Manaaki Whenua
Landcare Research

Naturally uncommon ecosystems – recommendations for updating the list

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Summary

Project and client

- Otago Regional Council contracted Manaaki Whenua – Landcare Research to refine and update the published list of naturally uncommon ecosystems (NUEs).

Objectives

- To review and make recommendations for updating the list of NUEs.

Methods

- Information was gathered on potential ecosystems to add to, divide, or subtract from the original list of NUEs published in 2007.
- This input was received from ecological experts via email and informal discussions.
- The responses were collated, and two workshops were held to review the suggestions. A set of refinements and additions was proposed.
- These proposed refinements and additions were circulated for additional comment.

Results

- Refinements were suggested for 24 ecosystems.
- Fourteen additions to the list were suggested.
- Eleven refinements (including removing one system) and nine additions to the list are recommended.

Conclusions and recommendations

We recommend the following changes to the list (resulting in a total of 78 NUEs):

- Remove cloud forests.
- Modify the common name of four systems:
  - change 'braided riverbeds' to 'braid plain'
  - change 'geothermal streamsides' to 'geothermal stream and spring margins'
  - change 'estuaries' to 'estuary margins'
  - change 'heated ground (dry) to 'geothermally-heated ground (dry)'
  - change 'hydrothermally-heated ground (now cooled) to 'previously geothermally-heated ground (now cool)'
  - change 'lagoons' to 'lagoon margins'
  - change 'tarns' to 'tarn margins'
- Combine 'granitic sand plains' and 'granitic gravel fields' to give 'granitic sand and gravel fields'.

- Split moraines into two types:
  - ‘moraines (recently formed)’
  - ‘moraines (dry)’.
- Remove the word ‘usually’ from the definition of ‘tarn’.
- Remove the word ‘coastal’ from the definition of ‘seabird-burrowed soils’.
- Add eight systems to the NUE list:
  - ‘boulderfields of quartzose rocks’
  - ‘coastal colluvium’
  - ‘cobble bank wetland’
  - ‘geothermal wetland’
  - ‘dry deflation plains’
  - ‘inland dryland alluvium’
  - ‘inland salt springs’
  - ‘mud volcanoes’.

We also recommend:

- updating the factsheets and guidance documents, as outlined in sections 5.1, 5.2, Appendix 1, and Appendix 2
- revising the diagnostic classifiers to enable ecosystems that are known to be naturally uncommon, but not able to be defined with the current set of diagnostic classifiers, to be incorporated into the NUE framework
- defining how recently created analogue systems should be treated
- carrying out an ecosystem-by-ecosystem threat assessment on the updated list, following the approach used for global ecosystem red listing.

1 Introduction

Otago Regional Council, on behalf of Te Uru Kahika – Regional and Unitary Councils Aotearoa and the Biodiversity Working Group / Terrestrial Ecology Forum, contracted Manaaki Whenua – Landcare Research (MWLR) to refine and update the published list of 71 naturally uncommon ecosystems (NUEs) using the original framework in Williams et al. 2007. The resulting updated list and supporting information will help councils to meet their obligations under the Resource Management Act 1991, and will allow councils to give effect to policy statements such as the National Policy Statement for Indigenous Biodiversity and the New Zealand Coastal Policy Statement 2010, and to align with national directions in Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020.

This project arose as the result of current work[1] to refine the mapping of NUEs across New Zealand, including defining ways to locate and delimit them on the ground. During this process, additional ecosystems not on the 2007 list were suggested, and arguments were made for splitting or modifying others already present. Because the list of NUEs was intended to be a 'first approximation' rather than definitive (Williams et al. 2007), it is appropriate to carry out a review. For this work we use the definition of ecosystem and the framework set out by Williams et al. (2007).

2 Background

2.1 Overview

Williams et al. (2007) define an ecosystem as 'an ecological system formed by the interaction of co-acting organisms and their environment'. NUEs are defined as those that have a total extent of less than 0.5% (i.e. <134,000 ha) of New Zealand's total land area (268,680 km^2). They range from small (e.g. 100 m^2 to a few hundred hectares) but geographically widespread (e.g. coastal dune deflation hollows) to those that are larger (e.g. tens of thousands of hectares) but geographically restricted (e.g. frost flats on the North Island's Volcanic Plateau).

The 71 listed NUEs occur from the sea (e.g. coastal rock stacks) to the mountains (e.g. tarns), although many are found in lowland and coastal regions. Despite being small in overall extent, the often highly specialised, endemic, and diverse flora and fauna in these ecosystems contribute enormously to New Zealand's indigenous biodiversity. Thus NUEs only account for 3–10% of New Zealand's total land area but contain 86% of mainland New Zealand's nationally critical, endangered, and vulnerable plant species, of which 46% are restricted to NUEs (Holdaway et al. 2012).

The primary threats to NUEs are land-use change and land-use intensification. More specifically, the threats encompass removal of native vegetation cover, pressure from exotic animal pests and weeds (especially woody weeds and sward-forming grasses), changes to disturbance regimes, and

[1] Funded by Envirolink.

hydrological regimes and nutrient inputs associated with land-use change. NUEs are also highly vulnerable to the effects of climate change.

Williams et al. (2007) included a framework for defining these ecosystems alongside the initial list. The original intent of the framework was to have a flexible, national-scale system for delineating ecosystems that are often sparsely vegetated based on environmental and biophysical drivers. The seven abiotic classifiers that are considered for NUEs encompass soil age, parent material / chemical environment, particle size, landform, drainage, disturbance regime, and climate.

2.2 Challenges

The primarily abiotic framework has led to some challenges in identifying and delineating NUEs, which needs to be kept in mind when reviewing the list. First, the NUE framework is not a classification of vegetation types. Failing to recognise this this can lead to confusion, because an individual NUE can have more than one vegetation type associated with it. Many of these ecosystems occur across broad environmental gradients, along which their composition can vary continuously, although the functional expression of the environment may be broadly similar (see examples in Wiser et al. 2010 and Richardson et al. 2012). Further, exclusive reliance on vegetation characteristics to identify ecosystems on the ground can result in the mistaken inclusion or exclusion of ecosystems contrary to the NUE's environmentally based definitions, especially when attempting to infer an arrested succession.

For example, gumlands are noted by Williams et al. (2007) as containing vegetation ranging from 'fernland' to 'forest', yet the areas mapped as 'gumland' (e.g. at Kapowairua, by Neal Enright in the 1980s) were excluded from the Clarkson et al. (2011) paper on gumlands (in the 2000s) as NUEs because they contained tall shrublands. The stature and vegetation composition drove this decision rather than physical edaphic features (albeit peat formation does have a biotic origin) listed by Williams et al. (2007). Similarly, 'stable sand dunes' are often considered to be a different ecosystem when forested, rather than focusing on the underlying landform and edaphic origins that can support vegetation of differing stature (Peter Bellingham, MWLR, pers. comm., 2024). Some of the rarest kinds of lowland forest in northern New Zealand are the fragments (tiny) of old-growth forest on dunes on the west coast of the North Island (Woodhill, Pouto, Te Aupouri; Peter Bellingham, MWLR, pers. comm., 2024).

Second, difficulty also arises in interpreting the ecosystem definition on the ground, particularly delineating the extent of each ecosystem (a problem not unique to this typology). In the field, NUEs can have indistinct boundaries, tending towards mosaics and combinations of different physical substrates (e.g. calcareous screes, cliffs, tors, pavements). To maintain a list that applies to systems nationwide, careful thought is needed when forming definitions that are a unique combination of characters yet are wide enough to encompass some variation.

A third issue for consideration is the potential for confounding 'naturally uncommon' and 'once common, now rare'. Williams et al. (2007) acknowledged that historical rarity at a national scale was uncertain for 11 of the currently listed ecosystems. However, a full review of these 'once common, now rare' systems is out of scope for this update. To maintain the integrity of the naturally uncommon list, the original intent of historically rare should be adhered to.

Finally, we are aware that work is being done elsewhere on NUEs (by the Department of Conservation and others) and on the wider question of aligning New Zealand ecosystem classifications with that of the International Union for Conservation of Nature (IUCN) Global Ecosystem Typology[2]; any changes or modifications to the NUE list need to be aligned with these other work streams.

3 Objective

The objective of this project was to review and update the list of NUEs using expert knowledge.

4 Methods

At the start of the project an email was sent to ecologists at regional councils and territorial authorities, the Department of Conservation, universities, QEII National Trust, and ecological consultants to explain the project and gather supporting information on potential ecosystems to add to, divide, or remove from the Williams et al. 2007 list. For potential new or split ecosystems people were asked to provide:

- an example locality
- defining abiotic feature(s) or diagnostic classifiers
- a description of associated vegetation
- photos and/or a general description
- extent and distribution.

The 28 initial responses were collated into a document that was sent out for comment. Ecologists were asked to assess the ecosystems they felt qualified to comment on, and to indicate if they agreed or disagreed with the suggestions and/or make suggestions for further refinements.

After the initial responses were received two workshops were held to review and consider the suggestions (including the information from the initial assessments). During the workshop discussions, additional suggestions were made. For each refinement and addition three questions were addressed:

- Is the definition distinct from all existing defined NUEs?
- Does the definition describe a set of abiotic features that is naturally uncommon?
- Are the definition and the common name consistent with each other?

From the workshops, an agreed set of refinements and additions were proposed. These proposed refinements and additions were circulated for additional comment.

[2] The full list of Ministry for the Environment reports on this subject can be found here: https://environment.govt.nz/publications/national-ecosystem-typology/

5 Results

Of the 30 suggestions considered, nine refinements (including changes in circumscription) and eight additions are being proposed here for the list. The proposals for refinements and additions are given in two sections below, along with the discussion points, actions, and suggestions from the review rounds and workshops. The suggestions not currently supported (along with the reason(s) why) are listed in two appendices (Appendix 1 and Appendix 2). For many of the ecosystems, further details were supplied (photos or more explanation, or a list of published references), and for completeness this information is given in Appendices 3 to 17.

5.1 Proposed refinements

Modifications and refinements were suggested for 24 ecosystems. We propose implementing changes to eleven ecosystems (Table 1). Below is an outline of the reasoning for the proposed changes for each of these eleven ecosystems.

Table 1. The current ecosystem name and the change proposed

Current ecosystem name	*Definition (i.e. diagnostic classifiers) and notes*	*Vegetation structure*	*Change proposed*
Braided riverbeds	Raw–recent/sand–boulders/plain/periodically flooded	Open land, herbfield	Rename to 'braid plain'
Cloud forests	High cloud cover (<1,500 sunshine hours and >200 rain days p.a.)/inland	Forest	Remove from list
Estuaries	Coastal/estuary	Open land, sedgeland, rushland, reedland, herbfield, shrubland, scrub	Rename to 'estuary margins'
Geothermal streamsides	Geothermal-excessive heat/near permanently saturated (but water table not high)	Open land to scrub	Rename to 'Geothermal stream and spring margins'
Granitic sand plains & Granitic gravel fields	Raw/granite/sand–gravel/hillslope, hillcrest (mostly alpine) Raw/granite/gravel/hillslope, hillcrest	Open land	Combine the two ecosystems and rename to 'granitic sand and gravel fields'
Heated ground (dry)	Geothermal-excessive heat	Open land, mossfield, shrubland, scrub	Rename to 'Geothermally-heated ground (dry)'
Hydrothermally-heated ground (now cool)	Geothermal-acid soils, toxic elements	Open land, shrubland, scrub	Rename to 'Previously geothermally-heated ground (now cool)'
Lagoons	Coastal/lagoon	Open land, sedgeland, rushland, reedland, herbfield, shrubland, scrub	Rename to 'lagoon margins'
Moraines	Raw–recent/cobbles–boulders/moraine/(various parent materials)	Open land, shrubland, herbfield, tussockland	Split to 'moraine (recent)' and 'moraine (dry)'
Seabird burrowed soils	Seabirds – burrowing/coastal	Open land to forest	Remove 'coastal' from definition

Current ecosystem name	*Definition (i.e. diagnostic classifiers) and notes*	*Vegetation structure*	*Change proposed*
Tarns	Open water/depression/alpine (usually)	Tussockland, sedgeland, cushionfield	Rename to 'tarn margins' and remove '(usually)' from definition

Note: The ecosystem name, definition, and vegetation structure columns are from Williams et al. 2007.

5.1.1 Braided riverbeds

Change sought

Rename to 'braid plain' to better describe the ecosystem.

Reasons

These highly dynamic ecosystems are characterised by multiple mobile channels that migrate across extensive plains, resulting in a mosaic of vegetation communities and habitat types of various ages. 'Braid plain' would encompass the 'mobile channels across a gravel floodplain, with evidence of recent channel migration within the active riverbed and of historical movement of the active bed across the floodplain' (quote from the factsheet). The term 'braid plain' is used globally to refer to the area over which the channels (braids) of a braided river move. The Braided Rivers Group provide a good illustration of how to differentiate between flood plains and braid plains (see 'Appendix 3 – Braided riverbeds').

Definition/s

No change is required to the definition.

Action points

- There needs to be further clarity about whether the definition will refer to the current, recent (since human settlement) or historical (prior to human settlement) braid plain extent.
- 'Active braided riverbeds' could be another name for this system.
- For defining the extent, we could use the definition of ECan and NIWA, which refers to the area where the river could flow now in the absence of flood control (i.e. the space the river has influence over). They refer to this as the 'topographic extent'.
- Add 'shrubland' and 'woodland' as potential vegetation structure.

Conclusions

- The name change is supported in principle. We just need to clarify the extent (current, recent or historical).
- Add shrubland and woodland vegetation types as potential vegetation structure.

5.1.2 Cloud forests

Change sought

Preferred suggestion: remove from the list.

Alternative suggestion: refine the criteria.

Reasons

Preferred suggestion: remove. True cloud forest only occurs in the tropics and subtropics (Bruijnzeel et al. 2011), so for this reason it should be removed from the list. Globally cloud forests are poorly defined and some definitions include temperate regions (Haggar 1988), but we prefer not to include those from temperate regions. Even if we did, the current climatic definition is too broad, extending well beyond those areas to which the temperate definition is currently applied (the upper parts of Te Hauturu-o-Toi / Little Barrier Island and Te Moehau) to include most of Stewart Island / Rakiura, Fiordland, upland Westland, Mount Taranaki, etc.

Alternative suggestion: rename to 'warm temperate cloud forest' and refine the criteria to:

- sea temperature > 19°C
- potential evapotranspiration 750–950 mm
- annual rainfall 1,400–2,000 mm
- annual sunshine hours 1,700–1,900.

The type locality would then be Waimā range, Northland.

(See 'Appendix 4 – Cloud forest' for further details.)

Definition/s

A refined definition can't be written with current descriptors and no other NUE is defined solely in climatic terms.

Conclusions

There is support for removing 'cloud forest' from the list because the current definition is a vegetation type not an abiotic type, so it does not currently fit into the NUE framework. The proposed descriptors for 'warm temperate cloud forest' are not encompassed by the current set of descriptors. Revising the diagnostic classifiers and adding descriptors is beyond the scope of this project, though it should be considered in a later phase.

5.1.3 Geothermal streamsides

Change sought

Rename to 'geothermal streams and streamsides and spring and margins'.

Reasons

The title for the type 'geothermal streamsides' is a poor descriptor of the habitats it represents. It is also intended (based on the description on the Manaaki Whenua Landcare website) to include hot spring margins that occur in the geothermal streamside ecosystem type. Geothermal streamsides are obviously totally reliant on the presence of a heated stream with associated steam influence on the margins. The name could be altered to reflect the key role of heated streams.

Definition/s

No change required.

Action points

- To align with the IUCN Global Ecosystem Typology (GET) the name should be 'geothermal stream and spring margins'.

Conclusions

Renaming to 'geothermal streams and spring margins' is supported.

5.1.4 Estuaries

Change sought

Rename to 'estuary margins'.

Reasons

Renaming to 'estuary margins' is in line with naming for other edge-of-waterbody systems because the framework specifically pertains to terrestrial ecosystems, excluding permanent freshwater bodies such as ponds, lakes and lagoons, and the aquatic component of water channels and springs below the depth limit of rooted plants (littoral zone). This will support alignment with the IUCN Global Ecosystem Typology (GET).

Definition/s

No change required.

Conclusions

- Renaming to 'estuary margins' is supported by the fact that alignment with the IUCN GET will support future ecosystem threat assessment.

5.1.5 Granitic sand plains

Change sought

Combine ‘granitic sand plains’ and ‘granitic gravel fields’ to ‘granitic sand and gravel fields’.

Reasons

Since publication of the list, work has shown that granitic sand plains and granitic gravel fields are physically indistinguishable (Richardson et al. 2012). The factsheets currently state this. The current definition of 'granitic sand plains' can be applied to both: raw/granite/sand–gravel/hillslope, hillcrest/(mostly alpine).

Action/discussion points

- Replace '(mostly alpine)' with 'alpine'.

Definition/s

raw/granite/sand–gravel/hillslope, hillcrest/alpine

Conclusions

Given the above research this change is recommended.

5.1.6 Heated ground (dry)

Change sought

Rename to ‘geothermally-heated ground (dry)’.

Reasons

The ‘heated ground (dry)’ concept works well within the naturally uncommon ecosystem framework. However, it is suggested that the term ‘geothermal’ is added to the name, as this will make it clear that they are linked to a below ground heat source (at depth, from the Earth’s heat), and not solar radiation, or other human influences.

Definition/s

No change required

Conclusions

This name change is recommended.

5.1.7 Hydrothermally-heated ground (now cool)

Change sought

Rename to 'Previously geothermally-heated ground (now cool)'.

Reasons

The 'hydrothermally-heated ground (now cool)' concept works well within the naturally uncommon ecosystem framework. However, it is suggested that the term 'geothermal' is added to the name, as this will make it clear that they are linked to a below ground heat source (at depth, from the Earth's heat), and not solar radiation, or other human influences.

Definition/s

No change required

Conclusions

This name change is recommended.

5.1.8 Lagoons

Changes sought

- Rename to 'lagoon margins'.
- Split intermittently closed estuaries from permanently open estuaries.

Reason

Renaming to 'lagoon margins' is in line with the naming for other edge-of-waterbody systems, because the framework specifically pertains to terrestrial ecosystems, excluding permanent freshwater bodies such as ponds, lakes and lagoons, and the aquatic component of water channels and springs below the depth limit of rooted plants (littoral zone). This will help to achieve alignment with the IUCN GET.

Splitting 'intermittently closed estuaries' from 'permanently open estuaries' (note that these are types of lagoons not estuaries)[3] could help with the management of these two different systems.

[3] See details of these systems in Hume et al. 2016 and in a report on Otago's intermittently closed estuaries (available on request to the ORC).

Definition/s

The current definition refers to Johnson & Gerbeaux 2004. It might be possible to refer to Hume et al. 2016 instead for the definitions of 'intermittently closed estuaries' and 'permanently open estuaries'.

Conclusions

- Adding 'margin' to the name is supported. A fuller definition and explanation of the range of types should be included in the factsheets.
- Splitting into two types is not supported because it is not possible using the current diagnostic classifiers. Also, the variation would be better captured through description, the factsheet, and guidance.

5.1.9 Moraines

Changes sought

- Split moraines into dry (eastern basins, non-forest) and wet (steep, western, forested) subtypes.
- Alternative suggestion: rename to 'moraines (recently formed)' and add 'moraines (dry)'.

Reasons

The original suggestion was to apply the wet/dry split suggested in Holdaway et al. 2012. However, the current vegetation description does not include forest; rather, it describes eastern dryland moraine vegetation. Also the current definition suggests that the original intention was to include only moraines on undeveloped soils (raw). The 'wet' vegetated moraines are probably not uncommon.

During discussions the vegetated semi-arid moraines were raised as an important and rare system. These could be defined through soil development age (soil chronological age is tricky in arid systems[4]). Intersecting maps of moraines, soil development age, and areas of semi-arid climate (annual water deficit = high to very high, i.e. 200–400 mm) is likely to result in a map of this system. There is also an aspect of drainage associated with it; either excessive or periodically dry could work, because there is no moisture/water-holding capacity in the soils. This system could be described as basin floors that are sparsely vegetated, dry (arid and/or excessively drained) on moraine materials. (See 'Appendix 5 – Moraines' for photos, and the excerpt from the LINZ guide.)

Definition/s

Moraines (recently formed): raw–recent/cobbles–boulders/moraine/(various parent materials)

Moraines (dry): mature/cobbles–boulders/moraine/semi–arid

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[4] See excerpt from LINZ technical guide, p. 31: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.landcareresearch.co.nz/assets/Tools-And-Resources/Maps/LENZ/LENZ_Technical_Guide.pdf

Action/discussion points

- Check that an intersection of spatial layers depicting moraines, soil development age, and areas of semi-arid climate results in a map of what we are trying to define.
- Check whether 'excessively drained' should be part of the definition.

Conclusions

- Change 'Moraines' to 'Moraines (recently formed)' and keep the current definition.
- Add a new ecosystem called 'Moraines (dry)' to capture the unique, dry, vegetated moraines if the checks in the action points above are met.

5.1.10 Seabird burrowed soils

Change sought

Remove 'coastal' from the definition because these soils are not confined to the coast.

Reason

There is good evidence that black petrels burrowed in soils on the slopes of Ruapehu and Titiraupenga until the early 20th century, and a Cook's petrel skeleton was found on the Maungaharuru Range (Janet Wilmshurst, MWLR, pers. comm. 2024). The mottled petrel formerly bred in the mountain ranges of the Central North Island, Kaimanawa Mountains, Ruahine Range, and Ruapehu, and throughout the whole of the South Island, including Banks Peninsula (Oliver 1955). There is also evidence of grey-backed storm petrels breeding in Fiordland Mountains (Miskelly et al. 2021). Work on a spatial layer predicting the historical distribution of seabird colonies is currently underway (Bellvé 2023).

It is likely that modern seabird-burrowed soil ecosystems, as found on some offshore islands, are modern artefacts of hyper-concentrated colonies of multiple seabird species, which act as refuges now that most of their former range is too dangerous to nest in because of predatory mammals. Assessment of pre-human vegetation on Tāwhiti Rahi (Poor Knights Islands) shows that they are likely to be artefacts (but still ecologically and culturally very valuable) (Wilmshurst et al. 2014). For many, if not most, northern New Zealand islands with dense seabird-burrowed soils, there is a key imprint of the history of management by mana whenua,[5] including fire, such that the forest vegetation on many (probably most) of the islands comprises successional communities (Atkinson 2004; Bellingham et al. 2010).

Definition/s

seabirds – burrowing

[5] Mana whenua: territorial rights, power from the land, authority/jurisdiction over land or territory, power associated with possession and occupation of tribal land; sometimes used to describe those associated with such rights/authority; or (more loosely) with tribal links to a specific area.

Action points

- How many burrows, and what density, are required in order to be defined as an ecosystem with 'seabird burrowed soils'?
- What happens if the seabird burrows are still present but the seabirds are not (especially as a result of predation); i.e. the active disturbance (sometimes only seasonal) goes but the nutrient legacy remains (along with the structuring of the community that favoured some plant species but not others)?
- This discussion raises important questions about how recently created analogues should be treated in the NUE framework. A simple solution would be to say that if the extent remains under 0.5% then they still count. This is especially important when historical locations are now extinct and the recent ecosystems function in the same way and support the same biota as the now extinct examples.
- Another example of this phenomenon is the Northland gumlands. Some think that all the 'original' gumlands are now extinct and the ones present now were created by humans, but this is at odds with statements in Perry et al. 2014. All the same, gumlands may be an example of a historically rare type and an anthropogenically induced type. If this human disturbance has expanded the extent beyond that defined as naturally rare, then it will be critical to be able to distinguish the two.

Conclusions

Removing 'coastal' from the definition is supported.

5.1.11 Tarns

Change sought

- Rename to 'tarn margins'.
- Refine the definition to 'alpine' rather than 'alpine usually'.
- Factsheet change: remove the reference to moraines in the text, as the water bodies referred to are ephemeral wetlands, not tarns. (From factsheet: 'Tarns on moraines in valleys east of the Main Divide, such as the upper Ashburton and Rangitata catchments, and Mackenzie Basin…').

Reason

Rename to 'tarn margins' because the framework specifically pertains to terrestrial ecosystems, excluding permanent freshwater bodies such as ponds, lakes, and lagoons, and the aquatic component of water channels and springs below the depth limit of rooted plants (littoral zone). This will help to achieve alignment with the IUCN GET (Keith et al. 2020).

Refining the definition to include only 'alpine' rather than 'alpine usually' has limited impact because many (but not all) of the intermontane basin 'tarns' in the eastern South Island will be mapped as kettle holes. However, this proposed change will clarify the definition and align it with international usage. A tarn is defined as a small mountain lake, especially one that collects in a cirque basin behind risers of rock material or in an ice-gouged depression.[6] Tarns can be associated with outwash[7]. Ice can be jumbled into the outwash on moraine edges, so that a tarn could form in what looks like an outwash surface from above but would effectively have originated in moraine (Ian Lynn, MWLR, pers. comm., 2024). Thus, tarns could form on surfaces near the edge of moraines, but certainly not at the lower end of the outwash gravels.

Definition/s

open water/depression/alpine.

Action/discussion points

- Johnson and Gerbeaux (2004) use the terms 'mountain' and 'uplands' in their definition of tarn.
- In New Zealand the term is used very widely to refer to a small lake that is not coastal.
- Although 'tarn' is not a wetland type (rather it could be one of several types), New Zealand wetland ecologists generally use the term to mean a small body of water in the uplands.
- The word 'tarn' is not used in the New Zealand Lakes ecosystem typology.
- In the GET the closest match is 'small permanent freshwater lakes'. The word 'tarn' is not used.
- We could set size limits for lakes and tarns, keeping both systems on the list (though size limits for water bodies is not one of the classifiers). So as not to miss small lowland waterbodies, we could make 'tarn margin' a subset of 'lake margin'; or we could remove tarn from the list and use 'lake margin' to cover all sizes and elevations.
- Lakes and tarns do differ: tarns potentially have more stable water levels, with no inflow of rivers of any size, and fetch/wave action is not common.
- If tarns are restricted to 'alpine' environments, the intermontane tarns would be captured as 'ephemeral wetland' or 'lake margins'.
- In the factsheet, it should be highlighted that the width of the margin will be variable but it relates to the ephemeral margin of the tarn (i.e. the area of fluctuating water height, which will also be of variable duration). Therefore, tarn margins (and lake margins) are a type of ephemeral wetland but are treated separately because the water levels in the associated water body fluctuate to a lesser degree.

Conclusions

- Renaming to 'tarn margins' is supported.
- Restricting to 'alpine' is supported. 'Lake margins' can capture those tarns that are not in the alpine zone. This would be the simplest way to separate tarns from lakes. The word 'tarn' seems to be mostly a vernacular term.
- The factsheets should be expanded to include more types and type localities.

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[6] https://www.nps.gov/articles/tarns.htm

[7] Outwash plains are glacial stream deposits of stratified drift from melt-water, braided, and overloaded. They occur beyond a glacial morainal deposit.

5.2 Proposed additions

We propose adding eight new ecosystems from the fourteen that were suggested (Table 2). Below is an outline of the reasoning for the proposed additions for each of the eight ecosystems. The list of additions not supported at this time and the reasons are given in Appendix 2.

Table 2. Summary of proposed additions to the list of naturally uncommon ecosystems

Tentative common name	*Definition*	*Vegetation structure*	*Example locality*
Boulderfields of quartzose rocks	raw/quartzose/boulders/talus	Open land, lichenfield, shrubland	Glasgow Range, north Westland
Mud volcanoes	Geothermal/groundwater salinity/periodically high water table/inland	Open land, herbfield	Runaruna, Northland; Waimatā Valley, Gisborne; Waikura Valley, Pōtaka
Coastal colluvium (coastal boulderfields)	raw/boulders/talus/coastal	Open land, herbfield	Banks Peninsula; Boulder Beach, Otago Peninsula
Cobble bank wetland	raw, recent/gravel–cobbles/permanently high water/coastal	Herbfield	Te Kawakawa Rocks, Palliser Bay
Dry deflation plains	raw/sand–gravel/plain/coastal	Openland, herbfield	Napier airport; Mirza Beach
Geothermal wetland	Geothermal – excessive heat/ regularly high water/toxic elements	Sedgeland, Rushland, Herbfield, Reedland, Shrubland, Algal mats	Waikite, Waikato; Parengarenga Wetland, Lake Rotoiti
Inland dryland alluvium	raw, recent/silt–cobble/plains, terraces/excessive drainage/inland, semi-arid	Open land, herbfield	Tekapo River, Mackenzie Basin
Inland salt springs	raw/groundwater salinity/permanently high water table/inland	Herbfield, open land	Wairau Valley, Marlborough

5.2.1 Boulderfields of quartzose rocks

Reason

This ecosystem was mistakenly left off the published list in Williams et al. 2007 but was included in Holdaway et al. 2012. The suggestion is to reinstate it to the published list and make a factsheet for it.

Definition/s

raw/quartzose/boulders/talus

Action/discussion points

None.

Conclusions

Add to the list.

5.2.2 Coastal colluvium (coastal boulderfields)

Reason

Coastal colluvium is a distinctive part of the extensive cliffs to which it is linked. Banks Peninsula is a good example. Here colluvium has been made more extensive from the earthquakes but is still much rarer than cliffs. Colluvium or boulderfields is sparsely vegetated generally, but hosts a distinctive flora of coastal species, especially on sunny aspects (e.g. *Senecio lautus*, *Chenopodium allanii*, *Asplenium obtusatum*), and this might be closest to the Singers & Rogers 2014 vegetation type CL8. Coastal colluvium provides important habitats for penguins and is where the threatened coastal plants *Lepidium agreum* and *Euphorbia glauca* have been recorded.

Definition/s

raw/boulders/talus/coastal

Action/discussion points

- The original proposal was for the type to be restricted to Banks Peninsula, but in workshop discussions it was decided this could be applied New Zealand-wide.
- Although suggestions were originally made for confining this to volcanics, salt spray is likely to be a bigger factor than rock type in selecting species, so this NUE should not be restricted to a rock type.
- 'Colluvium' could be a better name as there is a range of substrate sizes present; or the factsheet needs to define what proportion of substrate should be boulder (similar to how shingle beaches are described).
- Other boulderfield NUEs are based on geology, not proximity to the coast. However, other rocky systems are defined based on coastal vs inland (e.g. ultrabasic cliffs and scarps, and ultrabasic sea cliffs).

Preliminary conclusions

Add to the list.

5.2.3 Cobble bank wetland

Reasons

Cobble bank wetlands are formed behind cobbles that have built up on a rocky coast. They are mostly rain fed, with little surface or groundwater inflow. They are influenced by salt spray, as evidenced by the abundance of *Salicornia quinqueflora*, but, unlike in tidal pools, salt spray is not a daily occurrence. They don't seem to dry out so do not qualify as ephemeral wetlands. There is also no appreciable organic accumulation and so do they not qualify as maritime bogs. If a storm ever breached the cobble bank the water would drain away. Known locations include: Te Kawakawa Rocks south of Ngawi on the eastern tip of Palliser Bay, on the way to Cape Palliser Lighthouse; and Ōkupe Lagoon on the northern end of Kapiti Island, off the Wellington west coast. (See 'Appendix 6 – Cobble bank wetlands' for photos and further information.)

Definition/s

raw, recent/gravel–cobbles/permanently high water/coastal

Action/discussion points

- These formations are probably related to prograding gravel platforms and raised beaches.
- David Barrell (GNS geomorphologist) suggested that this system is a dip between stony beach ridges, akin to a slack between dunes in a dune system, with the difference being the size of the material and energy required to move the material.
- To be consistent with dunes and dune slacks, this system could be described as a stony beach slack. However, it cannot be included with stony beach ridges because that definition refers to 'ridges' as the landform.
- Other thoughts were that it might be a part of 'shingle beaches' (see photos in the appendix), which includes cobbles.

Conclusions

This could be added as a 'stony beach slack' and should be ground-truthed, as we can think of no other good examples of this ecosystem.

5.2.4 Dry deflation plains

Reasons

There seem to be two different systems here that are on opposite ends of a particle size spectrum. At one end is an inter-dune community on a coarse sand or fine gravel lag with potentially palaeo-pavements. This community is often associated with active dune habitats. The plant species include a large range of herbs, many commonly associated with coastal cliffs. *Raoulia* spp. and *Colobanthus* spp. may be indicator species of this habitat type. At Mason Bay, species include *Geranium sessiliflorum* var. *arenanium*, *Raoulia aff. hookeri*, and *Ranunculus recens*, among others. Localities include Mason Bay, Three Sisters at Omaui, Fortrose spit, Kaitorete Spit, and (potentially) Sandfly Bay, Otago

At the other end of the spectrum are flat plains of mobile sand and gravel with ventifacts. The vegetation includes *Pimelea* spp., and localities include Mirza Beach, Marlborough; Napier airport beach; and Kohangapiripiri, Wellington. (See 'Appendix 7 – Dry deflation plains' for photos of both systems.)

Definition/s

raw/sand–gravel/plain/coastal

Action/discussion points

- Note that the definition of 'dune deflation hollows' is raw/sand/depression/excessive drainage/coastal, so the definition doesn't actually mention dunes. Moreover, the factsheet[8] says, 'They often form between a series of sand dunes and when the dunes move further inland they enlarge the terminal deflation hollow behind', so we are not currently saying that they have to be associated with dunes.
- Thus both systems could be dune deflation hollows, just on different scales, because the main action here is wind removing materials until it can't (too wet or too large).
- If both systems are dune deflation hollows, then the name and definition could be expanded to accommodate the sites at Napier airport and Mirza Beach by broadening the name to something like 'Coastal deflation hollows and plains', with a definition of raw/sand–gravel/depression–plain/excessive drainage/coastal.
- David Barrell (GNS) was consulted about the three sites associated with the second system. He would call all three abandoned beaches.[9]
    - Napier airport beach was raised in the 1931 earthquake, and since then has lost the fines (sands) from the top, so that just the stony/gravels are left.
    - Mirza might be 'abandoned' because it was raised at some point in the past, or this may be due to accretion. There are lots of big rivers with source material not that far away, and the ocean has moved further away. Again, the sands on top have blown away leaving an armoured surface.
    - Kohangapiripiri was probably both raised and experienced accretion. The 1855 earthquake raised that area by 4–5 m and there are a couple of big rivers nearby to supply the material. However, it is also still active as you can see a sand dune on top of the old beach in the picture (Appendix 7, Figure A7.4).

Conclusions

- The first system is a 'dune deflation hollow' (which is already in the list), and the factsheets should be expanded to include the examples provided.

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[8] https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/inland-and-alpine/granitic-gravel-fields/

[9] 'Abandoned beaches' is a geological term for beaches that have been uplifted and are no longer modified by wave action.

- The second system should be added to the list as 'dry deflation plains' because it is not part of active sand dune systems (like the above) and does not fit with shingle or stony beaches (this needs further discussion to confirm).

5.2.5 Geothermal wetland

Reason

Geothermal wetland is a variable habitat type driven by the character of the geothermal system the wetland occurs in, e.g. the water chemistry, temperature variation of different springs or seepages, water depth, altitude, distance inland, landform, and adjoining features such as lakes. While these ecosystems are extremely variable, their geothermal origin is the key abiotic factor influencing plant species presence and distribution. For example, various species occur in geothermal wetlands outside their usual natural range, including species of coastal sites occurring inland, or with unusual latitudinal and elevation ranges such as: sea rush (*Juncus kraussii* subsp. *australiensis*), oioi (*Apodasmia similis*), and arrow grass (*Triglochin striata*). Because of the varied character of this system is best to define it in a broad sense so all the different types are captured. And even at its broadest definition, its estimated that the extent of geothermal wetlands nationally is less than 150 hectares. Representative sites for geothermal wetlands include: Waikite, Waikato; Waihunuahuna springs (edge of Lake Ohakuri); Waipahihi Valley (Wairākei Tauhara Geothermal System); Ngapuna (edge of Lake Rotorua, Rotorua); Parengarenga Wetland (Lake Rotoiti); Waitangi Soda Springs (south of Lake Rotorua). (See 'Appendix 8 – Geothermal systems' for photos and a short report on the Geothermal NUEs by Wildlands.)

Definition/s

Geothermal – excessive heat/regularly high water/toxic elements

Action/discussion points

The concise definition listed for this system needs to be confirmed as its been modified from the full suggested definition of: "Inland (including coastal to alpine), regularly high water table (permanently or ephemerally wet), with elevated temperatures, sourced at depth and also due to overflows, with higher temperatures and different chemistry than natural surrounding land."

Conclusions

Add to the list, need to confirm the definition.

5.2.6 Inland dryland alluvium

Reasons

These are terraces of river-deposited gravel, sand, and silt. They are stable, well-drained plains with thin soils of blown silts and can have frost heave surfaces found in the intermontane basins. Stonefields are occasionally also present. Plants include bryophyte and lichen communities, *Raoulia* and *Pimelea* species, *Festuca novae-zelandiae*, *Melicytus alpinus*. They differ from inland outwash gravels in that the source material is alluvial rather than fluvioglacial, e.g. these inland alluvial surfaces have been reworked by water. They are distinct from braid plains because inland dryland alluvium is isolated from major active river channels.

Inland dryland alluvium ecosystems have raw or recent soils and always have a high water deficit, either due to a semi-arid climate or excessive drainage. They occur on terraces, plains or low-relief fans, but they are always low relief (<2.5 degrees) as they are reworked by water and have no colluvial (formed by gravity) character.

Where inland, they can be defined by the Central South Island Glacial Geomorphology categories 'Holocene alluvial plain or terrace' and 'Early Otiran or older alluvial plain or terrace', as well as various ages of Otiran (Early, Late, or Latest Late Otiran) and Holocene alluvial fans. The example location is above the Tekapo River. (See 'Appendix 9 – Inland dryland alluvium'.)

Definition/s

raw, recent/silt–cobble/plains, terraces/excessive drainage/inland, semi-arid

Action/discussion points

- Need to check if there is overlap between some inland dryland alluvium that forms terraces and the new definition of 'braid plain'.
- There needs to be a clear explanation of the relationship between inland dryland colluvium, braid plain, and inland outwash gravels to show that these are all distinctive systems.

Conclusions

Add to the list.

5.2.7 Inland salt springs

Reasons

Along the Alpine Fault some spring upwellings rise through salty rock, dissolving salts out of the rocks. Around the springs the ground is salty, and salt-tolerant plants are present. These springs support a marsh of *Triglochin striata*, *Schoenoplectus pungens*, and *Cotula coronopifolia* (Wardle 1991). This differs from the inland saline (salt pans), as the inland saline springs are always wet as opposed to the dry soils of the salt pans. About 10 springs are known in the Wairau Valley, Marlborough. (See 'Appendix 10 – Inland salt springs' for photos.)

Definition/s

raw/groundwater salinity/permanently high water table/inland

Action points

Check if there are other examples from Central Otago. It may be that most of the wet inland saline systems are now gone. There was an active one still evident 5 years ago (albeit weed infested) at the Wilson Road saline site, Central Otago.

Conclusions

Add to the list.

5.2.8 Mud volcanoes

Reasons

Gas-driven mud volcano ecosystems are typically cold, and although mainly mud have characteristic vegetation that can tolerate the high mineral content (e.g. estuarine species *Machaerina juncea*, *Apodasmia similis*, *Samolus repens*, and *Cotula coronopifolia*), though freshwater species are also present. This ecosystem can apparently appear and/or expand with increased tectonic activity, and it has a scattered distribution from Wellington to East Cape and Northland. These have a geothermal element but don't fit any of the current ecosystem descriptions. (See 'Appendix 11 – Mud volcanoes' for further information and references.)

Definition/s

groundwater salinity/periodically high water table/inland

Action/discussion points

Check if 'geothermal' could be part of the definition.

Conclusions

Add to the list.

6 Conclusions and recommendations

We utilised expert knowledge to review and make recommendations for updating the list of naturally uncommon ecosystems (NUEs). This report documents the discussions and information gathered to support that update, including collating the information for systems that we agreed needed revision or adding, and for the suggested revisions and additions that were not supported at this stage. We imagine that as new research is carried out and a better understanding of the systems is gained, the NUE list will again evolve to reflect the new knowledge.

The discussions held during the project, one-on-one, and in workshops helped clarify the original intent in defining the NUEs and how new research has modified our understanding of these ecosystems. These discussions highlighted the robustness of the original work; all that was required for over half of the suggested refinements and additions was a small amount of clarification on the intent of the original definitions. However, the discussions also signalled that modifications to the diagnostic classifiers could be required to fully incorporate our current understanding of these ecosystems.

The discussions raised important questions about how recently created analogues should be treated in the NUE framework. A simple solution could be to say that if the extent remains under 0.5% then they still count. This is especially important when historical locations are now extinct and the recent ecosystems function in the same way and support the same biota as the now extinct examples. Examples of ecosystems where this should be considered are 'seabird burrowed soils', 'coastal turfs', and 'gumlands'.

We are also mindful that any changes or modifications need to be aligned with the work being done elsewhere on NUEs (by the Department of Conservation and Ministry for the Environment), and on the wider question of aligning New Zealand ecosystem classification with that of the IUCN GET. An ecosystem-by-ecosystem threat assessment should be carried out on the updated list following the approach for global ecosystem red listing – but tailored to New Zealand – as outlined by Keith et al. (2015) and Rodríguez et al. (2015). Again, such work needs to be coordinated with current efforts by the Department of Conservation, Ministry for the Environment, and MWLR.

We recommend the following changes to the list (resulting in a total of 78 NUEs):

- Remove cloud forests.
- Modify the common name of four systems:
  - change 'braided riverbeds' to 'braid plain'
  - change 'geothermal streamsides' to 'geothermal stream and spring margins'
  - change 'estuaries' to 'estuary margins'
  - change 'heated ground (dry) to 'geothermally-heated ground (dry)'
  - change 'hydrothermally-heated ground (now cooled) to 'previously geothermally-heated ground (now cool)'
  - change 'lagoons' to 'lagoon margins'
  - change 'tarns' to 'tarn margins'
- Combine 'granitic sand plains' and 'granitic gravel fields' to give 'granitic sand and gravel fields'.
- Split moraines into two types:
  - 'moraines (recently formed)'
  - 'moraines (dry)'.
- Remove the word 'usually' from the definition of 'tarn'.
- Remove the word 'coastal' from the definition of 'seabird-burrowed soils'.
- Add eight systems to the NUE list:
  - 'boulderfields of quartzose rocks'
  - 'coastal colluvium'
  - 'cobble bank wetland'
  - 'geothermal wetland'

- ‘dry deflation plains’
- ‘inland dryland alluvium’
- ‘inland salt springs’
- ‘mud volcanoes’.

We also recommend:

- updating the factsheets and guidance documents, as outlined in sections 5.1, 5.2, Appendix 1 and Appendix 2
- revising the diagnostic classifiers to enable ecosystems that are known to be naturally uncommon, but not able to be defined with the current set of diagnostic classifiers, to be incorporated into the NUE framework
- defining how recently created analogue systems should be treated
- carrying out an ecosystem-by-ecosystem threat assessment on the updated list following the approach for global ecosystem red listing.

7 Acknowledgements

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Appendix 1 – List of refinements not supported

Below are the refinements that have not received support. Many of these suggestions can be resolved by adding more details to the existing factsheets, which is happening in a parallel Envirolink Tools project.

Table A1.1. List of ecosystems for which the suggested refinement is not supported

Tentative common name	*Definition (i.e. diagnostic classifiers) and notes*	*Vegetation structure*	*Change proposed*
Acid rain systems	Geothermal-acid rain	Open land, scrub, tree, forest	Expand to include all geothermal atmospherically influenced systems and rename to 'Geothermally-derived natural atmospheric systems'
Active sand dunes	Raw/sand/dune/coastal	Grassland, sedgeland, open land	Split into transgressive and semi-stable
Cave entrances *Caves, and cracks in karst* *Sinkholes*	Raw/calcareous/cave entrance Calcareous/subterranean/coastal–alpine Raw/limestone, marble, dolomite/doline	Open land, herbfield none Open land shrubland, shrubland, tussockland, Thousand Acre Plateau, western Nelson	Merge cave entrances with these two systems.
Coastal turfs	Raw/atmospheric salinity/coastal, extreme exposure	Open land, herbfield	Change name to coastal grassland
Ephemeral wetlands	Seasonally high water table/depression	Herbfield, open land	Split into types
Frost hollows	Terrace/>200 frost days per year	Shrubland, scrub	Split into Singers & Rogers types
Inland outwash gravels	Raw–recent/sand–boulders/plain/inland	Open land, herbfield, treeland	Split out the frost hollows
Inland saline (salt pans)	Ground water salinity/semi arid/depression	Herbfield, grassland	Split based on salt type and source
Stable sand dunes	Recent/sand/dune/coastal	Shrubland, grassland, tussockland, herbfield, open land	Split stable dunes into 'grey dune' and 'forested dunes'
Strongly leached terraces	over-mature/sand-gravel/terrace–plain/inland	Open land, herbfield, shrubland	Add >200 frost days per year to definition

Acid rain systems

Change sought

- Expand to include all atmospherically influenced geothermal systems.
- Rename to 'Geothermally-derived natural atmospheric systems' to better describe the ecosystem.

Reasons

Acid rain systems are a sub-type of atmospherically influenced geothermal systems. Due to the rarity of geothermal systems nationally, combining these together may prove more useful from a management perspective and would help to ensure that no rare geothermal ecosystem sub-types are omitted. (See 'Appendix 8 – Geothermal systems' for a short report on Geothermal NUE systems by Wildlands)

Definition/s

No change is required to the definition.

Action points

- Need to clarify that the definition is still fit for purpose.
- Need to clarity if fumaroles should be included in this expanded system

Conclusions

Potentially this change could be made but needs further discussion.

Active sand dunes

Change sought

- Refine the definition of 'active dunes' and add more type localities and associated vegetation to capture the diversity of active dune types in New Zealand.
- Consider distinguishing between larger transgressive dune systems and smaller, more stable systems where mobility is restricted to the seaward margins.

Reasons

The classification is not entirely fit for purpose when used to identify active dunes, because the key abiotic classifiers are aeolian sand transport and geomorphic mobility. This is usually equated with relatively low vegetation cover and the presence of species tolerant to and/or dependant on sand burial. In larger systems (e.g. Mason Bay, Stewart Island / Rakiura), a mosaic of habitats occurs, reflecting spatial and temporal patterns of sand transport and geomorphic disturbance. Some of these habitat types are highly mobile or experience burial, some arise through sand erosion, and others are stable, with vegetation communities that develop through successional processes from dune obligate species to more generalist species. Distinct plant communities are often associated with each of these habitats, but collectively they define the character of active dunes. Failure to recognise these underlying diagnostic drivers results in this ecosystem type being applied only to depositional (i.e. foredune, sandsheets or constructional dunes) dune types.

A second complication is the distinction between stable and active dune types. Many active dunes contain larger areas of stable habitat, or semi-stable habitats. Active dunes also exist in a wide range of forms, reflecting a wide range of factors including underlying geology, sediment supply and size, wind exposure, and climate. Consideration could be given to developing an alternative list of coastal dune types to distinguish between highly active transgressive types (such as found on windward coasts), more stable lee coast systems (i.e. the east coast of Northland and Bay of Plenty), and geomorphically stable dunes. The plant species associated with active dunes also show a degree of variation around New Zealand, further complicating the development of a clear typology

There may also need to be a clearer distinction made between dunes and dune systems

(See 'Appendix 12 – Active sand dunes' for more information.)

Additional type localities: West coast systems on Stewart Island / Rakiura (e g. Smoky Beach, West and East Ruggedy Beach, Mason Bay, etc.); Fiordland (e.g. Big Bay, Martins Bay, Coal River; Farewell Spit; Kaitorete Spit.

Definition/s

We are not sure that the split between transgressive and stable dunes could be done using the current framework.

Action/discussion points

- Adding more type localities and associated vegetation to capture the diversity of active dune types will be addressed in the Envirolink Tools project.
- A clearer distinction between dunes and dune systems should be added to the factsheets and background information. It might be desirable to define the separate systems that may occur within the broader sand-dune complex. Some of these are already included as NUEs (e.g. 'active sand dunes', 'dune deflation hollows', 'dune slacks', 'damp sand plains').
- We shouldn't be subdividing NUEs based on geography.
- The variability in plant species associated with active dunes around New Zealand further highlights the problem of distinguishing NUEs based on their vegetation composition. It is not surprising that there is compositional variation within individual NUEs. This is what was found for gravel beaches around the country, and it certainly would also apply to all the rock outcrop NUEs. There may also be environmental differences across large geographical ranges – especially in climate – but that doesn't mean it is desirable to recognise all this variation within the NUE typology. The EcoVeg hierarchy (an international system) could help to resolve the tension between types defined based on environment with characteristic vegetation structure(s) and types within these that are differentiated based on species composition (Faber-Langendoen et al. 2014).

Conclusions

Splitting is not supported, but updating/expanding the factsheets and clarifying the definition would be beneficial.

Cave entrances

Change sought

Merge ‘cave entrances’ with ‘caves, and cracks in karst’ and ‘sinkholes’ (keeping ‘caves and cracks’ and ‘sinkholes’ as separate systems).

Reasons

Cave entrances are ecotones and should be considered part of the cave or sinkhole ecosystem. The counterpoint would be that ‘cave entrances’ are more broadly defined than the other two systems, so would result in missing cave entrances that are not associated with karst or sinkholes. Given this, merging of ‘cave entrances’ with ‘caves, and cracks in karst’ and ‘sinkholes’, wouldn’t result in a big gain in understanding/classification but could result in some ecosystems being missed.

Definition/s

No change is required for ‘caves, and cracks in karst’ and ‘sinkholes’, but the vegetation structure could be updated.

Action points

Double check the original recommendations from the expert.

Conclusions

Don’t merge. This is a fact sheet issue, such that we need to clearly define ‘subterranean’, ‘cave’, and ‘entrance’, and clarify how they relate to each other.

Coastal turfs

Change sought

Add ‘bedrock’ to the definition. Restrict the definition to gravelly/rocky coastal shelves, not the recent deeper soils (e.g. coastal rock shelves around Wellington and at Watsons Beach, Otago).

Reasons

Research published in the last 10 years has shown that sheep and rabbit grazing is a major driver of vegetation composition on headlands with deeper soils (Brownstein et al. 2014; Rogers & Monks 2016). With the removal of grazing, coastal turf sites like Long Point, and Maori Head (Otago), and

Waipapa Beach (Southland) have shifted towards tussockland. These sites could be moved to a new ecosystem called coastal grasslands/tussocklands (see suggested additions below).

Definition/s

raw/bedrock/atmospheric salinity/coastal, extreme exposure

Discussion points

- Pre-human, much of the Otago coastline would have been forested to nearly the cliff edge, so sites like Maori Head and Long Point probably would only have included minor amounts of coastal turfs.
- Although the name suggests turf species only, grasses and herbs are also present in mosaics. In many of our example locations this system has been modified by sheep grazing, which enhanced the competitiveness of turf species, and explains why these systems have only recently appeared as a mosaic (due to the exclusion of browsers).
- These are highly dynamic systems where the main driver is salinity, with herbivory and trampling as secondary drivers. The method, timing, and amount of salt delivered is what primarily selects for the halophytic vegetation.
- On the south coast of the South Island there are loams on headlands that get enough salt spray that halophyte vegetation is selected for. More of these systems might be expected to develop with climate change (i.e. more wind and king tides).
- Pre-human grazing and trampling by birds and sea mammals would have been important (a role now played in part by sheep, cattle and deer), but it is hard to know how extensive that would have been.

Conclusions

The main issue is that the system is named for a vegetation type (turf) when it should be coastal grassland/turf as this is the mosaic that occurs on windy, salty, headlands. However, the name 'coastal turf' is iconic now. Rather than change it, the factsheets could be expanded to explain that the major driver is salinity and that the system is a mosaic of grasses and herbs. This community is of variable extent and part of an ecotone, with vegetation sequences from open short turf into coastal shrubland and coastal forest. Factsheets could also be amended to highlight the secondary importance of trampling and grazing.

Ephemeral wetlands

Change sought

Split into types: kettlehole, schist depression, coastal, and ephemeral runoff channel.

Reasons

Kettlehole ephemeral wetland

- This is a distinct landform of glacial origin.

- The size and distribution of this ecosystem will probably be determined as part of Jane Gosden's PhD.[10]
- Vegetation composition and characteristic species are also likely to be available from Jane's work
- Examples are present on Ahuriri Valley glacial terraces.

Schist depression ephemeral wetland

- This wetland is characterised by small, very shallow depressions in schist geology on gentle ridge crests in low-rainfall zone
- Montane (c. 500–700 m asl) and sparsely vegetated, it is dominated by spring annuals, especially *Myosurus* and *Crassula* spp. (*C. multicaulis, C. mataikona, C. colligata*).
- Examples can be found present at the southern end of Flat Top Hill, near Alexandra, Central Otago

Coastal ephemeral wetland

- This is characterised by damp areas and ephemeral shallow ponds, with a thin layer of organic matter on top of gravels and sands.
- The vegetation is taller *Carex*, flax, jointed rush, and sometimes sparse, woody shrubs.
- This could be an older version of dune slack, similar to the gradient of active to stable dunes.
- Example locations are Waituna and Oreti, Southland.

Ephemeral runoff channel

- These occur in small ephemeral alluvial runoffs over depositional material, often only a few metres wide.
- The vegetation is composed of characteristic turf plants (e.g. *Epilobium angustum*, *Galium perpusillum* and *Lobelia ionantha*).
- Examples can be found in the Mackenzie Basin

(See 'Appendix 12 – Ephemeral wetlands' for photos and further notes.)

Definition/s

- Kettlehole ephemeral wetland: alluvium and till (glacial)/ seasonally high water table
- Schist depression ephemeral wetland: schist/depression/seasonally high water table
- Coastal ephemeral wetland: recent/sand, gravel/seasonally high water table
- Ephemeral runoff channel: alluvial (over depositional material)/ seasonally high water table

Action/discussion points

- These should all be considered variants and included in the guidance and factsheets (other variants are karst and slump types).

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[10] This is ongoing work

- Ephemeral runoff channels are unlikely to be environmentally distinct from kettleholes and the biological outcome is very similar.
- North Otago has hundreds of ephemeral wetlands over limestone and sedimentary rock. Alluvial flats typically have ephemeral wetlands too.
- Coastal ephemeral wetland sounds very similar to a dune slack. We note that the description of a dune slack includes 'especially those which periodically hold slack (scarcely moving) water at times of highest tides' (Johnson & Rogers 2003). In a broader sense these ecosystems include dune hollows, deflation hollows, and swales. 'Coastal ephemeral wetland' could be added as a synonym.

Conclusions

The split is not supported. However, the factsheets should be updated to better describe the various types and range of plant communities.

Frost hollows

Change sought

Split into Singers & Rogers 2014 frost flat types (i.e. TI2, TI4, & TI6).

Reasons

There is potential to differentiate by soils, temperature, and water deficit. 'Appendix 14 – Frost hollows' has the details of the Singers & Rogers 2014 ecosystem types.

Definition/s

- TI2: alluvial and till/terrace/>200 frost days per year, semi-arid.
- TI4: recent/terrace, hillslopes, moraine/>200 frost days per year.
- TI6: peat/terrace, depressions/near permanently saturated/>200 frost days per year.

Action/discussion points

- This split would mostly work and could help with this very broadly defined group.
- Splitting (and making the definitions narrower) could result in missing some areas that fall between the newly defined groups.
- The variation could be captured through description and guidance rather than splitting.

Conclusions

The split was generally not supported because it increased the chance of missing important areas and making determining what is a frost hollow more difficult, potentially complicating management of the systems. However, the expanded factsheets could highlight the variation possible in this system (e.g. referring to the Singers & Rogers ecosystem types), including that frost intensity (not frequency of frost) and summer drought are important factors driving the diversity (and mostly non-tall forest potential) in the appearance of frost hollows.

Inland saline (salt pans)

Change sought

Split based on salt type and source.

Reason

The split would recognise differences between clay outwash and erosion pans vs deposited silts/clays. This would split the locations Patearoa and Belmont.

Definition/s

Current definition: groundwater salinity/semi-arid /depression. It is not clear how to write a new definition to fit this split based on the current framework.

Action/discussion points

- This NUE does not have a large geographical range and is already classified as Critically Endangered. These types should be considered variants.
- Make sure the examples are well described in guidance and factsheets.

Conclusions

The split is not supported, but more detail should be added to the guidance and factsheets.

Inland outwash gravels

Change sought

Split out the frost hollows that are discretely nestled within fluvioglacial outwash terraces of the intermontane basins (potential name: 'fluvioglacial outwash frost hollows').

Reasons

They have a distinctly different flora compared to the 'generic' fescue tussock grassland on the deeper soils of the terraces proper. They are characterised by having thin, stony/sandy soil, lacking fescue tussock, and supporting hardy small species such as cushion plants (*Raoulia* spp., *Colobanthus* spp.), *Carex decurtata*, *Anthosachne falcis*, and numerous ephemeral species such as *Agrostis muscosa*, *Myosurus minimus*, *Poa maniototo*, and *Myosotis brevis*. Frost heave of the substrate is a characteristic. (See 'Appendix 15 – Inland outwash gravels' for photos.)

Definition/s

- Fluvioglacial outwash frost hollows: raw, recent/sand, boulders/plain/ inland/>200 frost days per year.
- No change to 'Inland outwash gravels': raw–recent/sand–boulders/plain/inland).

Action/discussion points

- If this is a 'frost hollow' then it already an NUE. If 'frost hollows' are split, then this could be moved into TI2.
- As in sand dunes, this may be another example of a scale issue, such that we have the larger fluvioglacial outwash terraces within which other NUEs are embedded, including ephemeral wetlands.
- If 'frost hollows' are left in with outwash gravels, a topographic landform classifier could be added to capture the bar and channel/swale topography that characterises 'inland outwash gravels'. That would address this proposal to recognise the distinctive hollows and help to distinguish 'inland outwash gravels' from 'strongly leached terraces' (currently the two ecosystems are only distinguished by soil age in the diagnostic classifiers, which is not easy to apply).
- This could be better captured through factsheets and guidance.

Conclusions

- These are probably already NUEs, so a split is not needed.
- We do need to update and expand the factsheets and guidance.

Stable sand dunes

Change sought

Split 'stable sand dunes' into 'grey dune' or 'back dune' and 'forested dunes' to reflect the different secessional stages.

Reason

Dunes can be recently stable (i.e. because of recent invasion by marram) or develop naturally with a characteristic associated plant community. The current definition doesn't distinguish these types well.

The European habitat system has a grey dune ecosystem type (https://en.wikipedia.org/wiki/Grey_dune), distinguishing it from yellow dunes (active dunes) and more well-vegetated stable dunes. This framework could distinguish the relatively open but geomorphically stable plant communities associated with certain types of back dune habitats compared to denser lupin/marram/shrubland stable dune plant communities. These habitats are currently included in active dunes when mapped or excluded. If they are indeed considered a part of the active dune ecosystem type, then this should be made explicit in the factsheets. (See 'Appendix 16 – Stable dunes' for more information.)

Additional example localities include: back dune habitats of Doughboy Bay, Stewart Island / Rakiura; back dune habitats of Farewell Spit; back dune habitats of East Coast, Bay of Plenty; and Northland.

Definition/s

This could be based on age of substrate (raw vs recent soil).

Action/discussion points

- It seems that 'grey dune' is an intermediate state between active and stable. It is probably more appropriate to include this in 'active dunes', but it is also important to consider soil development. If grouped with 'active dunes', these may be recognised as a vegetation type (distinct from differentiating finer-scale NUEs within the sand dune complex).
- The distinction between active and stable is raw versus recent soils. Given that spraying the marram grass can restore these systems to being dominated by native sand binders characteristic of active dunes, this suggests they are not that stable.
- We could follow the European system if the three types (active, grey, stable) can be distinguished using the current environmental descriptors of NUEs. One acid test may be whether the dunes are still mobile (active dunes) or not (stable sand dunes).
- Better guidance should be provided by expanding the factsheets to clarify defining characteristics of stable and active dues, including where 'grey dune' might fit.

Conclusions

There was little support for adopting grey dunes. We suggest that it would be better to clarify the description on the factsheets.

Strongly leached terraces

Change sought

Add the climate qualifier >200 frost days per year to the definition.

Reasons

Frost was noted by Peter Johnson and Brian Molloy as a characteristic of these ecosystems (Johnson & Molloy 1988). They noted that intense cold and frequent frosts prevent the development of beech forest in these ecosystems, and soil frost heave is also a characteristic feature.

Definition/s

over-mature/sand-gravel/terrace-plain/inland/>200 frost days per year.

Action/discussion points

- For the 2007 list there was debate about whether drivers for the leached terraces are primarily low soil fertility and frosts, or just low soil fertility.
- Although these systems are usually in very frosty conditions, the main driver seems to be the unusually low soil fertility.

- Frost could often be associated with ‘strongly leached terraces’ because of where these systems occur. To evaluate whether the frost days *per se* distinguishes the system from the surrounding landscape, we could measure frost frequency at a range of leached terrace sites and nearby non-leached-terrace sites.
- The ‘strongly leached terraces’ guidance (lucid key and factsheets) could be expanded to discuss the role of frost.

Conclusions

Expand the description via the factsheets and guidance.

Appendix 2 – List of additions not supported

Below are the suggested additions that were not supported. Some are subset types of current ecosystems, others are biotic rather than abiotic, and one occurs outside the area covered by the framework.

Table A2.1. Outline of the additions that are not supported

Common name	*Definition*	*Vegetation structure*	*Example locality*
***Chionochloa acicularis* tussockland**	Hillslope, plains, depressions/ permanently high-water table	Tussockland	Westland
Coal measures	TBD	Tussockland	Denniston plateau
Coastal grassland/tussockland	Recent/atmospheric salinity/terrace/coastal	Grassland, tussockland, herbfield	Waipapa Point, Southland
Inland Turfs	Silt/regularly high water table/bird and mammals trampling-grazing/inland	Herbfield	Waihola, Otago
Seepy Loess banks	Loess/hillslope, fan/periodically high-water table	Herbfield, open land	Banks Peninsula
Tall sub-Antarctic tussocklands	Recent/atmospheric salinity/coastal/extreme wind exposure	Tussockland	Snares Islands / Tini Heke, Auckland Islands

Chionochloa acicularis tussockland

Reasons

This ecosystem is a split of Singers & Rogers 2014 type WL7. It is restricted to the south-west of the South Island (i.e. Fiordland). An example site is the West Cape area. In a paper by Wardle et al. (1973), they describe the *Chionochloa acicularis* community as: saturated, infertile, silt loam (and peat) over coarse sand in flat depressions. The associated vegetation includes *Gleichenia circinata, Calorophus minor*, and stunted shrubs of *Leptospermum scoparium*.

This system may be a blanket mire. Although Williams et al. (2007) Table 2 doesn't list tussockland, the factsheets do, and Johnson and Gerbeaux (2004) use a picture of the West Cape community to illustrate blanket peatland.

Definition/s

hillslope, plains, depressions/permanently high-water table

Action/discussion points

- This is probably a blanket mire, given the example locality. This community is described as wind-exposed shrub-heath on a raised marine platform.

- Although *C. acicularis* is range restricted it is not rare, and too many locations where it occurs do not fit the definition. This is probably not an ecosystem that is naturally uncommon.

Conclusions

Part of this ecosystem most likely belongs in blanket mire (already on the list). The rest is most likely not naturally uncommon.

Coal measures

Reasons

This ecosystem was suggested as a split from sandstone erosion pavements of the Singers & Rogers 2014 type EP1. The example site is Denniston plateau.

Definition/s

Not provided, to be discussed.

Action/discussion points

- This was discussed during development of the original framework. At the time, Peter Williams did not think this ecosystem was uncommon. The Denniston plateau was captured under 'sandstone erosion pavements'.
- See 'Appendix 17 – Coal measures' for details on defining characteristics and discussions of this ecosystem.
- Possibly some of the confusion around 'coal measures' is due to the naming. The full name is 'coal measures sandstone', but the 'sandstone' tends to get dropped off.
- There is a good overview of coal measures on the Te Ara website: Coal resources – Te Ara Encyclopedia of New Zealand.[11]

Conclusions

These are sandstone erosion pavements (already in the list).

Coastal grassland/tussockland (short)

Reasons

This is found in narrow bands on coastal terraces with extreme exposure and high salinity. Predominantly grassland, dominated by *Poa* spp., it may also include *Puccinellia* spp. and other grass species, and coastal herbs (e.g. *Asplenium obtusatum, Blechnum blechnoides, B. durum, Anisotome lyallii, Hebe elliptica*). In areas with sheep/rabbit grazing, short turf becomes the

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[11] https://teara.govt.nz/mi/coal-and-coal-mining/page-2

dominant vegetation type with sparse tussocks (e.g. Maori Head, Dunedin). Examples are present on the coast between Slope Point and Waipapa Beach, Stewart Island /Rakiura, and Tītī / Muttonbird Islands. (See ‘Appendix 18 – Coastal grassland/tussockland’ for photos.)

Definition/s

recent/atmospheric salinity/terrace/coastal

Action/discussion points

- Although this is naturally occurring to a small extent, it probably occupies the same or similar areas to what we consider to be turf. Therefore, the ‘coastal turf’ NUE includes this vegetation type.
- This is more widespread now because the forest has been removed. Historically it would have been part of a coastal cliff shrubland mosaic.

Conclusions

This is not a new NUE. Rather, it occupies the same ecosystem space as ‘coastal turf’. The factsheets need to clarify that ‘coastal turf’ can include tussocks and herbs.

Inland turfs

Reasons

Inland turfs are found around waterbody edges, and are induced by grazing, nutrient additions, and compaction by indigenous birds. See Korsten et al. 2013 for further reading.

Location: Waihola, Otago.

Definition/s

silt/regularly high water table/bird and mammals trampling-grazing/inland

Action/discussion points

- This is a part of ‘lake margins’.
- The guidance could recognise the influence of avian grazing in these systems.

Conclusions

This is not a new system for the list as they are lake, tarn, and lagoon margins. However, the factsheets should be updated to include refences to avian grazing for the lake, tarn, and lagoon margins.

Seepy loess banks

Reasons

This is a distinctive ecosystem on low-altitude dry hills – winter wet, summer baked. The vegetation includes annual jersey fern (*Anogramma leptophylla*), turnip rooted geranium (*Geranium retrorsum*), *Pauridia glabella* var. *glabella*, and *Leptinella minor*. It is similar to coastal cut 'seepy' loess cliffs, which are a distinctive feature of North Canterbury. The coastal version has an interesting and distinctive flora and is a stronghold for *Sonchus kirkii*.

Definition/s

loess/hillslope, fan/periodically high-water table

Discussion points

These appear to be a variation of 'seepages and flushes'.

Conclusions

These belong in 'seepages and flushes' (already on the list). The factsheet should be updated to cover this type.

Tall subantarctic tussocklands

Reasons

These tussocklands comprise wet, cool temperate, coastal, windy, salt-spray loamfield. Vegetation includes *Poa littoralis* tussockland, *P. tennantiana*, and mega-herbs. They are found on the Snares Islands / Tini Heke, Auckland Islands, Campbell Island / Motu Ihupuku, and the Antipodes Island Group. This is a component of Singers & Rogers 2014 type SA10. The short and tall coastal tussocklands could be sub-types.

Definition/s

recent/atmospheric salinity/coastal/extreme wind exposure

Action/discussion points

- The current NUE typology does not include far offshore islands (except Stewart Island / Rakiura and those very close to the South and North Islands). Including these locations should be a future step in any revision of the diagnostic classifiers as there will need to be broader considerations.
- This is a historically rare ecosystem.

Conclusions

Although distinct, this ecosystem doesn't fit the current framework because the subantarctic islands are outside the geographical range of the current NUE framework.

Appendix 3 – Braided riverbeds

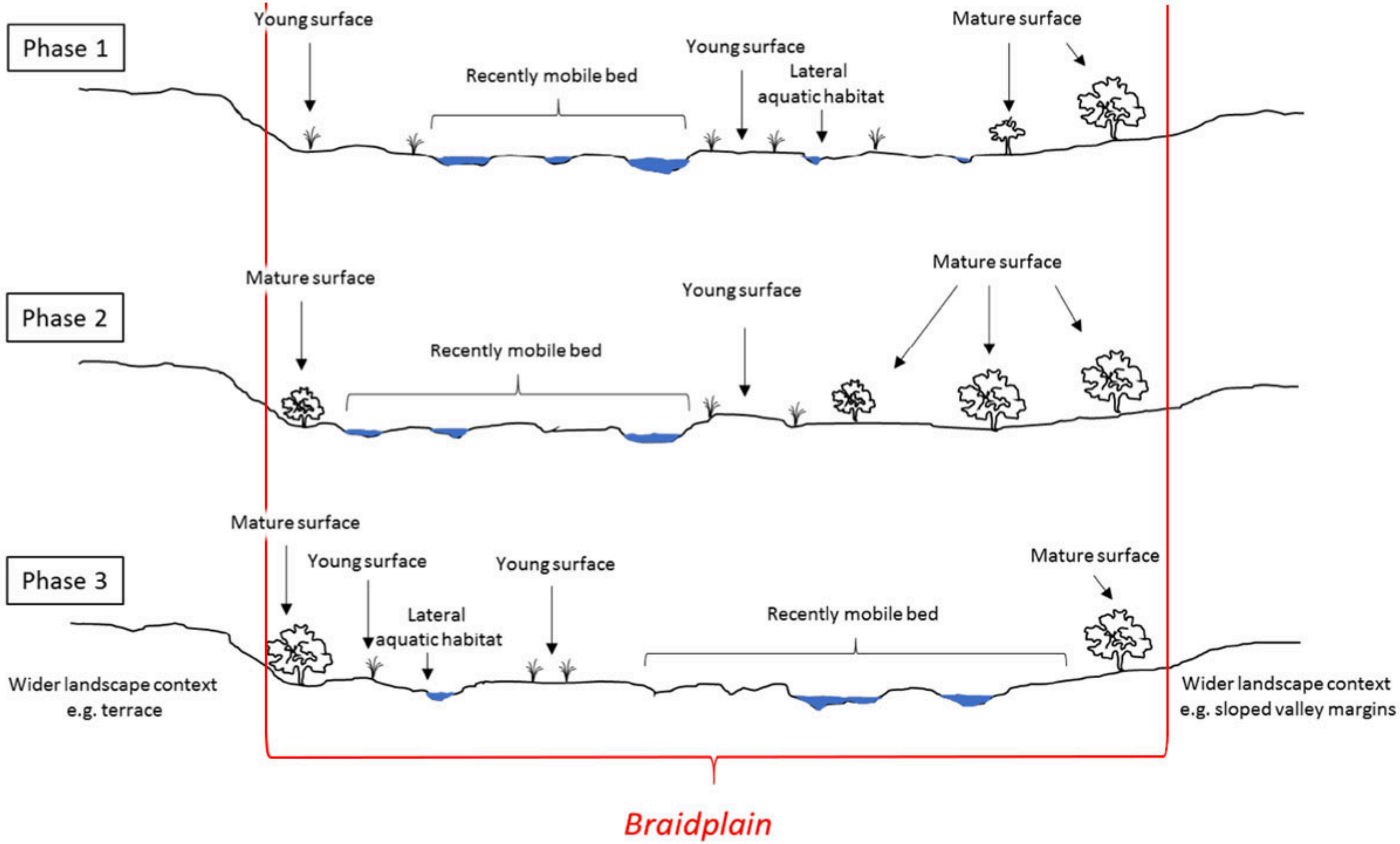

Figure A3.1. Illustration of a braided river within a braid plain.
(Source: https://braidedrivers.org/braidplains/)

Appendix 4 – Cloud forest

Notes Rowan Buxton has collated from various people and sources.

The best summary of cloud forest so far – but only for the Tropics – has some indicators as to what factors might be important in distinguishing cloud forest in New Zealand, but there are many different interpretations.

http://archive.unu.edu/unupress/unupbooks/80670e/80670E00.htm#Contents

The website gives this interpretation:

> Cloud forests include all forests in the humid tropics that are frequently covered in clouds or mist; thus receiving additional humidity, other than rainfall, through the capture and/or condensation of water droplets (horizontal precipitation), which influences the hydrological regime, radiation balance, and several other climatic, edaphic and ecological parameters.

There are various climatic and geographical factors that intervene and influence the elevation limits of the cloud forest bell in the humid tropics (the points below are summarised from https://archive.unu.edu/unupress/unupbooks/80670e/80670E03.htm):

- mean moisture content of the atmosphere
- cloud formation by convective or advective processes
- effect of the trade wind inversion and its variation on cloud formations
- direction and velocity of the prevailing winds
- mass elevation effect (Massenerhebungseffekt)
- size and orientation of the principal mountain ranges (macro-relief)
- micro-relief within mountains, which can have important topoclimatic effects
- mean distance to the nearest sea as a function of prevailing winds
- surface temperature and prevailing water currents of the nearest sea.

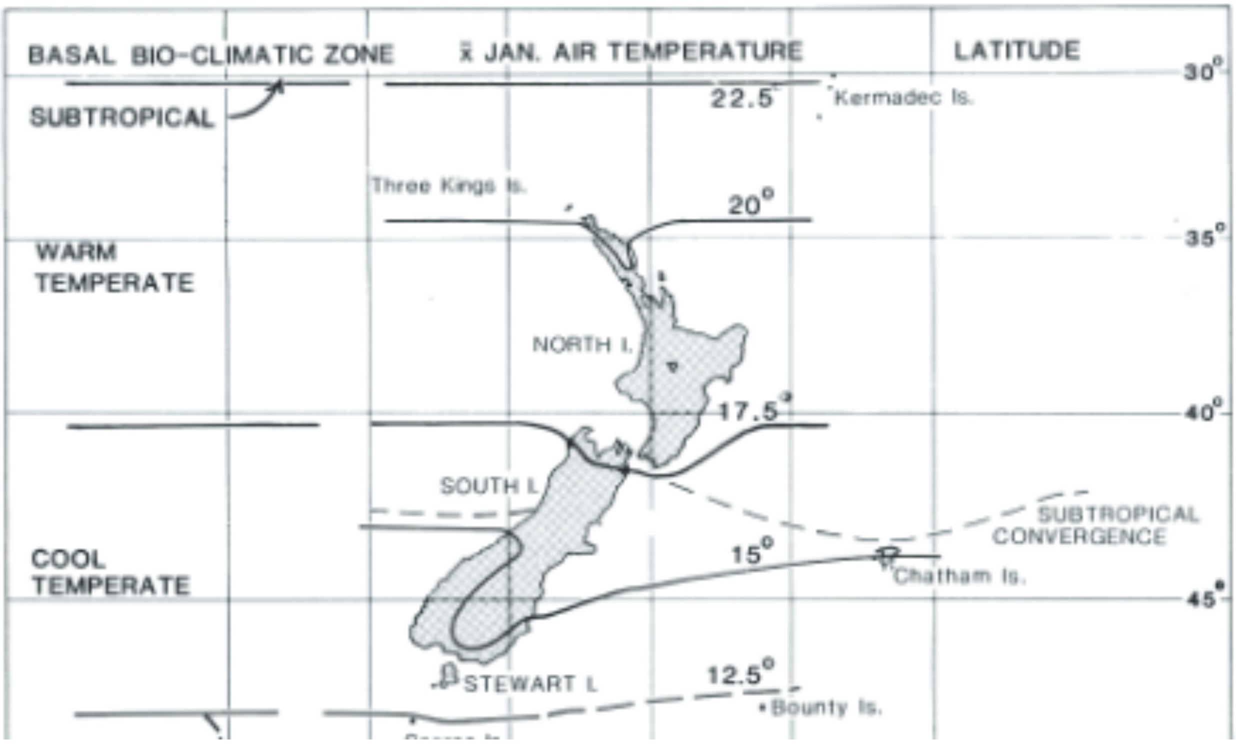

Figure A2.1. The climate zones of New Zealand. (Source: Meurk 1984)

The cloud forest in Northland lies within the warm temperate zone above the subtropical convergence (Meurk 1984). According to Meurk's (1984) diagram (http://www.newzealandecology.org.nz/nzje/free_issues/NZJEcol7_175.pdf) the humid warm temperate zone occurs where potential evapotranspiration is between 750 and 950 mm.

Appendix 5 – Moraines

The suggestions were to:

- either split moraines into dry (eastern basins, non-forest) and wet (steep, western, forested) subtypes.
- or rename 'moraines (recently formed)' and add 'moraines (dry)'.

Comment from review: The first photo shows the moraine that is consistent with the Williams et al. 2007 concept (Figure A5.1). In the other photos below, although the geomorphic origin of these sites is moraine, the soils are far too developed to fit within the definition of moraines in Williams et al. 2007, which is 'raw–recent/cobbles–boulders/moraine' (Figures A5.2 to A5.6). If the concept were this broad these would not be naturally uncommon.

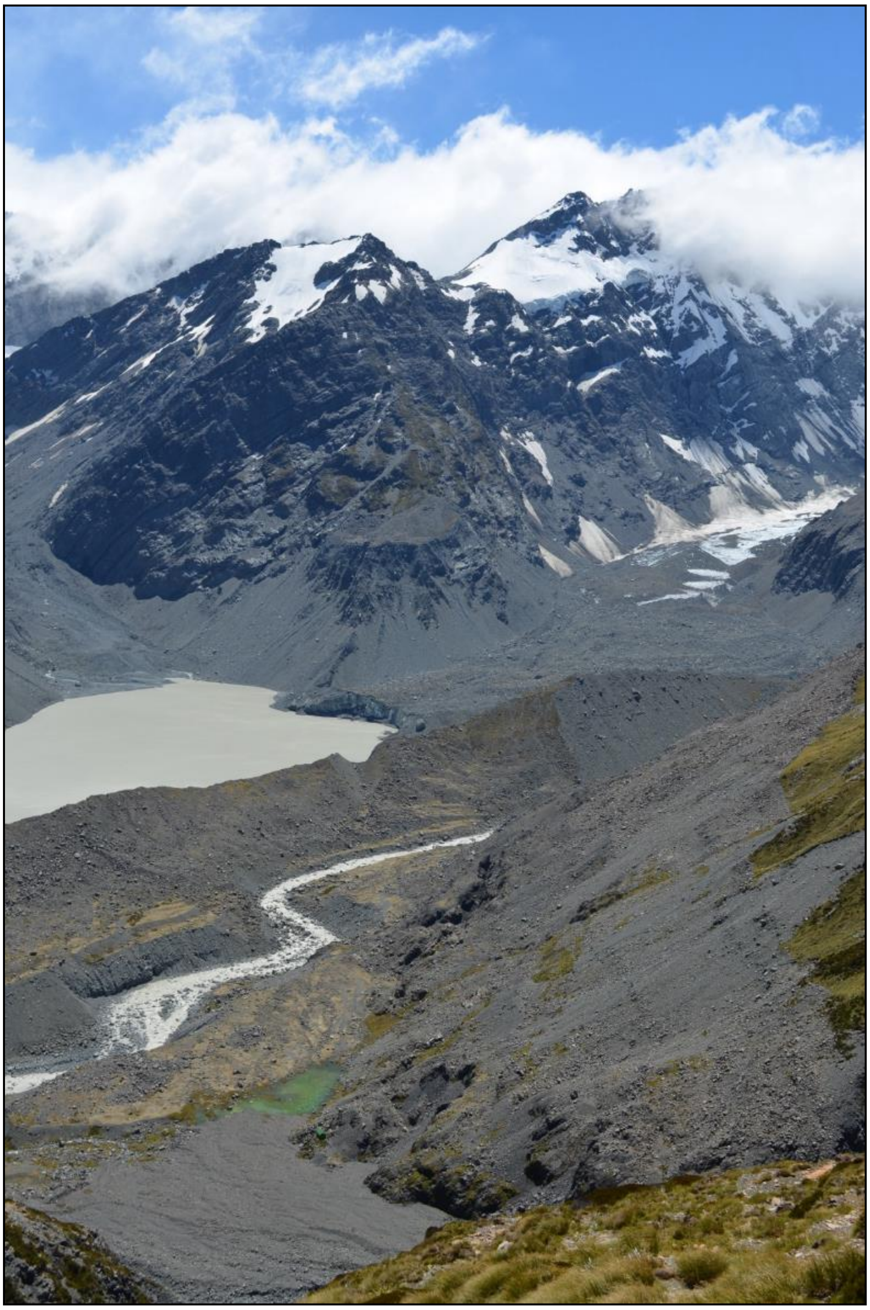

Figure A1.1. Example of newly formed (forming) moraines, Godley Valley. (Photo: Jane Gosden)

Figure A5.2. Lateral moraines near Porters Pass. (Photo: Jane Gosden)

Figure A5.3. Moraines on Glenmore Station. (Photo: Jane Gosden)

Figure A5.4. Forest on glacial deposits near Ōkārito. Other good examples would be the forest down in the Franz Josef and Fox glacier valleys. (Photo: Jane Gosden)

Figure A5.5. The moraines with kānuka forest at Lake Rotoiti, Nelson Lakes National Park. (Photo: Jane Gosden)

Figure A5.6. Moraine deposits above the Hurunui River in North Canterbury. (Photo: Jane Gosden)

Below is the definition of 'raw' and 'recent' soils (LENZ technical guide, p. 31; https://www.landcareresearch.co.nz/assets/Tools-And-Resources/Maps/LENZ/LENZ_Technical_Guide.pdf). Because soil development covaries with rainfall, in dry climates old moraine soils can have the properties of recent soils because the weathering rates are so slow.

The underlying data layers

Soil age

Soils were classified into two age classes based on their membership in the New Zealand Soil Classification. This describes soil age using morphological features associated with soil development rather than criteria based on chronological ages. As a consequence, soils classified as recent in dry cool environments may be much older than recent soils from warm, wet environments.

Table 2.14: Age classes, their definition and extent

Class	Definition	Area (km²)	Area (%)
Younger	All NZLRI soil units belonging to the Recent or Raw soil orders in the New Zealand Soil Classification, but excluding soils classified as recent because of erosion of an original intact soil	16,210	6.1
Older	All other NZLRI soil units	243,498	91.1

Figure A5.7. Table from the LENZ technical guide showing the definition for soil age classes.

Appendix 6 – Cobble bank wetlands

Like the rest of the Wellington coast, the wetland is on an uplifted wave-cut platform. The wave-cut platform is probably bedrock overlain with the colluvium for surrounding coastal cliffs and alluvium from streams being pushed along in longshore drift.

Thoughts are that the main wetland is either:

- a depression in this platform where water has ponded and vegetation established: this could be a depression between the current and historical storm berms or a depression in the bedrock platform itself, in which case the wetland may be perched and hydraulically separate from the coast, other than the odd wave overtopping and salt spray
- a small indentation at the end of the shore platform where a stony barrier has formed across the front, like a growing spit that has welded to the other side (think of a much smaller version of what happened at Lake Ōnoke), enclosing the feature, and water has ponded and vegetation established, in which case water will be connected with the sea level holding the water table up, and any additional rainwater will eventually percolate through the gravels.

The smaller wetland looks very much like a depression between uplifted historical storm berms.

It is unlikely that wave processes will erode these features, given the high-energy nature of this coastline and the fact that they have been here since the 1940s. Sea-level rise might have something to say regarding the larger wetland, but if anything it would push the barrier further inland and roll over the top of the depression to some degree rather than erode it away. However, it would depend on how high this barrier actually is and if sea-level rise outruns seismic uplift. This is a highly erosive coastline along some stretches and there is no lack of sediment being thrown around for barriers to build up.

When looking for other places like this nationally, start by looking for similar uplifting shore platform type coastlines.

Further reading:

R Gilbert Robert et al. 1984. A survey of coastal environments in the vicinity of Nain, Labrador. Atlantic Geology 20(3): 143–155.

PS Rosen 1979. Boulder barricades in central Labrador. Journal of Sedimentary Research 49(4): 1113–1123. doi: https://doi.org/10.1306/212F78C4-2B24-11D7-8648000102C1865D

Figure A6.1. Te Kawakawa Rocks south of Ngawi on the eastern tip of Palliser Bay; arrows point to the two wetlands. (Source: background image is from Google Earth)

Ōkupe Lagoon on the northern end of Kapiti Island, off the Wellington west coast, is similar in that it is bound by a boulder bank on the coastal edge. It differs in that it has water running off the hill, which feeds it through a small stream. It is doubtful whether the boulder bank is often, if ever, overtopped by the sea, but the salt spray must affect the salinity. If a storm ever breached the boulder bank the lagoon would surely drain. (The workshop noted that the Ōkupe Lagoon example would probably be classified as a 'lagoon margin'.)

Figure A6.2. Ōkupe Lagoon on the northern end of Kapiti Island, off the Wellington west coast, is similar to the one at Te Kawakawa Rocks in that it is bound by a boulder bank on the coastal edge.

Below are some examples of other apparently similar wetlands from the Wellington coastline that are considered part of the shingle beach system, which suggests that cobble bank wetlands are not their own system.

Figure A6.3. Apparently similar wetlands from the Wellington coastline that are considered part of the shingle beach system. (Photo: Rowan Buxton)

Appendix 7 – Dry deflation plains

There would seem to be two different systems here that are on opposite ends of a particle size spectrum. At one end is an inter-dune community on a coarse sand or fine gravel lag with potentially paleo-pavements. At the other end are flat plains of mobile sand and gravel with ventifacts.

Figure A7.1 Mason Bay, Stewart Island /Rakiura: a dune deflation hollow and dry sand plain. (Photo: Teresa Konlechner)

Figure A7.2. Mirza Beach site. (Photo: Susan Wiser)

Figure A7.3. Napier airport site. (Photo: Susan Wiser)

Figure A7.4. Kohangapiripiri, Wellington. (Photo: Susan Wiser)

Appendix 8 – Geothermal systems

Below is a short report prepared by Wildlands to comments on the previously-described geothermal ecosystem types and suggest some changes to names, and also suggest some potential rationalisation of types.

Comments on the Review of Geothermal Aspects of Naturally Uncommon Ecosystems by Manaaki Whenua Landcare Research

Prepared for:	Landcare Research	Reviewed and approved for release by:	Sarah Beadel Senior Principal Ecologist Wildland Consultants Ltd
Author:	Chris Bycroft, Sarah Beadel, William Shaw		
Report No:	7475		
Date:	February 2025		

1.0 Introduction

Manaaki Whenua Landcare Research is updating the classification of Naturally-Uncommon Ecosystems that have previously been described and ranked by:

- Williams *et al.* (2007) provided the rationale for the list.
- The threat status of each ecosystem was assessed by Holdaway *et al.* (2012) using the IUCN red-list criteria.
- The most recent overview of the naturally uncommon ecosystems was prepared by Wiser *et al.* (2013).

These assessments recognised five naturally rare geothermal ecosystems:

- Acid rain systems
- Hydrothermally-heated ground (now cool)
- Heated ground (dry)
- Geothermal streamsides
- Fumaroles

The last four of these were assigned a threat status of 'Nationally Critical' by Holdaway *et al.* (2012).

Geothermal wetland is not included in the above categories. It should also be noted that the above categories identified 15 wetland ecosystem types as being naturally uncommon but geothermal wetland was not one of these. The omission of geothermal wetlands has become quite important when assessing the values of geothermal sites for resource consents and other activities where the loss and decline in condition of this habitat type is a potentially significant issue. We have addressed this by stating that while geothermal wetlands have not been captured in previous assessments, they do nevertheless meet the criteria for a naturally uncommon ecosystem. Geothermal wetlands also provide habitat for many of the special plants that occur in geothermal habitats.

We also provide brief comments on the previously-described ecosystem types and suggest some changes to names, and also suggest some potential rationalisation of types.

At this stage we have not commented on the species included in descriptions of geothermal habitat types currently presented on the Manaaki Whenua Landcare website (https://www.landcareresearch.co.nz/publications/naturally-uncommon-ecosystems/geothermal), but some clearly require updating to be more representative of the species that actually occur in these habitat types. This could be addressed in a future exercise.

2.0 Extent

The most recent estimate for the national extent of geothermal habitat (terrestrial and wetland) is 1,300-1,400 hectares (Wildland Consultant 2020, 2023, and 2024), which means that it is not necessary to split habitats into smaller classes to meet the criteria for a nationally uncommon ecosystem.

Most geothermal habitat occurs in the Waikato Region, as does geothermal wetland. Wildland Consultants (2023) recently mapped and described all geothermal sites in the Waikato Region, identifying *c.*113 hectares of geothermal wetland vegetation and habitat. There are also areas of geothermal wetland in the Bay of Plenty Region and a very small area in the Northland Region.

Based on staff knowledge and recent assessments (Wildland Consultants 2020) at Waimangu (Wildland Consultants 2024), we estimate that there is probably less than 30 hectares of geothermal wetland in the Bay of Plenty Region. Small areas of geothermal wetland occur at other sites throughout New Zealand, but the total area would be very small. Our estimate is that there would likely be less than 150 hectares of geothermal wetland, nationally.

3.0 Threats

There has previously been a number of threats to geothermal wetland sites in the Waikato and Bay of Plenty regions including drainage, conversion to farmland, industrial and urban development, pest plant invasion (particularly willows and alder), forestry activities on margins, development of the underlying geothermal reservoir for electricity generation, flooding due to hydro dam development, impacts of pigs and other pest animals, and herbicide overspray. Many of these factors remain active threats at various sites.

4.0 Variation in Geothermal Wetlands

Factors Influencing Variability

It should be noted that geothermal wetland is an extremely variable habitat type. This variation includes features such as the character of the geothermal system the wetland occurs in, water chemistry, temperature variation of different springs or seepages, water depth, altitude, distance inland, landform, and adjoining features such as lakes. For example, acidity is a key attribute that influences plant species presence (and distribution).

Because of the varied character of sites, it is useful to identify geothermal wetlands in a broad sense, so that all the different types are captured.

Vegetation Structure

Geothermal wetlands are known to support the following vegetation structural classes:

- Sedgeland
- Rushland
- Herbfield
- Reedland
- Shrubland
- Algal mats

5.0 Representative Examples

The following are representative sites for geothermal wetlands:

Waikato Region

- Waikite
- Waiotapu (south end near Lake Ngakoro and Lake Orotu)
- Waihunuahuna springs (edge of Lake Ohakuri)
- Waikato River Springs, near Tutukau Bridge
- Waipahihi Valley (Wairākei Tauhara Geothermal System)
- Tokaanu Lakeshore Wetland

Bay of Plenty Region

- Waimangu – lower valley wetland
- Ngapuna (edge of Lake Rotorua, Rotorua)
- Parengarenga Wetland (Lake Rotoiti)
- Waitangi Soda Springs (south of Lake Rotorua)
- Tukuri

Northland Region

- Ngawha

A selection of site photographs is provided in Appendix 1.

6.0 Key Species

6.1 Vascular plants

Examples of key species associated with geothermal wetlands include (Threatened or At Risk rankings are from de Lange *et al.* 2023):

- *Christella* aff. *dentata* (b) (AK 126902; "thermal") (Threatened-Nationally Endangered).
- *Cyclosorus interruptus* (At Risk-Declining).
- *Thelypteris confluens* (At Risk-Declining).
- *Nephrolepis flexuosa* (At Risk-Naturally Uncommon).

The conservation status of many of these species would be higher if regional rankings were to be applied for the Bay of Plenty, Waikato, and Northland Regions.

Also, various species outside their usual natural range occur in geothermal wetlands, including species of coastal sites occurring inland, or with unusual latitudinal and elevation ranges such as:

- Sea rush (*Juncus kraussii* subsp. *australiensis*).
- Oioi (*Apodasmia similis*).
- Arrow grass (*Triglochin striata*).

6.2 Avifauna

In addition to many common water birds, the following are known to utilise geothermal wetlands (Threatened or At Risk rankings are from Robertson *et al.* 2021).

- *Botauruspoiciloptilus* (matuku-hūrepo/Australian bittern): (Threatened-Nationally Critical).
- *Bowdleria punctata vealeae* (koroātito/North Island fernbird): (At Risk-Declining).
- *Zapornia tabuensis tabuensis* (pūweto/spotless crake): (At Risk-Declining).

7.0 Previous Definitions of Geothermal Wetland

There are existing definitions for geothermal wetland, including:

- "Permanently or intermittently wet areas, shallow water, or land water margins that support a natural ecosystem of plants adapted to wet conditions, and in which some or all of the water is geothermally sourced" (Merrett and Clarkson 1999).

- "A wetland hydrosystem where the dominant function is geothermally heated water. The Resource Management Act (1991) defines geothermal waters as those heated by natural phenomena to 30 degrees Celsius or above. Geothermal wetlands may have water temperatures below this, but must be considered geothermal due to the chemical composition of the water. Geothermal wetlands are permanently or intermittently wet areas, shallow water, or land water margins that support a natural ecosystem of plants that have compositional, structural, and/or growth rate characteristics determined by current or former inputs of geothermally derived water." (Clarkson *et al.* 2004).

- "A hydrosystem where volcanic activity produces hot surface waters, or heated soils (30 C or more) or where geothermal chemistry affects wetland habitats." (Johnson and Gerbeaux 2004).

8.0 Suggested Definition of Geothermal Wetland

To provide a description of geothermal wetland, we have followed the layout used to describe naturally uncommon ecosystems, e.g. Williams *et al.* 2007, Holdaway *et al.* 2012, Wiser *et al.* 2013, and on the Manaaki Whenua Landcare website:

> Inland (including coastal to alpine), regularly high water table (permanently or ephemerally wet), with elevated temperatures, sourced at depth and also due to overflows, with higher temperatures and different chemistry than natural surrounding land.

9.0 Comments on other geothermal ecosystem types

<u>Geothermal Steamy Habitat</u>

Merrett and Clarkson (1999) used the term 'Atmospheric Influence' and identified two types.

(a) regular toxic gas emissions to the extent that vegetation growth is negatively influenced (e.g. Whakaari/White Island), or

(b) a warm micro-climate created by hot-springs discharge (e.g. the fern *Christella* aff. *dentata* ("thermal") occurs along the margins of hot streams where the atmosphere is influenced by steam).

Acid rain could still be a sub-type under type (a) above but, due to the rarity of geothermal systems nationally, combining these together may prove more useful from a management perspective and would help to ensure that no rare geothermal ecosystem sub-types are omitted.

The title for the type 'geothermal streamsides' is a poor descriptor of the habitats it represents. It is also intended (based on the description on the Manaaki Whenua Landcare website) to include hot spring margins that occur in the geothermal streamside ecosystem type. Geothermal streamsides are obviously totally reliant on the presence of a heated stream with associated steam influence on the margins. The name could be altered to reflect the key role of heated streams.

'Hydrothermally-heated ground (now cool)' and 'heated ground (dry)' work well within the naturally uncommon ecosystem framework. However, it is suggested that the term 'geothermal' is added to these titles, as this will make it clear that they are linked to a below ground heat source (at depth, from the Earth's heat), and not solar radiation, or other human influences. Suggested titles are.

- Previously geothermally-heated ground (now cool).
- Geothermally heated ground (dry).

A summary of suggested changes to geothermal habitat type names from Williams *et al.* 2001; Holdaway *et al.* 2012; and Wiser *et al.* 2013 is presented in Table 1.

Table 1 – Suggested name changes for naturally rare ecosystems as per Williams *et al.* (2001); Holdaway *et al.* (2012); Wiser *et al.* (2013).

Uncommon Ecosystems (Williams *et al.* 2001; Holdaway *et al.* 2012; Wiser *et al.* 2013)	Wildlands Recommendation
Hydrothermally-heated ground (now cool)	Previously geothermally-heated ground (now cool)
Heated ground (dry)	Geothermally-heated ground (dry)
Geothermal streamsides	Geothermal streams and streamsides and spring and margins
Fumaroles	Fumaroles
Acid rain systems	Geothermally-derived natural atmospheric systems
Not assessed	Geothermal wetland

<u>Other Geothermal Habitats</u>

Other geothermal habitat types 'missing' from the five currently-recognised rare geothermal ecosystems include:

- Mud pools.
- Geothermal lakes.

Acknowledgements

This work was initiated during a discussion at the New Zealand Ecological Society conference field trip to Waimangu in November 2024. During the discussion useful discussion was had with Scott Jarvie (Otago Regional Council) and Susan Wiser (Landcare Research). Subsequent discussion occurred with Gretchen Brownstein Landcare Research. We also thank William Shaw and other Wildlands staff for useful discussion and Waikato Regional Council and Bay of Plenty Regional Council, including their staff, who have initiated much of the field work we have undertaken at geothermal sites in the last 20-30 years and has been very helpful in formulating our ideas on geothermal habitats and other naturally rare ecosystems.

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Wildland Consultants (2024). Extent and condition of geothermal vegetation and habitats at the Waimangu-Rotomahana site. *Wildland Consultants Ltd Contract Report No. 7067a*. Prepared for Bay of Plenty Regional Council. 67 pp.

Appendix 1: Example photographs of geothermal wetlands

Plate 1 – A relatively large geothermal wetland occurs at the southern end of the lake Ngakoro, Waiotapu, Waikato Region. The wetland provides habitat for special plant and bird species. Photograph: Chris Bycroft/Wildland Consultants 2023.

Plate 2 — Geothermal wetlands occur on the margins of Lake Ohakuri at Waihunuhu Inlet, Orakei Korako Geothermal System, Waikato Region.
Photograph: Chris Bycroft/Wildland Consultants 2023.

Plate 3 – There are relatively large areas of geothermal wetland in the Waikite Valley located in the Waikato Region. The wetland provides habitat for many of the special geothermal fern species. Photograph: Chris Bycroft/Wildland Consultants 2023.

Plate 4 — Geothermal wetland at Otumuheke Stream in 2012. The springs in this wetland have retreated down the valley due to subsidence. Most of the wetland has since dried up and it is no longer wetland. Previously well over 1,000 *Cyclosorus interruptus* plants were present. Photograph: Chris Bycroft/Wildland Consultants 2012.

Plate 5 — Geothermal wetlands at Tukuri near the township of Kawerau, Bay of Plenty Region. Photograph: Sarah Beadel/Wildland Consultants 2024.

Plate 6 — Mats of algae occur on geothermal sinter near a small geyser at Waimangu, Bay of Plenty Region. Ferns such as *Nephrolepis flexuosa*, usually a species of warmer climates, occurs on wetland margins.
Photograph: Sarah Beadel/Wildland Consultants 2024.

Plate 7 — Geothermal wetland at Waimangu, Bay of Plenty Region. Photograph: Chris Bycroft/Wildland Consultants 2024.

Plate 8 — Geothermal wetland alongside the Tarawera River, Tarawera Forest, Bay of Plenty Region. Photograph: Chris Bycroft/Wildland Consultants 2019.

Appendix 9 – Inland dryland alluvium

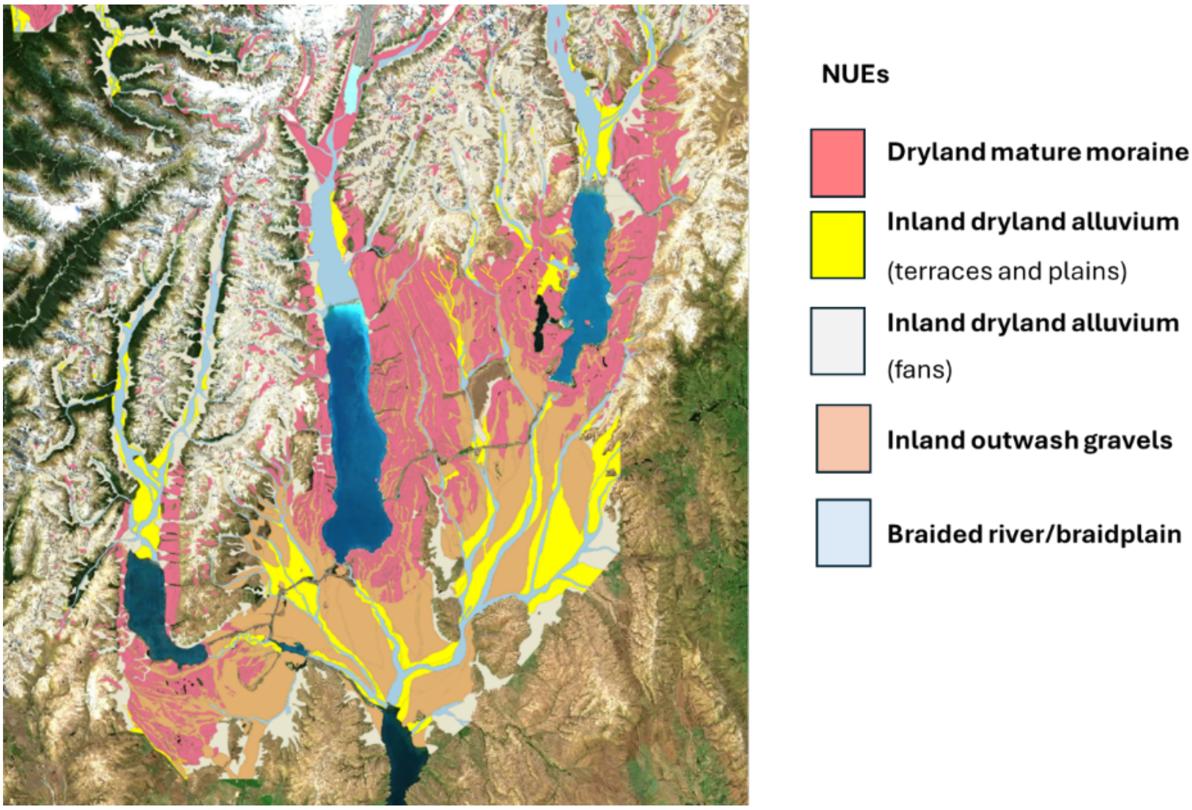

Figure A9.1. Map showing the location of inland dryland alluvium terraces and plains (yellow) and fans (light grey). (Polygons layer from: https://data.gns.cri.nz/csigg/map.html. Background imagery: https://data.linz.govt.nz/layer/95677-nz-imagery-survey-index/)

Figure A9.2. Vegetation patterns are related to soil depth in inland alluvial terraces, Mackenzie Basin. (Photo: Susan Walker)

Figure A9.3. Bryophyte and cushion plant communities in inland alluvial terraces, Mackenzie Basin.
(Photo: Susan Walker)

Figure A9.4. Terraces near Pukaki airport. There is definitely some patterning, with slightly deeper soils perhaps in the swales between the drier-looking ridges. This is probably quite different from the alluvial terraces on the Canterbury plains and elsewhere, but it's unclear what the main driver is.
(Photos: Rowan Buxton).

Appendix 10 – Inland salt springs

All photos are from Wairau Valley, Marlborough.

Figure A10.1. Inland salt spring vegetation patterns. (Photo: Mike Aviss)

Figure A10.2. Inland salt spring. (Photo: Mike Aviss)

Figure A10.3. *Samolus repens* around an inland salt spring. (Photo: Mike Aviss)

Appendix 11 – Mud volcanoes

Further reading:

BW Hayward, D Francis 2013. New Zealand's small mud volcano heritage" Geological Society of New Zealand Newsletter.

Nga Maunga Korero Ō-tū-pō-tehetehe – The Lake of Taikehu: https://maungakorero.wordpress.com/maunga-korero/issue-13-patangata/o-tu-po-tehetehe-the-lake-of-taikehu/

JR Pettinga 2003. Mud volcano eruption within the emergent accretionary Hikurangi margin, southern Hawke's Bay, New Zealand. New Zealand Journal of Geology and Geophysics 46(1): 107–121.

Figure A11.1. Mud volcano, Waimatā valley, Gisborne. (Photo: Bev Clarkson)

Figure A11.2. Mud volcano, Ōtōpōtehetehe Lake, near Pōtaka, Gisborne region. (Photo: Paul Cashmore)

Figure A11.3. Mud volcano, Ōtōpōtehetehe Lake, near Pōtaka, Gisborne region. (Photo: Paul Cashmore)

Appendix 12 – Active sand dunes

Further information can be found here: http://tinyurl.com/Activedunes

Associated vegetation:

- dune environments (constructional, high to moderate sand mobility): species include *Spinifex sericeus, Ficinia spiralis, Poa billardierei*
- less mobile habitats: species include *Coprosma acerosa, Pimelea lyallii, Pimelea villosa, Lachnagrostis billardierei, Acaena pallida*.

Appendix 13 – Ephemeral wetlands

Figure A13.1. Kettlehole ephemeral wetland on Ahuriri Valley glacial terraces. (Photo: John Barkla)

In Jane Gosden's kettlehole work she included some other tarns in the definition, even though they do not have a glacial origin when you look at GNS maps of glacial deposits and don't strictly fit the criteria for a kettlehole geologically. However, she suspects they are still of glacial origin and have had subsequent processes occur over the top (such as earthquake faulting for two tarns in Marlborough, or Holocene alluvial processes for three in Southland/Otago).

She now has a full extent and distribution for kettleholes, mapped as polygons and tarn centres (currently progressing for publication). Her work suggests that kettleholes are the most widespread/abundant of the ephemeral wetlands (in the South Island at least). However, they still fit the definition for naturally uncommon (<0.05% of land area).

Figure A13.2. Example of a tarn formed by fault action in the Molesworth Recreation Reserve near Lake Sedgemere. This ecosystem is ecologically similar to a kettlehole tarn, even if its origin isn't strictly glacial. (Photo: Jane Gosden)

Figure A13.3. Example of a tarn with Holocene deposits as its youngest geological deposit. This ecosystem also functions as a kettlehole tarn, even if its origin is not strictly glacial. (Photo: Jane Gosden)

Figure A13.4. Schist depression ephemeral wetland at the southern end of Flat Top Hill, near Alexandra, Central Otago. (Photo: John Barkla)

Figure A13.5. Ephemeral wetland in a temporary runoff channel. (Photo: Jane Gosden)

Ephemeral wetlands are often part of other wetland systems. The larger lakes around Lake Sedgemere in the Molesworth Recreation Reserve provide good examples of this type. Jane didn't include them in her kettlehole study because they function differently hydrologically. Jane suspects the ephemeral wetlands of the North Island are more likely to be like this.

The workshop commented that the lake edges are already included under lake margins and tarn margins, which are known to share species with the turfs of ephemeral wetlands.

Figure A13.6. A good example of an ephemeral wetland on the edge of other wetland systems. The photos are from Lake Sedgemere in the Molesworth Recreation Reserve (not far from Sedgemere Hut). This example illustrates how complicated some of these uncommon ecosystems are when they blend into something else or form mosaics. (Photo: Jane Gosden)

Appendix 14 – Frost hollows

The following is an excerpt from Singers & Rogers 2014, Appendix 3, with the four types that equate to frost hollows.

Ecosystem unit and code name	*Description*	*Distribution current and historic*	*References*
TI2: Kānuka, Olearia scrub/treeland	Scrub and treeland of kānuka, and species of Olearia, Carmichaelia and Melicytus, with korokia, matagouri, mountain tauhinu, prostrate kōwhai and lianes (e.g. Muehlenbeckia), and locally Leonohebe cupressiodes. Early successional derivatives include short tussock grasslands of species of Poa, Festuca, Deyeuxia and Rytidosperma, with inter-tussock prostrate herbfield species.	Driest inter-montane basins on Holocene terraces of Marlborough to Otago (e.g. Mackenzie and Heron Basins) with > 200 mm annual water deficit (Leathwick et al. 2003). Soils described by Molloy (1998: 24–25 & 157–158). Largely only highly degraded secondary derivatives remain, which are dominated by prostrate shrubland, short tussock grassland and scabweed herbfield.	McGlone & Moar (1998), McGlone (2001) and Rogers et al. (2005: 53). Includes rare ecosystem: frost hollows (Williams et al. 2007).
TI4: Coprosma, Olearia scrub [Grey scrub]	Scrub of two different variants: 1. on free-draining stony soils, with species including Carmichaelia, Coprosma, Olearia, Hebe, Corokia cotoneaster, mānuka, matagouri, and species of the lianes Muehlenbeckia, Rubus and Clematis; and 2. on poor-draining silty soils, with species such as Coprosma (C. propinqua, C. pedicillata), Pittosporum obcordatum and Olearia (O. polita, O. virgata). Early alluvial successions are dominated by short tussock grasslands (species of Poa, Festuca, Deyeuxia and Rytidosperma).	In the South Island, post-glacial river terraces, colluvial slopes and recent moraines west and east of the Main Divide, and in frost-prone areas further afield. In the North Island, localised in frosty hollows and river and stream margins. Often colloquially called 'grey scrub' or 'frost flats'. Many species are common to both types and both types can occur together as mosaics on the different alluvial landforms/soils. Often occurs as secondary shrubland on a wide range of previously forested landforms. Enters the humid zone in central ranges.	Equivalent to Matagouri shrubland class of Wiser & Hurst (2008). Wardle (1991: 207–211), Clarkson & Clarkson (1994), Molloy et al. (1999) and Rogers et al. (2005). Includes rare ecosystem: frost hollows (Williams et al. 2007).
TI5: Bog pine, mountain celery pine, silver pine scrub/forest	Scrub and short forest with several local variants, including mountain celery pine and bog pine, locally with silver pine, pink pine, yellow silver pine, pāhautea and Westland tōtara, and often with divaricating shrubs and Dracophyllum spp.	Central North Island (e.g. Kaimanawa Mountains) and western Tongariro National Park (e.g. Waimarino Plains). In the South Island, predominantly Nelson Lakes to Westland (e.g. upper Howard River). Locally also on levee and margins of wetlands.	Equivalent to G20 type of Nicholls (1976). Wardle (1991: 193–195). Includes rare ecosystem: frost hollows (Williams et al. 2007).
TI6: Red tussock tussockland	Tall tussock grassland of abundant red tussock with inter-tussock herbfield / short tussockland and prostrate shrub species. Early alluvial successions are dominated by short tussockland of Poa, Festuca, Deyeuxia and Rytidosperma species. Typically includes an embedded, complex mosaic of bog and fen wetlands on organic soils.	In the North Island, restricted to the volcanic plateau, from the Hauhungaroa Range south to Erua and the Kaimanawa Mountains on alluvial terraces and headwater basins, to southern Ruahine. In Northwest Nelson, occurs with wire rush (e.g. Gouland Downs and Thousand Acres Plateau) and with C. rigida in eastern Fiordland. Occurs on valley floors in Westland (e.g. Toaroha and Landsborough Rivers) and Fiordland (e.g. Takahe Valley).	Elder (1962: 22), Evans (1969a), Druce et al. (1987), Wardle (1991: 226), Grove (1994), Mark & Dickinson (1997) and Mark et al. (2003: 193 & 200–202). Includes rare ecosystem: frost hollows (Williams et al. 2007).

The following is an excerpt from Singers & Rogers 2014, Table 2, for temperatures greater than minus 9°C, cold air inversion topography.

Moisture	*Landform and soils*	*Ecosystem code*
Semi-arid	Mosaic of hummocky moraines and peri-glacial outwash, and alluvial terraces and plains with stony, semi-arid soils, e.g. Tekapo soils	TI1
	Terraces with recent semi-arid alluvial and pallic soils, e.g. Fork or Molyneaux soils	TI2
Sub-humid	Terraces and plains with recent deep pumice soils, e.g. Poronui and Kaingaroa soils	TI3
	Terraces, hillslopes and glacial moraines with alluvial, poor- and free-draining recent soils	TI4
Humid	Terraces, depressions and montane plateaus with recent volcanic, alluvial and podzol soils	TI5
	Montane to subalpine terraces and montane plateaus with poor-draining and organic soils	TI6

Appendix 15 – Inland outwash gravels

The following are photos of a fluvioglacial outwash ecosystem in the Mackenzie Basin with frost hollows.

Figure A15.1. A fluvioglacial outwash ecosystem with frost hollows throughout. (Photo: Nick Heads)

Figure A15.2. A fluvioglacial outwash ecosystem intermixed with frost hollows. (Photo: Nick Heads)

Appendix 16 – Stable dunes

Potential proposed split – grey dune and forested stable dune ecosystem.

The European habitat system has a grey dune ecosystem type (https://en.wikipedia.org/wiki/Grey_dune), distinguishing it from yellow dunes (active dunes) and more well-vegetated stable dunes.

Figure A16.1. Example of a potential grey dune from the east coast, Northland. Type species: *Ficinia nodosa, Calystegia soldanella*, non-thrifty dune building species (*Spinifex sericeus* and *Ficinia spiralis*), *Muehlenbeckia complexa*, and various non-native species. The defining characteristics are low sand mobility, some soil development, and low and relatively open vegetation cover.
(Photo: Teresa Konlechner)

Figure A16.2. Example of a grey dune from Farewell Spit. (Photo: Teresa Konlechner)

Figure A16.3. Example of a grey dune at Doughboy Bay, Stewart Island / Rakiura.
(Photo: Teresa Konlechner)

Appendix 17 – Coal measures

There is a good overview of coal measures on the Te Ara website: [Coal resources – Te Ara Encyclopedia of New Zealand]

Background

The Denniston plateau is often selected as an NUE because of the distinctive landscape and biota. This raises two questions: what type of ecosystem is the Denniston plateau, and is it naturally uncommon?

What is a coal measure?

Coal measures are simply coal-bearing strata. They can be old (Carboniferous) or relatively recent (Tertiary). They can be close to the surface or at great depth. Some are tilted, others are in horizontal planes. They are not an NUE in themselves because they do not define what's at the surface (i.e. the terrestrial ecosystems we see). In New Zealand, coal measures are *usually* Tertiary, and they are *sometimes* associated with deposits of conglomerates, sands, and finer-grained sedimentary rocks that *can be* exposed at the surface. These exposed rocks *can* form erosion pavements, and it is these pavements that are naturally uncommon ecosystems.

What is a sandstone erosion pavement?

Flat or gently tilting, eroded, exposed and cemented sandstone above a coal measure.

Conclusion

Because not all coal measures support erosion pavements it would be clearer if we referred to sandstone erosion pavements rather than coal measures. In north-west Nelson and on the West Coast we have tended to use 'coal measures' and 'sandstone erosion pavements' interchangeably, hence the confusion.

Outstanding questions

In 2012 we visited a suite of sandstone erosion pavement sites in north-west Nelson. We collected sediment cores from all of them to test the hypothesis that some areas of these exposed pavement ecosystems can be an artefact of fire, deforestation, and soil erosion. The full trip report and pollen and charcoal analyses are available from Janet Wilmshurst (MWLR).

Appendix 18 – Coastal grassland / tussockland

Figure A18.1. Example of coastal grassland, Waipapa Point, Southland. (Photo: John Barkla)

Figure A18.2. Example of coastal grassland, Maori Head, Dunedin. (Photo: Gretchen Brownstein)

Appendix 19 – List of contributors

The following people made suggestions for revisions to the list, and/or provided information to inform our thinking, and/or participated in the workshop discussions, and/or provided comments on and reviews of earlier versions. The list is in alphabetical order.

Warwick Allen, Mike Aviss, John Barkla, David Barrell, Sarah Beadel, Annabel Beattie, Peter Bellingham, Rowan Buxton, Chris Bycroft, Ciaran Campbell, Paul Cashmore, Bev Clarkson, Richard Ewans, Jane Gosden, Nick Heads, Mike Hilton, Scott Jarvie, Teresa Konlechner, Clement Lagrue, Kelvin Lloyd, Ellery Mayence, Adrian Monks, Peter Johnson, Brian Rance, Jill Rapson, Sarah Richardson, Geoff Rogers, William Shaw, Robyn Simcock, Roger Uys, Susan Walker, Susan Wiser, Debra Wotton