shaw, W.; Beadel, S. and Nicholls, J. (1998). A framework for monitoring ecological integrity in the Bay of Plenty region. Lucas Associates with Manaaki Whenua Landcare Research and Wildland Consultants Ltd. Report prepared for Environment Bay of Plenty.

McKelvey, P.J. 1973. The Pattern of the Urewera Forests. New Zealand Forest Service, Wellington.

Natural Environments (2007). Taneatua Ecological District SNA site boundary field checks. Report prepared for Environment Bay of Plenty.

Nicholls, J.L. 1959: The Volcanic Eruptions of Mt Tarawera and Lake Rotomahana and effects on Surrounding Forests. NZ Journal of Forestry Vol 8(1).

Nicholls, J.L. 1964. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N74: Rotorua. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1965a. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N58: Tauranga. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1965b. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N59: Matata. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1965c. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N67: Te Puke. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1966a. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N76: Ruatoki. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1966b. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N86: Galatea. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1967. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N77: Tarawera. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. (1968). Forest types and Scenic Reserves. South Auckland Land District. *Unpublished report.* (Held on file 31/6, Forest Research Institute, Rotorua), 18pp.

Nicholls, J.L. 1969a. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N95: Te Whaiti. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1969b. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N104: Maungataniwha. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1969c. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N96: Maungapohatu. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. (1969d). Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N68: Matata. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1969e. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N87: Waimana. Forest Research Institute, New Zealand Forest Service.

Nicholls, J.L. 1969f. Forest type map of New Zealand Series 2. 1:63, 360. Map Sheet N78: Ruatoki. Forest Research Institute, New Zealand Forest Service.

Regnier, C.E.; Courtney, S.P. and Wiessing, M.I. (1988). Pukeamaru Ecological District. Survey report for the Protected Natural Areas Programme. Department of Conservation, Wellington.

Renner, M. (2009). Indigenous biodiversity of Tauranga City – state of the environment reporting 2008 – updated 2009. Wildland Consultants Ltd. Report prepared for Tauranga City Council.

Sakai, A.; Wardle, P. 1978. Freezing resistance of New Zealand trees and shrubs. *New Zealand Journal of Ecology 1*: 51–61.

Shaw, W.; Beadel, S.; Hosking, M.; Bishop, C. and Nicholls, J. (1999a). Natural heritage of Opotiki District – Part 1. Wildland Consultants Ltd. Report prepared for Environment Bay of Plenty.

Shaw, W.; Beadel, S.; Hosking, M.; Bishop, C. and Nicholls, J. (1999b). Natural heritage of Opotiki District – Part 2. Wildland Consultants Ltd. Report prepared for Environment Bay of Plenty.

Singers, N. J., & Rogers, G. M. (2014). *A classification of New Zealand's terrestrial ecosystems*. Science for Conservation 325, Department of Conservation, Wellington.

Smith, S. Percy, Assistant Surveyor General Auckland, 19 June 1886: Volcanic Eruption at Tarawera (Preliminary report on the); Appendix to the Journals of the House of Representatives, 1886 Session I, H-26. http://atojs.natlib.govt.nz/cgi-bin/atojs?a=d&d=AJHR1886-I.2.3.3.37

Taylor, J. (2005a). Interim lists of nationally and regionally significant wetlands in the Bay of Plenty region.

Taylor, J. (2005b). Rotorua lake margin wetlands survey. Environment Bay of Plenty: Environmental Publication 2005/11.

Taylor, J. (2005c). Wetland vegetation condition report. Environment Bay of Plenty: Environmental Publication 2005/15.

Timmins, S. M. (1983). Mt. Tarawera: 1. Vegetation types and successional trends. *New Zealand journal of ecology*, *6*, 99-105.

Wildland Consultants Ltd (2000). Indigenous biodiversity of Tauranga District – state of the environment reporting. Report prepared for Tauranga District Council.

Young, K.; Froude, V.; Beadel, S.; Owen, K.; Richmond, C.; Norton, B.; Shaw, W.; Jones, A.; Mankelow, B. (1994a). Schedule of sites of significant conservation value – Volume 1. Department of Conservation, Bay of Plenty. Unpublished report.

Young, K.; Froude, V.; Beadel, S.; Owen, K.; Richmond, C.; Norton, B.; Shaw, W.; Jones, A.; Mankelow, B. (1994b). Schedule of sites of significant conservation value – Volume 2a. Department of Conservation, Bay of Plenty. Unpublished report.

Young, K.; Froude, V.; Beadel, S.; Owen, K.; Richmond, C.; Norton, B.; Shaw, W.; Jones, A.; Mankelow, B. (1994c). Schedule of sites of significant conservation value – Volume 2b. Department of Conservation, Bay of Plenty. Unpublished report.

Young, K.; Froude, V.; Beadel, S.; Owen, K.; Richmond, C.; Norton, B.; Shaw, W.; Jones, A.; Mankelow, B. (1994c). Schedule of sites of significant conservation value – Volume 2b. Department of Conservation, Bay of Plenty. Unpublished report.