MAPPING OF POTENTIAL NATURAL ECOSYSTEMS AND CURRENT ECOSYSTEMS IN OTAGO REGION

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MAPPING OF POTENTIAL NATURAL ECOSYTEMS AND CURRENT ECOSYSTEMS IN OTAGO REGION

Contract Report No. 5015a

July 2020

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EXECUTIVE SUMMARY

Potential terrestrial ecosystems are those ecosystems that would have occurred in Otago prior to human settlement of New Zealand. Mapping of potential terrestrial ecosystems was undertaken across Otago, based on the Singers and Rogers (2004) classification of indigenous ecosystem types. Mapping was undertaken using a range of existing layers and database information, including spatial information on soil types, which was particularly useful in lowland and montane parts of Otago, and land cover spatial information which was particularly useful above treeline. Other spatial layers such as the Topo50 topographic layer, and the QMap geological layer, were also helpful. In addition, considerable new mapping was undertaken of wetland, valley floor, and lowland coastal ecosystems. Knowledge of current ecosystems was also informative, as mature examples of forest generally reflect the original pre-human forest, and many wetland ecosystem types can be identified by their current information. Information on climate and geology was also helpful.

Sixty-one potential terrestrial ecosystem types were mapped across Otago, which was largely covered by indigenous forest prior to human arrival, but with significant areas of tussock grassland and other alpine ecosystems above treeline.

Evidence from subfossil logs, pollen analysis, sub-fossilised plant fragments preserved in wetlands and in rock shelters, together with observations of exotic tree growth in different parts of Central Otago, indicates that forest cover extended across most of Central Otago, apart from in the driest and coldest areas. Almost none of these Central Otago forests remain today. On deeper soils on alluvial sites and basin floors, the forest canopy would have comprised manatū/lowland ribbonwood, narrow-leaved lacebark, kāpuka/broadleaf, kōhūhū, kōwhai, and fierce lancewood, with scattered emergent matai and Hall's tōtara. On the adjacent mountain slopes, and in areas with thinner soils, forest dominated by Hall's tōtara, mountain celery pine, and kāpuka/broadleaf would have been predominant.

While other studies have suggested that 40,000 hectares of saline vegetation was present in Central Otago, 14,366 hectares of this habitat was mapped, based on the distribution of the most highly saline Linnburn soils. It is also likely that saline vegetation did not occur fully across these soils, but was located in patches of locally higher salinity.

Fifteen wetland ecosystems, comprising 8,274 wetland polygons and 34,941 hectares, were mapped within Otago Region. This mapping built on wetlands mapped by the Land Cover Database, FENZ, and Topo50, but numerous additional wetlands were mapped. The most extensive ecosystem types mapped were WL16 red tussock, *Schoenus pauciflorus* tussockland (12,060 hectares), WL18 flaxland (6,037 hectares), and WL20 Coprosma, twiggy tree daisy scrub (5,935 hectares). As much of the mapping was based on the spatial distribution of current wetlands, this wetland mapping comprises a significant advance on wetland mapping in Otago Region, both in terms of spatial resolution and thematic resolution.

Current indigenous cover was predominantly undertaken by classifying land cover database cover types into Singers and Rogers (2004) ecosystems, but wetlands were added from the potential ecosystems layer where the mapping was based on current wetlands. A comparison of potential vs current ecosystem extent shows that approximately 200,000 hectares more tall tussock grassland currently occurs in Otago compared to the pre-settlement extent. Indigenous forest has experienced the opposite trend, being historically the ecosystem type of greatest extent in Otago, but now being reduced to approximately 10% of its original extent. A variety of scrub, shrubland, and fernland ecosystems that replaced the former forest also occur extensively across Otago.

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1. INTRODUCTION

Regional Councils across New Zealand have agreed to map potential and actual natural terrestrial and wetland ecosystems, using the Singers and Rogers (2014) ecosystem classification, to add to the national picture of potential and actual terrestrial ecosystems by using a consistent methodology. Otago Regional Council commissioned Wildland Consultants to undertake this mapping across Otago Region.

In addition, Otago Regional Council commissioned mapping of the significant habitats of indigenous fauna across Otago Region, including the coastal marine part of the Region, and to map significant freshwater ecosystems.

The maps are intended to be used to

- Prioritise areas within Otago that would benefit most from active biodiversity management.
- Provide a baseline of the integrity and extent of indigenous biodiversity within Otago.
- Inform the upcoming reviews of the Regional Water Plan and the Regional Plan Coast.

The key outputs of the project are:

<u>Vegetation Mapping</u>

Three separate maps of:

- Actual vegetation (classified according to Singers and Rogers 2014).
- Potential vegetation (classified according to Singers and Rogers 2014).
- Terrestrial habitat of significant indigenous fauna.

<u>Freshwater Ecosystems and Habitat</u>

Two separate maps of:

- Fresh water ecosystem types
- Freshwater habitats of significant fauna

<u>Coastal/Marine Ecosystems and Habitat</u>

Two separate maps of:

- Ecosystem types.
- Coastal/marine habitats of significant indigenous fauna.

This report describes the methods that were used to map potential terrestrial ecosystems and current ecosystems, and describes the existing data layers that were used to map freshwater ecosystem types and coastal/marine ecosystem types. A companion report

describes the mapping of significant habitats of indigenous fauna across Otago's terrestrial, freshwater, and marine ecosystems.

2. POTENTIAL ECOSYSTEM MAPPING

2.1 Overview

Potential ecosystem mapping across Otago Region used both existing layers and new mapping, informed by a wide range of resources including research articles and reports, species distribution data, aerial imagery, and Wildlands in-house knowledge. The mapping was based on the Singers and Rogers (2014) classification of indigenous ecosystem types, modified in some cases by adding new ecosystem types or sub-units of ecosystem types. The mapping approach is explained in more detail below.

2.2 Fundamental soils layer

Due to the generally strong relationships between soils and vegetation, soil mapping from the fundamental soils layer (FSL) was frequently used as the basis for mapping of potential vegetation in lowland and montane habitats, and in upland habitats in Central Otago and eastern Otago, especially where the former natural indigenous vegetation had been strongly modified or completely cleared. The limitations of FSL soil mapping are that it is at a broad scale, is relatively coarsely resolved, and transitions between soil polygons are necessarily sharp, and would not always correspond to broad ecological transitions along environmental gradients.

Therefore more resolved mapping was undertaken where soil mapping related less well to natural vegetation patterns. This is particularly the case in coastal habitats and around river mouths, and for mountain landscapes in western Otago. In these areas, more detailed mapping was undertaken by hand digitisation, based on evidence from existing vegetation, existing vegetation maps, staff knowledge, and descriptions of vegetation in books, reports, and other publications.

The Dunedin urban area is not covered by soil mapping, and the Dunedin waterfront sits on reclaimed land. For these reasons the potential ecosystems present in the Dunedin urban area were defined by topographical and ecological information, and an area roughly corresponding to the reclaimed land was classified as an estuarine wetland ecosystem, WL10 Oioi restiad rushland/reedland.

2.3 Establishment of treelines and mapping of alpine ecosystems

In western Otago, where beech forest is the dominant forest type, we used a different approach. Elevation thresholds were used to define the upper forest limit, and the lower limit was established either by defining a lower elevation threshold, or mapping all other low elevation ecosystems and then filling the remainder with beech forest. Upper forest limits varied in different parts of Otago, with the highest forest limit of 1,200 metres above sea level (asl) used for CDF3 mountain beech forest in the rainshadow of the Southern Alps where mountain beech charcoals are most abundant between 900-1,200 metres (Molloy *et al.* 1963). A treeline of 1,100 metres asl was used in western areas where CLF11 silver beech forest formed the treeline, but reduced to 900 metres

asl in the uplands of the Garvie/Old Man/Old Woman Ranges, where wet upland soils may have limited the upper treeline.

The Land Cover Database Version 5 (LCDB) was then used to allocate ecosystems to cover classes above treeline (Table 1), in some cases using other layers such as QMAP to differentiate different ecosystem types. Hand digitisation was used to map the CL11 mountain tutu, *Hebe*, whahariki, *Chionochloa* shrubland/tussockland/rockland ecosystem above treeline in western areas such as in the Eyre Mts and the upper Matukituki catchment.

Table 1: Allocation of Singers and Rogers (2014) ecosystem types to LCDB land cover types above treeline

Ecosystem Type	Land Cover Class	Other Criteria
AH Alpine herbfields	Gravel or rock	AH1 on greywacke and in drier western areas.
	Gravel or rock	AH2 on schist in the Central Otago block mountains.
	Gravel or rock	AH3 in the higher rainfall western mountains.
IC1 Permanent snow and Ice	Permanent snow and ice	
AL7.1 Pungent snow tussock tussockland/ shrubland	Alpine grass/herbfield	Close to the Main Divide.
AL6 Mid-ribbed and narrow-leaved snow tussock tussockland/ shrubland	Tall tussock grassland	Close to the Main Divide, informed by distribution data for mid-ribbed snow tussock.
AL1 Narrow-leaved and slim snow tussock tussockland/shrubland	Tall tussock grassland, Low producing grassland	In eastern areas, based on the distribution limit of slim snow tussock. Also mapped on BAM soils.
CDF2 Dracophyllum, Phyllocladus, Olearia, Hebe scrub [subalpine scrub]	Subalpine shrubland	
SC1 scree	N/A	Mapped using topographic polygons and manual additions.

Like the FSL soils layer, LCDB does have limitations, including moderately coarse resolution and misclassification of polygons. Misclassifications were less common in the western parts of Otago, and in upland areas elsewhere where a more natural vegetation cover persists, so have probably not had a great effect on potential ecosystem mapping.

2.4 Other treelines

Tōtara logs have largely been found from 450-1,000 metres asl (Molloy *et al.* 1963), so the CLF1 Halls tōtara, mountain celery pine, broadleaf forest ecosystem was mapped up to 1,000 metres asl in Central Otago. The lowest upper forest limit of 900 metres asl was used in coastal Otago, based on the lack of forest remnants above this elevation in this coastally-influenced part of Otago. Cooler coastal weather is the likely cause of the lower elevation treeline in coastal Otago.

2.5 Lowland/montane podocarp/broadleaved ecosystems

Podocarp/broadleaved forest ecosystems other than CLF1 were mapped widely in coastal hill country and in the lower Clutha catchment, and as smaller examples in the lower Makarora and Matukituki valleys and on the Hawea plains. This mapping was generally based on the distribution of remnant examples of these forest types, and the landforms on which they occur outside Otago Region. The most widespread of these types was CLF4 kahikatea, tōtara, matai forest. The distribution of different podocarp/ broadleaved forest types on different landforms and areas is described in Table 2.

Table 2: Landform attributes used to map lowland podocarp/broadleaved forest types.

Ecosystem Type	Ecosystem Types
MF3 Matai, tōtara, kahikatea broadleaved forest	Mostly well-drained lowland recent alluvial sites.
MF4 Kahikatea forest	Poorly-drained lowland recent alluvial sites.
CLF1 Halls tōtara, mountain celery pine, broadleaf forest	Slopes of inland mountains, rocky soils in southern Macraes Ecological District.
CLF2 Halls tōtara forest	Coastal sand dunes.
CLF4 Kahikatea, tōtara, matai forest	Hill country and downlands, coastal and lower Clutha catchment.
CLF6 Kamahi, southern rata, podocarp forest	Higher rainfall areas, Catlins and Wisp Range.

2.6 Wetlands

Wetland ecosystems were mapped in a number of ways.

Soil maps were used to identify wetland ecosystems in valley floor and inland basin ecosystems, and as the initial basis for wetland mapping in coastal areas. These always required verification as in some cases wetland soils (Table 3) were mapped broadly and included significant areas of non-wetland habitat, e.g. dry hill slopes. Also, some wetland soil types had more than one potential ecosystem type on them (Table 3).

Table 3: The relationship between wetland soils and potential ecosystems.

FSL SOIL Type	Ecosystem Types
GOT, GOO Orthic soils	MF4 Kahikatea forest.
GRT, GRQ Recent soils	WL18 Flaxland, MF4 Kahikatea forest, WL10 Oioi restiad rushland/reedland, WL20 Coprosma, twiggy tree daisy scrub.
OFS Fibric soils	WL16 Red tussock, *Schoenus pauciflorus* tussockland, WL6 Lesser wire rush, tangle fern restiad rushland/fernland.
OMA, OMM Mesic soils	WL18 Flaxland,
PPF Perch-gley soils	MF4 Kahikatea forest.
ZPP Perch-gley soils	Identified some upland wetland complexes that were mapped using LCDB.

Where existing polygons, such as LCDB ‘herbaceous freshwater vegetation’ polygons, were mapped reasonably accurately, these were incorporated into the potential ecosystems layer and allocated ecosystem classifications based on knowledge of wetland types in those areas. The main areas where LCDB ‘herbaceous freshwater vegetation’ polygons were used in this way were on the uplands of the Lammermoor/Lammerlaw Ranges and Manorburn area, and in the uplands stretching from the Nokomai wetland complex around the Garvie Mountains and the Old Man Range, to wetlands on the Umbrella Range. These were mostly WL17, WL8, and/or

WL16 wetland ecosystems, with the former on flat to gently sloping landforms, and the latter on steeper slopes.

Wetlands were hand-digitised in other areas, especially where significant areas of wetland vegetation were not captured by any existing layer, for example on the Remarkables Range and Hector Mountains. Wetlands were also hand-digitised for greater accuracy after locating wetlands from wetland symbology on the NZ Topo layer and the FENZ wetland layer.

Wetlands were classified into ecosystems based on Wildlands staff knowledge of wetlands in different parts of Otago, and features of particular wetland types that could be determined in aerial imagery. For example WL17 *Schoenus pauciflorus* seepages/ flushes and WL8 herbfield/mossfield/sedgeland ecosystems often had similar dark coloration in aerial imagery, but were distinguished by WL8 ecosystems occurring on flat sites and often containing small pools, and WL17 occurring on steeper slopes and often having linear downhill striping.

Ephemeral wetlands were poorly mapped in existing layers such as LCDB and FENZ, as they generally occur at much smaller areas than the minimum mapping units of these classifications. However, ephemeral wetlands are in most cases easily distinguished in aerial imagery, and were mapped by hand digitisation across all parts of Otago where ephemeral wetlands occur. Almost 3,000 ephemeral wetlands were ultimately mapped. Very shallow ephemeral wetlands would be less easy to distinguish and are not likely to have been mapped, and other ephemeral wetlands where the wetland boundary is not sharp.

Sedge-dominant wetlands corresponding to WL22 *Carex*, *Schoenus pauciflorus* sedgeland were widely mapped in lower elevation sites, typically in gullies. These wetlands are generally swamps.

In upland parts of Otago, WL16 red tussock, *Schoenus pauciflorus* tussockland was widely mapped. Wetlands that were dominated by narrow-leaved snow tussock were included in this potential ecosystem type, and sphagnum moss (*Sphagnum cristatum*) is generally abundant in them.

Wood and Walker (2008) identified *Olearia* shrubland as occupying marsh and swamp wetlands in the upper Taieri catchment. *Olearia* shrubland has no analogue in the Singers & Rogers (2014) ecosystem classification. A new ecosystem type, WL23 *Olearia* shrubland, was therefore created to map the potential ecosystem in these basin-floor wetland habitats in the upper Taieri.

The end result of these wetland ecosystem mapping approaches is wetland mapping of significantly better spatial and thematic resolution than any other existing regional scale mapping of wetlands.

2.7 Thermally-induced ecosystems

Thermally-induced ecosystems are typically found in frost hollows and on plains, but also occur in upland plateaux (Singers and Rogers 2014). The TI1 bog pine, mountain celery pine scrub/forest ecosystem was mapped extensively in the colder basins of

Central Otago, and also in mountain valleys such as the Greenstone. T12 kānuka, *Olearia* scrub/treeland was mapped in Central Otago, mostly in the upper Clutha River catchment, where it was mapped on recent alluvial soils and on the drier parts of outwash terraces. Some of the land that would have supported this ecosystem is now occupied by Lake Dunstan. TI2 was also mapped on north-facing rocky slopes at Bendigo and near Luggate, where makahikatoa (*Kunzea serotina*) woodland remains extensive today, and near the junction of the Kawarau River and Clutha River where a smaller existing stand of makahikatoa remains. TI6 red tussock tussockland was mapped on volcanic uplands centred on Mt Siberia in the Kakanui mountains, where impeded drainage on the volcanic plateau has favoured establishment of copper tussock (*Chionochloa rubra* subsp. *cuprea*) grassland. This unit was also mapped in the upper Greenstone Valley.

2.8 Central Otago potential ecosystems

Central Otago presented a challenge for potential ecosystem mapping due to the scarcity of intact indigenous vegetation in lowland and montane habitats, and its unique climate and soils. As McGlone (2001) stated: "Eight hundred years of fire and 150 years of pastoral development have obscured the original vegetation patterns of the south-eastern South Island. Over large stretches of country no vegetation associations corresponding to those of the pre-human situation remain." Mapping of Central Otago habitats therefore took account of recent research and modelling on the paleoecology of the area.

McGlone (2001) suggested that low forest-scrub-grassland vegetation was originally present in Central Otago and that matai (*Prumnopitys taxifolia*) was highly unlikely to have been present in the semi-arid Central Otago area, apart from immediately east of the axial mountains. However matai is abundant in the pollen diagram for the Idaburn Valley site described in this paper, along with tōtara (*Podocarpus* spp.), mountain celery pine (*Phyllocladus alpinus*) and *Olearia*. At Earnscleugh Cave, matai and/or tōtara pollen were abundant, along with abundant *Myrsine* and *Coprosma*. At Teviot Swamp, abundant matai pollen, along with with *Halocarpus*, *Phyllocladus*, and beeches, was deposited in pre-human times.

Matai charcoal and seed cases have been recorded from Tekapo moraines (Molloy *et al.* 1963), illustrating its occurrence in inland basins, while Holloway (1954) observed matai/tōtara/kahikatea stands in the lower reaches of the Makarora Valley. He noted that matai stumps were present near Lake Hawea. Matai is currently still present in the lower Matukituki Valley (Peter Johnson, Landcare Research, pers.comm.). Singers (2018) developed an additional cool forest ecosystem, CLF13 Matai, broadleaf forest, to accommodate the matai forests that were believed to have dominated the Awatere valley floor and been historically more extensive in southern Marlborough, inland North Canterbury, and possibly Central Otago. As evidence of matai is mostly from alluvial landforms, CLF13 was mapped on alluvial flats and terraces in the inland valley floors. The presence of a wide range of exotic trees on these landforms today is evidence that there are few limitations to the growth of taller forest in these habitats, apart from where landforms are too cold, too dry, or too wet to support tall forest. Besides matai and broadleaf, it is likely that the CLF13 ecosystem type would also have included trees such as kōwhai, lowland ribbonwood (*Plagianthus regius*), narrow-leaved lacebark (*Hoheria angustifolia*), and fierce lancewood (*Pseudopanax ferox*). As

no indigenous forest remains in the areas where CLF13 has been mapped, there is more uncertainty relating to the occurrence and extent of this ecosystem type than for most other ecosystem types.

Molloy *et al.* (1963) concluded that forest would have covered almost all areas of the South Island below treeline, apart from sites that were too dry or subject to frequent natural disturbance. Wardle (2001) noted widespread subfossil logs and charcoal on slopes in Central Otago, predominantly from beech, but also including matai, Hall's tōtara (*Podocarpus laetus*), mountain toatoa, bog pine (*Halocarpus bidwillii*), and kānuka (*Kunzea* spp.). Tōtara logs were found between 590 metres asl and 1,040 metres asl. On Mou Waho Island (Lake Wanaka), charred tōtara and matai logs were found in a small lake. Logs were widespread, but none were found on the western slopes of the Pisa Range, or on the Dunstan Mountains, although they occur on the eastern slopes. Park (1908) noted tōtara logs on the Dunstan, Pisa, Remarkable, and Carrick Ranges. Holloway (1954) noted that tōtara was common in the Nevis Valley. Buchanan (1875) noted that mountain celery pine was common on the central mountains and on Dunedin hilltops. Based on the widespread evidence of Hall's tōtara and mountain celery pine on the inland range slopes, the CLF1 Halls tōtara, mountain celery pine, broadleaf forest ecosystem was mapped widely in these habitats.

Walker *et al.* (2003) mapped 12 woody ecosystem types across Central Otago, noting the main gradient is an elevation gradient caused by climate. These ecosystems don't neatly fall into Singers and Rogers (2004) ecosystems, possibly because they relate to only woody species. Walker *et al.* (2003) concluded that a suite of frost- and drought-tolerant but fire-sensitive tall woody species were eliminated from the valley floors, leaving only fire-resistant species. They suggest that Central Otago valley floors are likely to have supported woodlands of mountain toatoa (*Phyllocladus alpinus*) and bog pine (*Halocarpus bidwillii*) which survive in fire refugia on basin floors elsewhere in the eastern South Island. These associations are typically found in frost-prone habitats, and some of the best remaining examples in Otago occur in the Greenstone Valley (Johnson and Lee 1993). Accordingly, we mapped this vegetation as a thermally-induced ecosystem (TI1 Bog pine, mountain celery pine scrub/forest) in the most frosty parts of the Central Otago, including the Nevis Valley, upper Manuherikia Valley, southern part of the Idaburn Valley and upper Taieri Plains.

Walker *et al.* (2003) also concluded that the widespread matagouri (*Discaria toumatou*)-mingimingi (*Coprosma propinqua*) associations in Central Otago are derived from invasion of more disturbance-tolerant shrubs following destruction of the forests that used to grow in these locations. They also concluded that the broad Otago range tops supported woody vegetation as well as snow tussocks. The Singers and Rogers (2014) classification is consistent with this, as its alpine tussock ecosystems always include shrubs.

Wood and Walker (2008) identified broadleaved-scrub forest with scattered tōtara as occupying rocky gorges in Central Otago, and a likely widespread distribution of lowland ribbonwood on valley floors. In contrast, kānuka and matagouri (*Discaria toumatou*) were not recorded in the sites sampled by Wood and Walker (2008), suggesting the current abundance of these species in Central Otago is due to increased fire frequency and vegetation clearance following the arrival of humans. This does not support the modelling of Walker *et al.* (2003), which suggested kānuka-dominant

woodland occurred in these gorges. However, kānuka was mapped more widely on recent landforms as described above.

2.9 Saline ecosystems

Saline and alkaline soils are located at about 200-600 metres elevation in the main basins of Otago, and were thought by Allen *et al.* (1997) to have occupied at least 40,000 hectares in Otago at the time of European settlement.

Soils are not saline where rainfall is greater than 18 inches (Cossens and Rickard 1968), but are present on brown-grey earths where rainfall is less than 18 inches. Apart from shallow or stony soils, brown-grey earths accumulate soluble salts. In the southern part of the Ida Valley, salty soils occurred to a minor extent on downlands on the toes of some fans, but the main salty area was associated with Linnburn soils on the intermediate terrace, where saline soils were present on ridges between shallow depressions (Cossens and Rickard 1968). Raeside *et al.* (1966) noted that, in general, salt concentrations were not particularly high on the Maniototo Plains, but that localised, highly saline soils did occur, scattered through the areas with lower salt concentrations. Linnburn soils had the greatest salt concentrations, with the most saline of these on the valley floors of the streams draining Rough Ridge, south of Waitoi Creek.

Rogers *et al.* (2000) noted that 40,000 hectares of saline soils had been mapped, and considered that this would all have supported saline-adapted indigenous vegetation. Given the patchy distribution of highly saline soils across the Maniototo (Raeside *et al.* 1966), it is likely that a lower proportion of the 40,000 hectares would have supported indigenous saline vegetation. Based on evidence that Linnburn soils had the highest salinity, 14,366 hectares of Linnburn soils in Central Otago were therefore mapped as the inland saline ecosystem (SA11 Kirk's scurvy grass herbfield/loamfield) corresponding to the salt meanders, pans, and plains that have suffered the greatest loss of saline ecosystems (Rogers *et al.* 2000). This extent, which would have had varying salinity, and likely over-represents the original extent of saline vegetation, was supplemented by additional areas of hand-digitised salt knolls and salt aprons based on currently known highly saline sites.

2.10 Cliff and rockland ecosystems

As described above, CL11 Mountain tutu, Hebe, whaririki, *Chionochloa* shrubland/tussockland/rockland was applied to cliffs and rockland in upland western areas. The other two cliff ecosystems mapped were CL5 Harakeke, *Hebe elliptica* flaxland/rockland on coastal cliffs and slopes, and CL8 *Helichrysum*, *Melicytus* shrubland/tussockland/rockland on limestone cliffs in North Otago and on terrace risers in the upper Clutha basin. Limestone cliffs were located using topographical cliff symbols, but were digitised by hand as the topographic symbols were not amenable to conversion to cliff areas.

2.11 Successional ecosystems

Successional ecosystems would have been widespread in the pre-settlement natural vegetation of New Zealand, but as dynamic ecosystems, would not necessarily occur in

the same places they would currently occupy if human settlement of New Zealand had not occurred. Successional ecosystems are denoted VS in the Singers & Rogers (2014) ecosystem classification. We mapped two of these in Otago: VS6 Matagouri, *Coprosma propinqua*, kōwhai scrub (grey scrub) was mapped on recent river flats and along montane stream corridors, while VS11 Short tussock grassland was mapped in western mountain valley floors alongside braided rivers where more frequent disturbance occurs, and in the coastal delta of the Waikouaiti River.

2.12 Higher-resolution ecosystem definitions

In potential ecosystem mapping in Southland Region, subunits of the Singers and Rogers (2014) classification were used in some cases. We were able to apply subunits to some ecosystem types based on their geographic distributions or elevation ranges (Table 4). Boundaries between alpine tall tussock grassland ecosystems in Fiordland had not previously been defined, but we were able to map AL7, pungent snow tussock tussockland/shrubland, into three different subunits using Wildlands staff knowledge and previous research (Lloyd 2000). The relevant unit in Otago is AL7.1, dominated by *Chionochloa crassiuscula* subsp. *torta*. Silver beech forest (CLF11) was divided into low elevation and upland subunits, based on variants 2 and 3 of Singers and Rogers (2014), while Rockland (EP1) was mapped as either siliceous rockland (EP1.1) or calcareous rockland (EP1.2). CLF6 kamahi, southern rata, podocarp forest comprises at least five sub-units (N. Singers pers. comm.) across New Zealand, with two of those used in Otago (Table 4). Finally, we created an additional subunit of CLF4, with CLF4.3 applying to rimu-dominant podocarp/broadleaved forest ecosystems on the Dunedin hills.

Table 4: Singers & Rogers (2014) ecosystem types that were divided into subunits.

Code	Ecosystem Type	Subunits
AL7	Pungent snow tussock tussockland/shrubland	AL7.1 is dominated by *Chionochloa crassiuscula* subsp. *torta*, *C. rigida* subsp. *amara*, and *C. pallens* subsp. *cadens*. and was mapped on higher mountain ranges, north of the Middle Arm of Lake Te Anau and mostly east of the Main Divide.
		AL7.2 has prominent *Chionochloa acicularis*, and was mapped in western Fiordland, west of Lake Poteriteri and the Main Divide.
		AL7.3 has prominent Chionochloa *teretifolia*, which is often co-dominant, and is mapped in south-eastern Fiordland
CLF4	Kahikatea, tōtara, matai forest	CLF4.2 occurs on better-drained hill country sites and rimu is less prominent
		CLF4.3 was mapped over the volcanic hills of Dunedin, where a wetter climate results in rimu-dominance in this forest type
CLF6	Kamahi, southern rata, podocarp forest	CLF6.1 has emergent rimu, miro and locally Hall's tōtara over a canopy of kamahi and southern rata. Occurring in humid climates typically with acidic soils (e.g. BMA) and podzols on shallow to moderate hillslopes. It was mapped in the southern and western Catlins.
		CLF6.5 comprises emergent rimu, matai, tōtara, miro and locally kahikatea over a sub-canopy kamahi, and southern rata. Occurring in sub-humid climates on brown soils on shallow to moderate hillslopes. This subunit was mapped in the eastern Catlins on the Wisp Range, and in the Kaitangata area.
CLF11	Silver beech forest	CLF11.2 was mapped above 600 m elevation, and corresponds to 'variant 2', upland silver beech forest, as described by Singers & Rogers (2014)

		CLF11.3 was mapped below 600 m elevation and corresponds to 'variant 3', southern lower elevation silver beech forest as described by Singers & Rogers (2014)
EP1	Rockland	EP1.1 'siliceous rockland', was mapped in coastal Otago
		EP1.2 'calcareous rockland' was mapped in North Otago

2.13 Non-vegetated ecosystems below treeline

Polygons for rivers and lakes were obtained from the Freshwater Environments of New Zealand (FENZ) layer. Some additional mapping was undertaken along river corridors and around lakes that the FENZ layer did not include. Some large FENZ lakes were reclassified as ephemeral wetlands in the Middlemarch area.

Beaches were mapped manually when delimiting the coastal environment.

2.14 Uncertainties in the mapping

A key issue with potential ecosystem mapping is that the outcome necessarily results in lines determining boundaries between different ecosystem types, whereas ecological boundaries between different ecosystems are sometimes diffuse or have significant inter-fingering. In addition, the certainty relating to the identification of an ecosystem is generally weaker at the boundary compared with the centre of a polygon. These considerations are particularly relevant to woody non-wetland ecosystem types such as forest, scrub, and shrubland. The consequences of these issues are that if a site is close to a boundary between different potential forest, scrub, and/or shrubland ecosystem types, then either ecosystem (on different sides of the boundary) may have been present.

Ecosystem types that are very small in extent are potentially under-represented or not accurately represented in the mapping. For example, the mapping of inland saline ecosystems (SA11) likely over-represents the extent of inland saline vegetation because it relied on soil mapping, and salinity is not uniform in those soils. Whereas mapping of WL11 Machaerina sedgeland, which would have occurred in small-scale zonations around estuarine wetlands and in some inland wetlands, will have been under-estimated in the mapping due to the lack of evidence to discriminate these small examples. Ephemeral wetlands (WL14) were one class of ecosystem that could be mapped at very small scale, as often there was a sharp outline to the natural boundaries of these ecosystems.

Other ecosystems were mapped widely, but are associated with greater uncertainty because little direct evidence of them being present in an area remains. This is particularly the case in the inland Otago basin floors, where CLF13 Matai, broadleaf forest and TI1 Bog pine, mountain celery pine scrub/forest were widely mapped. In the case of these two ecosystem types, TI1 was mapped across the very cold parts of these basins, and CLF13 in the slightly milder areas.

3. FRESHWATER AND MARINE ECOSYSTEM MAPPING

New mapping for freshwater ecosystems was not undertaken because the existing FENZ classification and mapping of freshwater ecosystems is comprehensive. The FENZ database is a recently-developed set of spatial layers that provide consistent

national coverage of information about freshwater ecosystems, including their geographical distribution, their physical and biological attributes, and their current condition (Leathwick *et al.* 2010). The FENZ data sets can be accessed by sending an email to fenz@doc.govt.nz.

An existing coastal ecosystem classification and mapping scheme developed by the Ministry of Fisheries and Department of Conservation is suitable for the classification of the coastal marine environment in the Otago Region. Fourteen broad coastal marine biogeographic regions have been mapped across the New Zealand coastline, one of which (Southern South Island) occurs in Otago Region. There are four additional sub-levels based on environment type (estuarine or marine), depth (intertidal, subtidal, shallow subtidal, deep subtidal), exposure (low-medium-high) and habitat type (relating to substrate type). The coastal habitat layer is available at:

https://www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/marine-protected-areas/coastal-marine-habitats-and-marine-protected-areas-in-the-new-zealand-territorial-sea-a-broad-scale-gap-analysis/

4. CURRENT ECOSYSTEM MAPPING

LCDB was used as the basis for current indigenous ecosystem mapping. It should be noted that LCDB contains widespread thematic and spatial inaccuracies so that while general patterns may be reliable, the outcomes at a particular site may be misleading.

The classification of LCDB classes into indigenous and exotic cover types is shown in Table 5. The LCDB cover types 'low producing grassland' and 'depleted grassland' LCDB types were not classified as indigenous when assessing the amount of indigenous cover remaining with an ecological district, though these cover types often contain indigenous species at low density. However, if these cover types had been included as indigenous, this would over-estimate indigenous cover. The LCDB cover type 'high producing exotic grassland' also contains many areas of indigenous vegetation, as the resolution of the mapping is poor in places like the Waipori Ecological District where incised gullies are not differentiated in LCDB. These issues mean that the actual extent of indigenous cover will be under-estimated in this report.

Table 5: Classification of LCDB cover classes into indigenous and exotic categories.

Land Cover Classes (LCDB5)	
Indigenous Cover Types	**Exotic Cover Types**
Alpine Grass Herbfield	Deciduous Hardwoods
Broadleaved Indigenous Hardwoods	Depleted Grassland
Estuarine open water	Exotic Forest
Fernland	Forest - Harvested
Flaxland	Gorse and Broom
Herbaceous freshwater vegetation	High Producing Exotic Grassland
Herbaceous saline vegetation	Low Producing Grassland
Gravel or Rock	Mixed Exotic Shrub
Indigenous Forest	Orchard, vineyard, or other perennial crop
Landslide	Short-rotation cropland
Lake or pond	Surface mine or dump

Manuka and Kānuka	Transport infrastructure
Matagouri or Grey Scrub	Urban parkland/open space
Permanent snow and ice	
River	
Sand or Gravel	
Sub Alpine Shrubland	
Tall Tussock Grassland	

Indigenous LCDB cover types were better defined by classifying them into Singers and Rogers (2004) ecosystems. Due to the extensive modification of indigenous ecosystems below treeline, many indigenous cover types no longer support their original vegetation. This means that a straightforward intersect of potential ecosystems and indigenous cover would produce misleading results. We therefore restricted the allocation of potential ecosystems to current cover as outlined in Table 6. In some cases, the choice of potential ecosystem was constrained (e.g. 'tall tussock grassland' can only be allocated to an AL ecosystem above treeline), in others whatever potential ecosystem that intersected with the LCDB polygon was allocated. Indigenous LCDB polygons retained the LCDB cover name where they were not allocated a potential ecosystem, or when there were additional mapped ecosystems within an LCDB polygon to the constrained ones.

Table 6: Classification of indigenous LCDB cover classes into Singers and Rogers (2014) ecosystem types.

Land Cover Classes (LCDB5) and Ecosystems	
Indigenous Cover Types	**S&R Ecosystem Allocation**
Alpine Grass Herbfield	The relevant potential ecosystem
Broadleaved Indigenous Hardwoods	VS5 Broadleaved species scrub/forest
Estuarine open water	Estuary
Fernland	VS10 Bracken fernland
Flaxland	WL18 flaxland
Herbaceous freshwater vegetation	The relevant WL ecosystem
Herbaceous saline vegetation	SA3 Glasswort herbfield
Gravel or Rock	Gravel or rock <400m, the relevant potential ecosystem >400m
Indigenous Forest	The relevant MF, CLF, or CDF ecosystem
Landslide	The relevant potential ecosystem
Lake or pond	Lake or Pond
Manuka and Kānuka	Differentiated using geographic and elevation limits
Matagouri or Grey Scrub	VS6 Matagouri, Coprosma propinqua, kowhai shrubland
Permanent snow and ice	Permanent snow and ice
River	River
Sand or Gravel	Sand or Gravel
Sub Alpine Shrubland	CDF2 Dracophyllum, mountain celery pine etc scrub
Tall Tussock Grassland	The relevant AL ecosystem

LCDB 'Mānuka or kānuka' polygons were differentiated into three possible units, corresponding to makahikatoa (*Kuzea serotina*) scrub and shrubland (corresponding to the TI2 ecosystem) in most inland areas, kānuka (*Kunzea robusta*) scrub/forest in coastal areas, the lower Clutha Valley, and the southern and northern slopes of the

Dunstan Mountains (de Lange 2014), and manuka (*Leptospermum scoparium*) scrub/forest allocated to LCDB 'mānuka or kānuka' polygons above 600 metres asl where kānuka was present, and above 900 metres asl where makahikatoa was present.

In the Catlins, where kānuka is absent (de Lange 2014), all LCDB 'mānuka or kānuka' polygons were allocated to mānuka scrub/forest.

5. POTENTIAL ECOSYSTEM MAPPING OUTCOMES

5.1 Wetland ecosystems

Fifteen wetland ecosystems, comprising 8,274 wetland polygons, with an average polygon size of 5.6 hectares, totalling 34,941 hectares in area, were mapped within Otago Region (Table 7). The most extensive ecosystem types mapped were WL16 red tussock, *Schoenus pauciflorus* tussockland (12,060 hectares), WL18 flaxland (6,037 hectares), and WL20 Coprosma, twiggy tree daisy shrubland (5,935 hectares).

Wetland ecosystems that were mapped as being historically uncommon in Otago included WL9 cushionfield, WL11 *Machaerina* sedgeland, WL13 sphagnum mossfield, WL15 herbfield (lakeshore turf), and WL19 raupo reedland. While Otago has abundant upland cushionfield, most of this is not wetland vegetation, and wetland vegetation comprising cushion vegetation was mostly mapped within WL8 herbfield, mossfield, sedgeland. WL11 *Machaerina* sedgeland was likely more widespread in Otago than we mapped, but is likely to have occurred in relatively small patches that were below our mapping resolution. Singers and Rogers (2004) define WL13 sphagnum mossfield as riverine/lacustrine ecosystem, rare in both the North Island and South Island. While wetlands containing *Sphagnum* are widespread and extensive in the Otago uplands, most of these comprise other wetland types, commonly WL6 lesser wire rush, tangle fern, restiad rushland/fernland and WL16 red tussock, *Schoenus pauciflorus* tussockland. In Otago, WL13 sphagnum mossfield was mapped only on the margins of two small lakes in the lower Dart River. Lakeshore turf is present on the margins of the larger Otago lakes, but was difficult to map, because of its occurrence in narrow bands along lake shores, and because lake polygons from the FENZ layer incorporate most lakeshores. Similarly, WL19 raupo reedland would have been more common than the mapping suggests, because it would also have occurred in areas mapped as lake.

Table 7: Wetland ecosystem types historically present in Otago.

S&R Ecosystem	Zone	Total Area (ha)	Number of Polygons	Mean Polygon Size (ha)
WL6 Lesser wire rush, tangle fern restiad rushland/fernland	High rainfall areas	712	40	18
WL8 Herbfield, mossfield, sedgeland	Upland and alpine areas	3,587	1,035	3
WL9 Cushionfield	Upland and alpine areas	91	72	1
WL10 Oioi restiad rushland	Lowland estuarine	388	38	10

S&R Ecosystem	Zone	Total Area (ha)	Number of Polygons	Mean Polygon Size (ha)
WL11 Machaerina sedgeland	Montane swamp	17	2	9
WL12 Mānuka, tangle fern scrub/fernland	High rainfall areas	129	15	9
WL13 Sphagnum mossfield	Montane lake margins	10	2	5
WL14 Herbfield (ephemeral wetland)	Montane basins	294	2,927	0.10
WL15 Herbfield (lakeshore turf)	Inland lake shores	2	2	1
WL16 Red tussock, Schoenus pauciflorus tussockland	Montane uplands	12,060	2,009	6
WL17 Schoenus pauciflorus sedgeland (alpine seepages/flushes)	Upland and alpine areas	3,819	1,594	2
WL18 Flaxland	Lowland swamps	6,037	98	62
WL19 Raupo reedland	Lowland and coastal lakes and inland basins	76	11	7
WL20 Coprosma, twiggy tree daisy scrub	Lowland swamps	5,935	37	48
WL22 Carex, Schoenus pauciflorus sedgeland	Lowland swamps	1,784	392	4
TOTAL		**34,941**	**8,274**	**5.6**

As noted above, the wetland mapping approach we used is a significant advance in both spatial and thematic resolution than any previous wetland mapping layer covering Otago, though numerous small (<0.5 hectares) wetlands remain un-mapped in the Lammermoor/Lammerlaw uplands. Wetland types whose current distribution and extent closely matches their potential distribution and extent are WL8 Herbfield, mossfield, sedgeland, WL13 *Sphagnum* mossfield, WL14 herbfield (ephemeral wetland), WL16 red tussock, *Schoenus pauciflorus* tussockland, WL17 *Schoenus pauciflorus* sedgeland (alpine seepages/flushes), and WL22 *Carex*, *Schoenus pauciflorus* sedgeland. These current wetland ecosystems comprise approximately two thirds of the historic extent of wetlands mapped across Otago.

5.2 Forest and scrub ecosystems

Forest historically covered most of Otago, including the inland basins that are currently devoid of indigenous forest.

CDF3 Mountain beech forest, CLF1 Hall's tōtara, mountain celery pine, broadleaf forest, CLF4 Kahikatea, tōtara, matai forest, CLF11 Silver beech forest, CLF6 Kamahi, southern rata, podocarp forest, and CLF13 matai, broadleaf forest were the predominant forest types in Otago (Table 8). These forest types were generally not mixed together and occurred in different parts of Otago. CLF4 Kahikatea, tōtara, matai forest dominated the relatively dry eastern lowland hill country within the region, while CLF1 Hall's tōtara, mountain celery pine, broadleaf forest and CLF13 matai, broadleaf forest occupied the inland basins of Central Otago. CDF3 Mountain beech forest occurred in the rainshadow mountains east of the Main Divide, while CLF11 Silver beech forest occupied mountain valleys along and close to the Main Divide, and also higher-rainfall

uplands further east. CLF6 Kamahi, southern rata, podocarp forest dominated hill slopes in South Otago and in the Catlins.

Table 8: Forest ecosystem types historically present in Otago.

S&R Ecosystem	Zone	Total Area (ha)	Number of Polygons	Mean Polygon Size (ha)
CDF1 Pahautea, Hall's tōtara, mountain celery pine, broadleaf forest	East Matukituki, upper Shotover	3,678	14	263
CDF2 Dracophyllum, Phyllocladus, Olearia, Hebe scrub (subalpine scrub)	Mountain valleys above treeline	29,931	1,924	16
CDF3 Mountain beech forest	Otago lakes area	334,418	123	2,719
CDF6 Olearia, Pseudopanax, Dracophyllum scrub (subalpine scrub)	Catlins, margin of Ajax Plateau	35	1	35
CLF1 Hall's tōtara, mountain celery pine, broadleaf forest	Central Otago uplands	417,690	130	3,213
CLF2 Hall's tōtara forest (dune forest)	Old dunes	2,530	30	84
CLF4.2 Kahikatea, tōtara, matai forest		631,622	135	4,679
CLF4.3 Kahikatea, tōtara matai forest	Dunedin hills	27,965	8	3,496
CLF6.1 Kamahi, southern rata, podocarp forest	Southern Catlins, Kaitangata	54,931	185	297
CLF6.5 Kamahi, southern rata, podocarp forest	Northern Catlins	73,175	25	2,927
CLF9 Red beech, podocarp forest	Western lakes	4,425	13	340
CLF10 Red beech, silver beech forest	Western and south-western valleys	55,854	54	1,034
CLF11.2 Silver beech forest	Above 600m	141,564	514	275
CLF11.3 Silver beech forest	Below 600m	277,361	321	864
CLF12 Silver beech, mountain beech forest	Western lakes	38,593	68	568
CLF13 Matai, broadleaf forest	Inland basins	101,827	100	1,018
MF3 Matai, tōtara, kahikatea, broadleaved forest	Lowland plains	81,672	186	439
MF4 Kahikatea forest	Lowland plains	35,138	96	366
TOTAL		**2,312,409**	**3,927**	**589**

5.3 Alpine ecosystems

Nine ecosystems were historically present above treeline in Otago (Table 9), and all remain present, though some with their extent changed. For example there is less AL1 narrow-leaved and slim snow tussock tussockland/shrubland currently above treeline, due to the widespread loss of slim snow tussock due to historic fire and grazing. AL1 narrow-leaved and slim snow tussock tussockland/shrubland was historically by far the most extensive alpine ecosystem in Otago, due to its presence on all the eastern

ranges and most of the western ranges. AL6 mid-ribbed and narrow-leaved snow tussock grassland was mapped in the westernmost alpine areas within Otago Region, with AL7.1 at higher elevation in these same areas. Alpine herbfield ecosystems were largely differentiated by geology and climate, with AH1 gravelfield, stonefield present on the drier, steeper mountains in the north and southwest of Otago Region, AH2 *Dracophyllum muscoides* cushionfield on the Central Otago block mountains, and AH3 gravelfield/stonefield/mixed species cushionfield in the western high-rainfall mountains. CL2 mountain tutu, *Hebe*, whararikі, *Chionochloa* shrubland/tussockland/ rockland was mostly mapped in the Eyre Mountains.

Table 9: Alpine ecosystem types historically present in Otago.

S&R or Non-Vegetated Ecosystem	Total Area (ha)	Number of Polygons	Mean Polygon Size (ha)
AH1 Gravelfield, stonefield	25,612	2,269	11
AH2 Dracophyllum muscoides cushionfield	41,095	330	134
AH3 Gravelfield/stonefield/mixed species cushionfield	45,352	1,687	27
AL1 Narrow-leaved and slim snow tussock tussockland/shrubland	448,651	1,181	380
AL6 Mid-ribbed and narrow-leaved snow tussock tussockland/shrubland	49,995	272	184
AL7.1 Pungent snow tussock tussockland/shrubland	8,347	166	50
CL11 Mountain tutu, Hebe, whararikі, Chionochloa shrubland/tussockland/rockland	500	17	29
IC1 Permanent snow and ice	14,636	510	29
SC1 Gravelfield (screes and boulderfields)	17,348	1,114	16
TOTAL	**651,536**	**7,546**	**86**

6. CURRENT INDIGENOUS ECOSYSTEM MAPPING OUTCOMES

Current indigenous ecosystems in Otago are dominated by AL1 narrow-leaved and slim snow tussock tussockland/shrubland, which remains extensive (414,328 hectares) in alpine areas, and has an additional 328,509 hectares of LCDB 'tall tussock grassland' below treeline, where most of it would not have historically occurred (Table 10). In total therefore there are currently 742,837 hectares of tall tussock grassland in Otago, which is approximately 300,000 hectares more than would have historically occurred. In contrast, only 212,643 hectares of broadleaved, podocarp/broadleaved, and/or beech forest remains, which is approximately 10% of the original extent of indigenous forest across Otago. At least 90,016 hectares of scrub and shrubland below treeline, and 28,447 hectares of bracken fernland have partially replaced this indigenous forest. Some coastal ecosystems, such as SA7 Ice plant, glasswort herbfield/loamfield and SA9 *Olearia*, *Brachyglottis*, *Dracophyllum* scrub/herbfield/loamfield are still present, but they are not captured as an indigenous cover type by LCDB, thus have no area or only minimal area in Table 10. Wetlands have fared differently depending on whether they are lowland or upland ecosystems, as shown by the trends for WL16 red tussock, *Schoenus pauciflorus* tussockland and WL18 flaxland. Both occurred extensively (>6,000 hectares of each) in Otago prior to human settlement, but while WL16 red

tussock, *Schoenus pauciflorus* tussockland remains extensive on Otago's upland plateaux, the lowland WL18 flaxland has been reduced to 25% of its original extent.

Table 10: Current indigenous ecosystem types in Otago Region. Not all LCDB cover types could be resolved as Singers and Rogers (2014) ecosystems.

Singers and Rogers or LCDB current ecosystem	Total Area (ha)	Number of Polygons	Mean Polygon Size (ha)
AH1 Gravelfield, stonefield	25,591	2,268	11
AH2 Dracophyllum muscoides cushionfield	10,290	410	25
AH3 Gravelfield/stonefield/mixed species cushionfield	45,286	1,685	27
AL1 Narrow-leaved and slim snow tussock tussockland/shrubland	414,328	1,382	300
AL6 Mid-ribbed and narrow-leaved snow tussock tussockland/shrubland	49,041	264	186
AL7.1 Pungent snow tussock tussockland/shrubland	8,301	161	50
BR1 Hard tussock, scabweed gravelfield/stonefield	1,534	161	10
BR2 Scabweed gravelfield/stonefield	942	173	5
CDF1 Pahautea, Hall's tōtara, mountain celery pine, broadleaf forest	942	29	32
CDF2 Dracophyllum, Phyllocladus, Olearia, Hebe scrub (subalpine scrub)	45,657	1,902	24
CDF3 Mountain beech forest	36,231	1,219	30
CDF6 Olearia, Pseudopanax, Dracophyllum scrub (subalpine scrub)	8	8	1
CL11 Mountain tutu, Hebe, whararikí, Chionochloa shrubland/tussockland/rockland	87	11	8
CL5 Harakeke, Hebe elliptica flaxland/rockland	465	90	5
CL8 Helichrysum, Melicytus shrubland/tussockland/rockland	12	5	2
CLF1 Hall's tōtara, mountain celery pine, broadleaf forest	957	201	5
CLF10 Red beech, silver beech forest	18,053	418	43
CLF11.2 Silver beech forest	36,108	536	67
CLF11.3 Silver beech forest	37,358	534	70
CLF12 Silver beech, mountain beech forest	17,192	418	41
CLF13 Matai, broadleaf forest	144	40	4
CLF2 Hall's tōtara forest (dune forest)	26	18	1
CLF4.2 Kahikatea, tōtara, matai forest	2,597	443	6
CLF4.3 Kahikatea, tōtara matai forest	3,226	154	21
CLF6.1 Kamahi, southern rata, podocarp forest	24,746	226	109
CLF6.5 Kamahi, southern rata, podocarp forest	5,395	298	18
CLF9 Red beech, podocarp forest	884	37	24
DN3 Pingao sedgeland	315	34	9.2
DN5 Oioi, knobby clubrush sedgeland	138	9	15
EP1.1 Siliceous rockland	170	78	2
EP1.2 Calcareous rockland	0	0	0
MF3 Matai, tōtara, kahikatea, broadleaved forest	440	112	4
MF4 Kahikatea forest	199	55	3
SA11 Kirk's scurvy grass herbfield/loamfield	0.3	2	0.2
SA3 Glasswort herbfield	600	214	2.8

Singers and Rogers or LCDB current ecosystem	Total Area (ha)	Number of Polygons	Mean Polygon Size (ha)
SA5 Herbfield (coastal turf)	19	9	2
SA7 Ice plant, glasswort herbfield/loamfield	0	0	0
SA9 Olearia, Brachyglottis, Dracophyllum scrub/ herbfield/loam field (mutton bird scrub)	0	0	0
SC1 Gravelfield (screes and boulderfields)	13,885	1,309	11
TI1 Bog pine, mountain celery pine scrub/forest	93	38	2
TI2 Kānuka, Olearia scrub/treeland	36	21	2
TI4 Coprosma, Olearia, matagouri scrub (grey scrub)	26	34	1
TI6 Red tussock tussockland	17	20	1
VS10 Bracken fernland	28,477	683	41
VS11 Short tussock grassland	0.2	1	0.2
VS5 Broadleaved species forest	27,684	2,300	12
VS6 Matagouri, Coprosma propinqua, kōwhai scrub (grey scrub)	32,145	3,212	10
WL10 Oioi restiad rushland	269	28	10
WL11 Machaerina sedgeland	17	2	8
WL12 Mānuka, tangle fern scrub/fernland	131	15	9
WL13 Sphagnum mossfield	11	7	2
WL14 Herbfield (ephemeral wetland)	345	3,032	0.1
WL15 Herbfield (lakeshore turf)	0	0	0
WL16 Red tussock, Schoenus pauciflorus tussockland	12,297	2,044	6
WL17 Schoenus pauciflorus sedgeland (alpine seepages/flushes)	3,840	1,594	2
WL18 Flaxland	1,564	109	14
WL19 Raupo reedland	76	13	6
WL20 Coprosma, twiggy tree daisy scrub	4,167	49	85
WL22 Carex, Schoenus pauciflorus sedgeland	2,238	639	4
WL6 Lesser wire rush, tangle fern restiad rushland/fernland	750	34	22
WL8 Herbfield, mossfield, sedgeland	3,645	1,045	3
WL9 Cushionfield	95	73	1
LCDB cover types not differentiated into S&R types			
Estuary	112	359	0.3
Gravel or Rock	8,233	777	11
Herbaceous freshwater vegetation	3	1	3
Indigenous forest	461	736	1
Kānuka scrub/forest	33,342	1,789	19
Lake or pond	77,808	1,241	63
Makahikatoa scrub and shrubland	12,292	908	14
Mānuka scrub/forest	12,840	1,309	10
Permanent ice or snow	14,671	519	28
River	8,484	265	32
Sand or gravel	51	54	1
Tall tussock grassland	328,509	5751	58

ACKNOWLEDGMENTS

Rachael Brown of Otago Regional Council is thanked for providing project liaison. John Leathwick is thanked for discussion on potential ecosystems from inland Otago. John Barkla is thanked for undertaking a peer review of the mapping.

REFERENCES/INFORMATION SOURCES

Allen R.B. 1981: Papatowai Scenic Reserve. Botany Division, DSIR, Dunedin.

Allen R.B. 1985: The ecology of *Nothafagus menziesii* in the Catlins Ecological Region, south-east Otago, New Zealand. Ph.D thesis, University of Otago.

Allen R.B. 1988: A forest succession in the Catlins Ecological Region, south-east Otago, New Zealand. *New Zealand Journal of Ecology 11*: 21-29.

Allen R.B., Johnson P.N. and Lee W.G. 1988: Vegetation of the Kakanui Mountains volcanic complex, Dansey Ecological District, Otago. Botany Division, DSIR, Dunedin.

Cossens G.G. and Rickard D.S. 1968: Irrigation investigations in Otago, New Zealand. *New Zealand Journal of Agricultural Research 11*: 445-461.

de Lange P.J. 2014: A revision of the New Zealand *Kunzea ericoides* (Myrtaceae) complex. *Phytokeys 40*: 1-185.

Department of Conservation 2004: Conservation Resources Report. PO 241 Ben Nevis.

Department of Conservation 2004: Conservation Resources Report. PO 311 Rees Valley.

Department of Conservation 2004: Conservation Resources Report. Walter Peak Special Lease (PS41) and Walter Peak-Beach Bay Recreation Reserve.

Department of Conservation 2012: Conservation Resources Report. PO 047 Earnslaw.

Johnson P.N. 1984: Wanaka area reserves: botanical report. Botany Division, DSIR, Dunedin.

Johnson P.N. 1985: Black swamp: botanical report. Botany Division, DSIR, Dunedin.

Johnson P.N. 1986: False Islet Recreation Reserve: Report on botany. Botany Division, DSIR, Dunedin.

Johnson P.N. and Lee W.G. 1993: Greenstone, Elfin Bay, and Routeburn Stations: botanical report. Landcare Research Contract Report LC 9293/39.

Johnson P.N., Mark A.F., and Baylis G.T.S. 1976: Vegetation at Ajax Hill, south-east Otago, New Zealand. *New Zealand Journal of Botany 15*: 209-220.

Leathwick J.R., West D., Chadderton L., Gerbeaux P., Kelly D., Robertson H., and Brown D. 2010: Freshwater Ecosystems of New Zealand (FENZ) Geodatabase. Version One - August 2010. User Guide. Department of Conservation, Wellington.

Lee W.G. 1986: Sherwood Bush, Heriot, West Otago. Botanical Report. Botany Division, DSIR, Dunedin.

Lee W.G., Williams P.A., and Begg J. 1979: Botanical report on Silver Island, Lake Hawea. Botany Division, DSIR, Dunedin.

Lloyd K.M. 2000: The comparative ecology of rare and common *Acaena* and *Chionochloa* species. PhD thesis, University of Otago.

Partridge T.R. 1980: The vegetation of Wharekakahu (off Otago Peninsula coast). Botany Division, DSIR, Dunedin.

Raeside J.D., Cutler E.J.B. and Miller R.B. 1966: Soils and related irrigation problems of part of the Maniototo Plains, Otago. *New Zealand Soil Bureau Bulletin 23*. DSIR, Wellington.

Rogers G., Hewitt A., and Wilson J.B. 2000: Ecosystem-based conservation strategy for Central Otago's saline patches. *Science for Conservation 166*. Department of Conservation, Wellington.

Singers N. 2018: A potential ecosystem map of the Marlborough District. *NSES Report 29: 2017/2018*. Prepared for Marlborough District Council.

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

Wardle P. Holocene forest fires in the upper Clutha District, Otago, New Zealand. *New Zealand Journal of Botany 39*: 523-542.

Wardle P. and Johnson P.N. 1987: Botany Division excursion to the Hunter Valley, Lake Hawea, Otago, with notes on soil charcoals and forest remnants in the upper Clutha Basin. Botany Division, DSIR, Dunedin.

Wildland Consultants 2007: Assessment of new facilities sites at Routeburn Falls Hut, Routeburn Track. *Wildland Consultants Contract Report No. 1332.* Prepared for Tourism Milford Ltd.

Wildland Consultants 2011: Ecological evaluation of wetlands in South Otago and Central Otago. *Wildland Consultants Contract Report No. 2656*. Prepared for Otago Regional Council.

Wildland Consultants 2013: Assessment of natural areas in Tokoiti Forest, coastal Otago. *Wildland Consultants Contract Report No. 2767*. Prepared for City Forests Ltd. 50 pp plus appendix.

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