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Kaimaumau-Motutangi Wetland Mapping

Methods, Wetland and Vegetation Descriptions and Constraints

Prepared for the Department of Conservation

Document Quality Assurance

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Cover photograph: Looking west over Kaimaumau-Motutangi Wetland from near Otiaia Point and the entrance to Rangaunu Harbour, © Scott Hooson, Boffa Miskell, 2018

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1.0 Introduction

1.1 Background

The Kaimaumau-Motutangi wetland complex is a nationally significant ecosystem of approximately 2,600 ha on Northland's east coast. The wetland is immediately inland of Ngārui-o-te-Marangai / East Beach and between Kaimaumau and the Houhora Heads, north of Kaitaia (Figure 1). Kaimaumau-Motutangi Wetland is a very important ecosystem for maintaining and enhancing New Zealand's indigenous biodiversity and has been ranked as a priority for conservation by both the Northland Regional Council (NRC) and the Department of Conservation (DOC).

DOC has commissioned technical and monitoring projects, to inform the future management of the wetland and to address some of the uncertainty about:

- the extent of different wetland and vegetation types in Kaimaumau-Motutangi;
- the extent of groundwater versus surface water fed wetland systems; and
- the distribution of key weed species.

As part of this, DOC engaged Boffa Miskell Ltd (BML) to develop a detailed geospatial map to accurately delineate the wetland types and vegetation communities within the wetland complex. This mapping will allow DOC to:

- advocate for the protection of wetland values in resource consent applications relating to groundwater extraction and wetland development at Kaimaumau;
- design monitoring projects relating to hydrology, vegetation and fauna; and
- prioritise investment in on-ground operations, such as weed management.

1.2 Purpose

The purpose of this report is to:

- Document the methods used to map and classify the wetlands and their vegetation communities;
- Describe the methodology used to ground-truth (validate) the draft maps;
- Describe the key wetland plant communities associated with the vegetation classifications used in mapping the wetlands; and
- Outline the constraints of the mapping and ground-truthing components of the work and provide recommendations to improve the methodology.

2.0 Mapping Methods

This section of the report describes the methods that were used to map the Kaimaumau-Motutangi wetlands and waterways and generate the geospatial layers.

2.1 Overview of the Approach

The approach used to map and classify the wetlands, streams and drains within the mapping area followed the approach outlined in Hooson and Robertson (*draft, in prep*) (Figure 2). The mapping approach had several stages. Firstly, the extent of the mapping area / wetland extent was mapped, then a helicopter reconnaissance flight was undertaken. Following this, detailed mapping and classification of the wetland and vegetation and waterways geo-spatial layers was completed in ArcGIS using aerial photographs. The maps were then validated in the field using drone video footage and limited ground surveys. Finally, the geospatial layers were amended where discrepancies were found between the desktop mapping and the field validation work.

2.2 Output Layers

Based on the Scope of Work provided by DOC, and the recommended output layers from Hooson and Robertson (*draft, in prep*) the following output layers from this work were proposed by Boffa Miskell and agreed with DOC:

- Base imagery
- Mapping area / wetland extent
- Wetland and vegetation layer
- Waterways (streams, drains)

2.3 Base Imagery

Potential imagery for using as the base imagery for the mapping and classification work was evaluated. The NRC imagery was identified as the most recent, best quality imagery available. It was flown between 2014 and 2016, and has a resolution of 0.4 m.

2.4 The Mapping Area / Wetland Extent

The extent of the mapping area was defined by DOC in the initial Scope of Work. Based on this, a draft 'wetland extent' was then mapped by Boffa Miskell, using the base imagery. This draft layer was issued to DOC and refined in discussion with DOC to create the final 'wetland extent' layer.

The final 'wetland extent' (the area within which all the wetlands were identified, mapped and classified) included the contiguous wetland (including freshwater and estuarine wetlands) and dune sequences that comprise the Kaimaumau-Motutangi wetland complex. DOC administered land, Ngai Takato land and other land tenure were mapped where they formed part of the contiguous wetland / dune system.

Coastal habitats (i.e. the open water estuarine habitats of the Rangaunu and Houhora Harbours) were excluded from the mapping area.

The extent of the mapping area is shown in Figure 3.

File Ref: C18058_007_A4P_WetlandLocation.mxd

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KAIMAUMAU MOTUTANGI WETLAND MAPPING

Wetland Extent

Date: 30 November 2018 | Revision: 0

Plan prepared for Department of Conservation by Boffa Miskell Limited

Project Manager: **scott.hooson@boffamiskell.co.nz** | *Drawn:* BMc | *Checked:* SHo

Figure 1

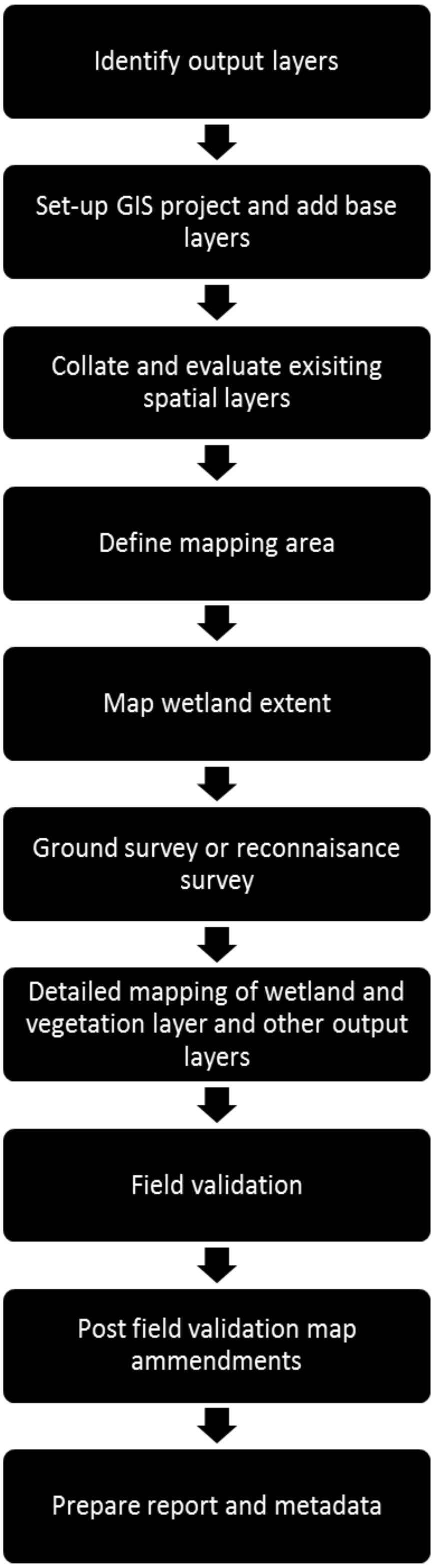
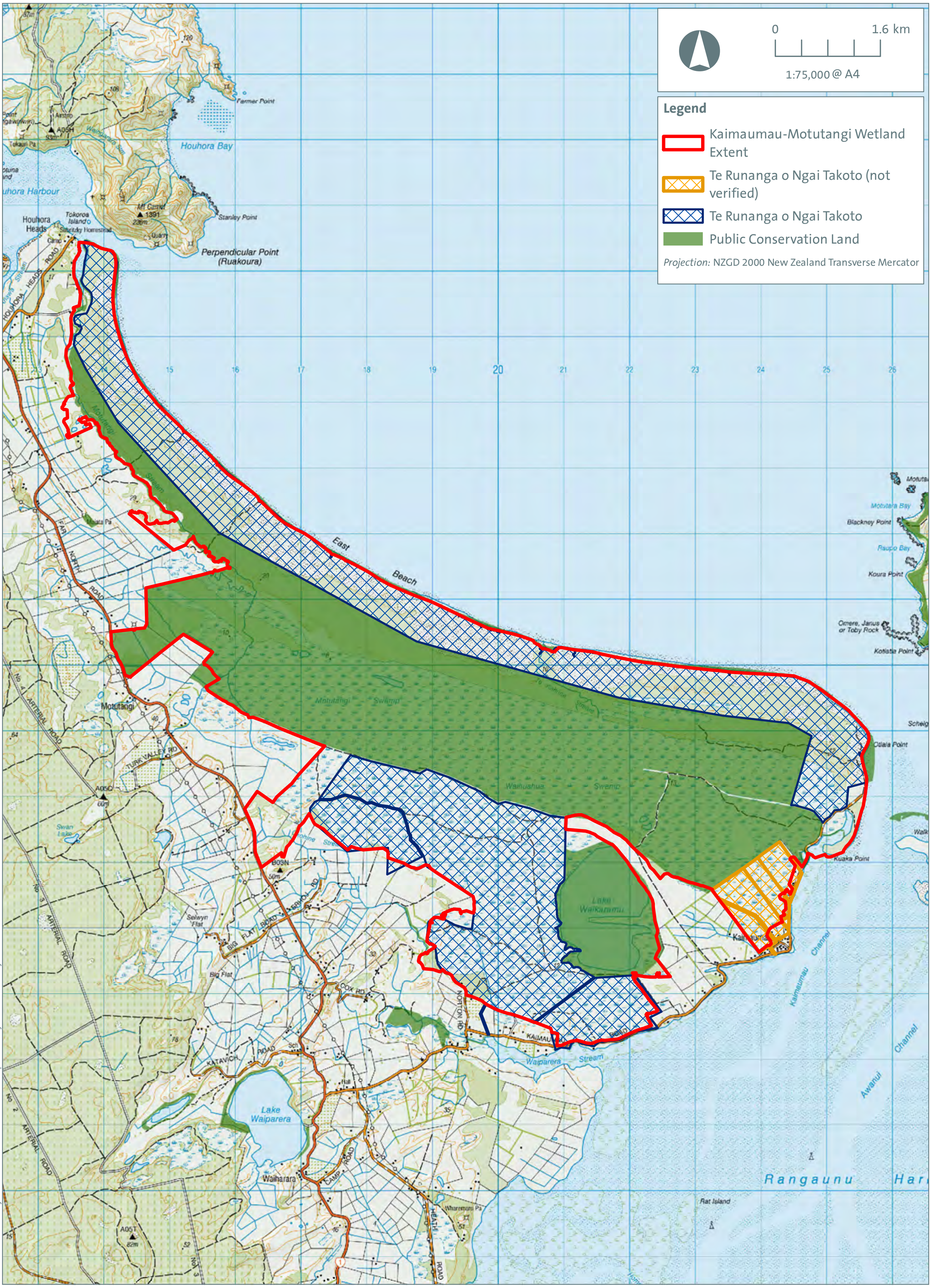


Figure 2: *Flow diagram of steps in the mapping process (from Hooson and Robertson (draft, in prep)).*

File Ref: C18058_008_A4P_WetlandExtent.mxd



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KAIMAUMAU MOTUTANGI WETLAND MAPPING

Extent of Mapping Area

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Figure 3

2.5 Reconnaissance Survey

Once the 'wetland extent' had been finalised a reconnaissance survey was undertaken. For the mapping and classification of large wetlands such as Kaimaumau-Motutangi, reconnaissance surveys are very useful because they allow the person(s) undertaking the mapping to familiarise themselves with the topography, gain a better understanding of the extent of hydrosystem and wetland classes, familiarise themselves with the vegetation communities and relate these back to the aerial imagery.

2.5.1 Helicopter Reconnaissance

A helicopter survey of the wetland was undertaken on 8 June 2018. An initial 30 min overview flight was undertaken by Scott Hooson (BML), Hugh Robertson and Kaio Hooper (DOC) and a Ngai Takato representative. A second and longer (1 hour, 40 minute) flight was then undertaken by Scott Hooson and Georgia Cummings (BML) and Hugh Robertson (DOC). As much of the wetland, and as many vegetation types as possible, were examined in the time available.

During both flights an iPad, with the wetland extent layer and aerial photographs loaded into AVENZA Maps, was used to locate the position of the helicopter within the wetland and help guide the pilot to areas of interest. GPS waypoints were taken using a handheld Garmin Geographic Positioning System (GPS). Notes were made on wetland hydrology (hydrosystem and wetland class), vegetation structural classes and dominant species. Photographs of the different vegetation communities were also taken using a Canon EOS 6D camera with an internal GPS unit.

2.5.2 Ground Reconnaissance Survey

A very limited (2.5 hour) ground-based reconnaissance survey was undertaken by Hugh Robertson, Scott Hooson, Georgia Cummings and Kaio Hooper and the Ngai Takato representative on the afternoon of 8 June 2018. This was limited to a very small proportion of the most accessible parts of the wetland that could be visited in the limited time available. The areas visited were:

- where Kaimaumau Road crosses the part of the estuarine / wetland system near Kuaka Point;
- a 4WD vehicle track on the western side of Kaimaumau Road north of Kaimaumau settlement; and
- 4WD vehicle tracks on the western and southern sides of Lake Waikaramu (accessed from Norton Road).

Again, GPS waypoints were taken using a handheld Garmin GPS, notes were made on wetland hydrology, vegetation structural classes and dominant species, and photographs of vegetation communities were taken. This ground reconnaissance work allowed for a closer inspection of the wetland hydrology and dominant plant species at those areas visited, but was constrained by difficulties accessing the dense wetland vegetation away from the vehicle tracks and time.

2.6 Detailed Mapping and Classification

Following the reconnaissance survey above, detailed wetland mapping and classification was undertaken to produce the wetland and vegetation and waterways geo-spatial layers.

These geospatial layers (including their associated attribute tables) were produced in ArcGIS Version 10.6 using geo-databases. The co-ordinate system used was NZGD 2000 New Zealand Transverse Mercator.

All mapping was undertaken at a scale of 1: 2,000, although occasionally, it was necessary to zoom in (closer than 1: 2,000) on specific vegetation types to identify vegetation communities with more accuracy.

2.6.1 Mapping the Wetland and Vegetation Layer

The wetland and vegetation layer was mapped and classified following the methodology described in Hooson and Robertson (*draft, in prep*). Similar methodologies have been used to map and classify the hydrology and vegetation of the Awarua / Waituna wetland (Boffa Miskell Ltd and Urtica Inc. 2010) and the Ō Tu Wharekai / Ashburton Basin wetland complex (Boffa Miskell 2015). Only information relevant to this mapping project is provided in the following sub-sections; Hooson and Robertson (*draft, in prep*) should be referred to for further detail.

Aerial Imagery

The NRC imagery (described in Section 2.3) was used to map the wetland and vegetation layer. For some parts of the wetland, Google Earth imagery was used to assist mapping and classification.

Reconnaissance Survey Data

The GPS waypoints from the helicopter and ground reconnaissance surveys were imported into the ArcMap project. The corresponding notes on wetland hydrology, vegetation structural classes and dominant species were used to assist the hydrology and vegetation mapping and classification process. The photo locations were also imported into the ArcMap project and used to assist mapping and classification.

Additional Information

To assist with the mapping and classification of the wetlands, DOC provided two spreadsheets with data from 10x10 m and 5x5 m wetland vegetation plots from 6 plots within the wetland measured in 2014 as part of DOC's Tier 1 monitoring programme. The plot data was converted to geospatial layers (point features) in ArcGIS. The relevant information from the spreadsheets (imported into the layers' attribute fields) was used to assist wetland mapping and classification.

Part way through the mapping and classification process, DOC undertook a high-level classification of the dominant vegetation within approximately 400 ha of the wetland on Ngai Takato owned land (formerly Sovereign Station). DOC used the unclassified polygons mapped by BML for this project to complete this vegetation classification. This high-level vegetation class data was then provided to BML as a GIS shapefile.

Background information on the hydrology, vegetation communities and plant species composition of the Kaimaumau-Motutangi Wetland was obtained from the following reports:

- Options for managing the Kaimaumau wetland, Northland, New Zealand (Hicks et al. 2000);
- Succession in the Kaimaumau gumland, Northland, New Zealand, following fire (McQueen and Forester 2000);
- Current status of land use and ecological values, Sovereign Station, Kaimaumau. (Wildland Consultants Ltd 2011a);
- Ranking of top wetlands in the Northland region. Stage 4 - rankings for 304 wetlands (Wildland Consultants Ltd 2011b); and
- Nature Heritage Fund Application: Sovereign Station, Kaimaumau, Far North (DOC 2014).

2.6.2 Classification of the wetland vegetation layer

During classification of the wetland and vegetation layer the following classification data and other information was recorded for each polygon in the layer's attribute table:

- Wetland name;
- Site name;
- Landform / habitat type;
- Hydrosystem (for wetlands only);
- Wetland class (for wetlands only);
- Vegetation structural class;
- Dominant species;
- Confidence level in the accuracy of the boundary;
- Confidence level in the accuracy of the data in the attribute fields; and
- Area (ha)

For efficiency, attributes for each polygon were entered into each attribute field as coded data (e.g. p = palustrine, f = fen, ls = *Leptospermum scoparium var. incanum*) and then converted to full text later.

Additional information included in the attribute table before the final output layer was issued included:

- Mapping scale;
- Date of field validation (start date);
- Field validation surveyor name; and
- Aerial imagery owner and year(s) flown.

Mapping Weed Species

It was recognised in the Project Brief that detailed mapping of weed distribution may not be possible given the scale of the mapping and the quality of the aerial imagery. How well these weed species were able to be identified and mapped is discussed in Section 5.6.10. Nevertheless, a best attempt was made to map the distribution of the following weeds:

- Sydney golden wattle (this was the priority species);
- Prickly hakea; and
- Gorse.

Structural Class of Bog Schoenus

Structural classes were mapped following the methodology described in Hooson and Robertson (*draft, in prep*).

Following the structural classes described in Section 2.7 of Johnson and Gerbeaux (2004), this study classifies bog schoenus (*Schoenus brevifolius*) as rushland because of its rush-like growth form ("stiff erect stems or similarly non-flattened leaves", cf. sedgeland "plants having grass-like but usually coarser leaves"). Johnson and Gerbeaux (2004) also state that the rush growth form includes members of other genera including several *Schoenus* spp. The approach used in this study differs from previous studies, where bog rush was classified as sedgeland (i.e. Wildland Consultants 2011a).

2.6.3 Mapping the Waterways Layer

Streams and drains (linear features) were mapped as polyline features in a separate output layer following the methodology described in Hooson and Robertson (*draft, in prep*).

The accuracy of the Topo50 river centre line vector data and REC river layers was examined to determine whether it would be of any use in generating the waterways layer. These polyline features were not accurate enough to warrant their use, but the Topo50 vector river polyline (river centreline) was used to help identify waterways with the wetland extent that were then digitised.

The NRC imagery (described in Section 2.3) was used to digitise the waterways layer at a scale of 1: 2,000.

The following information was recorded for each line feature in the layer's attribute table:

- Waterway type (stream or drain); and
- Length (m) of each waterway segment (automatically generated in ArcGIS).

Additional information included in the attribute table before the final output layer was issued included:

- Mapping scale;
- Date of field validation (start date);
- Field validation surveyor name; and
- Aerial imagery owner and year(s) flown.

Constraints to mapping waterways and drains within the wetland are discussed in Section 6.4.

3.0 Field Validation Methodology

Following completion of the desktop wetland mapping and classification, field validation was undertaken over two days on 24 and 25 October 2018.

The purpose of the field validation was two-fold:

1. To update and correct the wetland and vegetation layer based on the findings of the field validation; and
2. To provide a brief description of the main vegetation communities mapped.

A drone was used for field validation and limited ground surveys were also carried out at the locations from which the the drone was flown. The approach to the field validation is described below.

3.1.1 Drone-based field validation

Drone field validation was undertaken using a DJI Inspire drone, piloted by David Irvine (Senior Visualisation Specialist, Boffa Miskell).

Use of a drone was chosen over other field validation methods as it was more cost effective and / or efficient than the other options available. Although a helicopter was the preferred method for field validation, the high costs of ferrying a DOC approved helicopter to the site meant this approach was not cost effective. Also, the dense vegetation within the wetland meant access on foot was difficult and time consuming, meaning ground surveys alone would have substantially restricted the extent of the wetland that could be ground-truthed in the time available.

4WD vehicles and a 'Rhino' all-terrain vehicle were used to access the locations from which the drone was flown. Drone missions were flown from those locations that were accessible in the time available, for example, from roads, private land, the beach on the eastern side of the wetland and driveable 4WD tracks within the wetland. Some of the tracks within the wetland could not be used either because landowners could not be contacted to gain access, or because sections of the tracks were impassable (due to deep standing water or mud).

The drone missions focussed on those areas of the wetland that had a greater concentration of polygons that were assigned low levels of confidence (scores of 1 and 2 particularly) in the accuracy of the boundary, or the attributes of the polygon during the wetland mapping and classification stage. In addition, polygons where specific comments or queries had been entered into the "Comments" attribute field during classification of the wetland and vegetation layer were also checked where possible (these comments were removed from the final geo-spatial layer).

4K video footage was captured during 12 drone flights over the two days of field validation. In total, 115 minutes of video footage was acquired.

The drone flight paths are shown in Figure 4.

3.1.2 Ground-based field validation

Very limited ground-based surveys of the vegetation communities at the locations from which drone missions were flown were undertaken by Scott Hooson and Andrew Townsend (Technical Advisor, Terrestrial Ecology Unit, DOC). Due to the limited amount of time available at each location, and the challenges of walking through the dense scrub and rushlands within the wetland, much of these observations were limited to polygons adjacent to, or near, the wetland's margin, or along the 4WD tracks within the wetland.

iPads displaying the wetland data and aerial photographs in Avenza PDF maps were used to navigate to and validate specific polygons and mark locations using 'placemarks'. A laminated and bound 'map-book' with the same information was also used, and any boundary amendments were marked on the hard copy maps with permanent pen.

A datasheet was used to record the following information for polygons where amendments were required:

- Polygon I.D. no. (a unique identifier for each polygon);
- Mapped code (refer to Section 2.6.2);
- Hydrosystem;
- Wetland class;
- Structural class;
- Dominant vegetation; and
- Comments / associated species.

The vegetation communities inspected were briefly described by listing the dominant and characteristic plant species present. Photographs were taken, and any other notes of relevance were recorded.

File Ref: C18058_009_A4P_DroneFlightPath.mxd

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KAIMAUMAU MOTUTANGI WETLAND MAPPING

Drone Flight Paths

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Plan prepared for Department of Conservation by Boffa Miskell Limited

Project Manager: **scott.hooson@boffamiskell.co.nz** | *Drawn:* BMc | *Checked:* SHo

Figure 4

4.0 Post-Field Validation Map Amendments

Following field validation, the drone video footage and ground-based field validation data sheets were used to amend the wetland and vegetation layer where there were discrepancies between the desktop mapping and the field validation work.

No amendments to the waterways layer were made as a result of the field validation work.

4.1.1 Analysis of the Drone Video Footage

For each of the drone flights, where video footage was recorded, the corresponding telemetry file was downloaded from the drone. This recorded the time, location (GPS track), the heading of the drone and the pitch angle of the camera attached to the drone. This information, once synchronized with the video footage in the ArcGIS Full Motion Video (FMV) extension[1], allowed us to determine where the camera was pointing at any particular time and to project this as a 'view cone' on to the map containing the wetland and vegetation layers.

The wetland and vegetation layer was loaded into an ArcGIS project with the FMV extension. Each polygon was labelled to show the wetland class, structural class and dominant vegetation for each polygon.

The FMV extension was used to synch the drone footage with the GPS track of the drone's flight path and reflect changes in the speed of the drone.

FMV allows the drone's location along the flight path and the field of view of the camera to be displayed in the ArcGIS project along with the wetland and vegetation layer polygons. Individual polygons within the wetland and vegetation layer were amended based on the video footage acquired by the drone. The drone footage was able to be paused at any time, allowing closer inspection of the vegetation communities.

5.0 Results

This section of the report describes the results of the mapping and classification work. It briefly describes the final outputs of the work, provides a summary of the habitat type, hydrosystem and wetland class data and provides a brief description of the main vegetation communities. Tables summarising the dominant species classes are provided in Appendix 2.

5.1 Outputs

The final output consists of two geospatial layers:

[1] https://www.esri.com/en-us/arcgis/arcgis-full-motion-video

1. A wetland and vegetation layer (polygon layer) with associated attribute fields (as described in Section 2.6.2); and
2. A waterways layer (polyline layer) with associated attribute fields (as described in Section 2.6.3).

Metadata has not been provided with the geospatial layers issued to DOC. It is anticipated that metadata will be added by DOC in its own customised format.

The GIS data was issued to DOC in a geo-database.

5.2 Habitat Types

Wetland habitats made up the majority of the polygons mapped, both by number and area (Table 1), followed by dune habitat. Some polygons were classified as being possible wetland habitats, but it was unclear as to whether these areas were terrestrial or wetland (gumland).

Table 1: *The number of polygons and area (in ha) of each of the habitat types mapped within the mapping area.*

Habitat Type	Count	Area (ha)
Wetland	2203	2615.9
Dune	518	1813.7
Wetland?	112	305.2
? (neither wetland or dune)	70	75.7

5.3 Hydrosystems

Three wetland hydrosystems were mapped within the study area: palustrine, estuarine and riverine. The majority of the polygons that were classified as wetlands (i.e. not terrestrial / dune habitats), both by number and area, were classified as palustrine (Table 2).

Approximately 30 ha of the mapping area was classified as estuarine. Estuarine hydrosystems were confined to a small inlet on the eastern side of the wetland inland of Kuaka Point and at the northern end of the mapping area at the mouth of Motutangi Stream at Houhora Heads.

Only 11 ha of wetland habitats were classified as riverine partly because there are very few natural waterways within the Kaimaumau Motutangi Wetland and because linear waterways were mapped in the waterways layer (and therefore were not classified by hydrosystem). Riverine hydrosystems were associated with the stream flowing into the inlet inland of Kuaka Point, Motutangi Stream and Te Kahuna Stream. Te Kahuna Stream flows directly out to sea through the dunes partway along Ngārui-o-te-Marangai / East Beach.

As discussed in Section 5.2, where polygons palustrine wetlands or terrestrial habitats could not be classified with confidence, they were classified as "palustrine / terrestrial?".

Lake Waikaramu was classified as a palustrine, shallow water wetland, although it could arguably also be classified as a lacustrine wetland. Lacustrine wetlands are defined by Johnson and Gerbeaux (2004) as:

"Wetlands associated with the waters, beds, and immediate margins of lakes and other bodies of open, predominantly freshwater which are large enough to be influenced by characteristic

lake features and processes such as fluctuating water level, wave action, and usually permanent and often deep water that has nil or only slow flow. Lakes can be arbitrarily defined as having a major dimension of 0.5 km or more."

Although Lake Waikaramu is approximately 2 km in length, it is very shallow, is likely to be ephemeral, is broken by numerous shallow dune ridges and doesn't appear to exhibit features and processes characteristic of typical lakes.

Table 2: *The number of polygons and area (in ha) of each of the hydrosystems mapped within the mapping area.*

Hydrosystem	**Count**	**Area (ha)**
Palustrine	2119	2581.8
Terrestrial	585	1867.1
Palustrine / terrestrial?	122	317.2
Estuarine	51	33.0
Riverine	26	11.5

5.4 Wetland Classes

Eight wetland classes were identified within the Mapping Area[2]. Of the wetland classes identified, gumlands and bog covered the largest total area. Wetlands classified as shallow water, marsh, fen, swamp, saltmarsh and ephemeral wetland covered a much smaller total area (Table 3). The constraints associated with accurately classifying wetland class are discussed in Section 6.2.

Table 3: *The number of polygons and area (in ha) of each of the wetland classes mapped within the mapping area.*

Wetland Class	**Count**	**Area (ha)**
N/A (terrestrial)	579	1864.0
Gumland (incl. gumland?)	954	1362.9
Bog	959	1016.1
Shallow water	120	246.7
Marsh	103	200.0
Fen	35	36.4
Swamp	83	35.1
Saltmarsh	50	23.0
Ephemeral wetland	19	16.4
Shallow open water	1	9.9

[2] Shallow open water and shallow water are all part of the shallow water wetland class but were classified separately following Johnson and Gerbeaux (2004).

5.5 Vegetation Structural Classes

Sixteen wetland classes were identified within the Mapping Area. Scrub, forest and rushland covered the largest total area (77% of the area mapped) (Table 4). In descending order of coverage, shrubland, reedland, grassland, fernland and sandfield were next most important with each covering a total area of over 100 ha.

Table 4: *The number of polygons and area (in ha) of each of the vegetation structural classes mapped within the mapping area*

Structural Class	Count	Area (ha)
Scrub	952	1377.5
Forest	132	1317.0
Rushland[3]	1099	1032.5
Shrubland	260	333.2
Reedland	108	230.7
Grassland (incl. grassland?)	66	154.3
Fernland	114	141.8
Sandfield	34	101.0
Tussockland	35	45.2
Shallow water	53	42.2
Treeland	34	23.4
Forest and scrub	3	9.5
Flaxland	3	0.9
Siltfield	4	0.4
Mudfield	3	0.4
? (unknown)	2	0.3
Sedgeland	1	<0.1

5.6 Vegetation Communities

A total of 227 dominant species classes were mapped. Table A2.1 in Appendix 2 provides a summary of the dominant species classes, including the total number of polygons and the total area (ha) of each. A number of these dominant species classes are similar but have differences in either species composition or canopy height. Following the classification system of Atkinson (1985), they have been assigned a different compositional name. A simplified vegetation type name has been included in the attribute table for the wetland and vegetation geo-spatial layer. However, the full (un-simplified) list of dominant species classes in Table A2.1 has been retained. The full names convey important information on the composition and relative height of the dominant species in the canopy within each polygon / vegetation type.

[3] As discussed in Section 2.6.2 bog schoenus was classified as rushland because of its rush-like growth form.

The most extensive vegetation communities, in terms of their coverage, were Sydney golden wattle-kanuka forest, manuka scrub, *Machaerina* spp. rushlands and reedlands, Sydney golden wattle forest and scrub and Sydney golden wattle-kanuka-manuka forest and scrub.

The following information provides brief descriptions of the 11 most extensive vegetation communities that were identified and mapped. These descriptions are based on the information gathered during the limited amount of field validation undertaken, and from observations from the helicopter during the reconnaissance survey.

The following sub-sections are not intended to provide comprehensive descriptions of all the vegetation communities present in the Kaimaumau-Motutangi Wetland. Photographs of those vegetation communities that were viewed and photographed during the helicopter reconnaissance flight or field validation field work are provided in Appendix 3.

5.6.1 Sydney golden wattle-kanuka forest and scrub

Sydney golden wattle-kanuka forest and scrub (Photo 1, Appendix 3) occurs on dune and dryland habitats within the mapping area. It is the dominant vegetation type on the extensive dune system at the northern end of the mapping area between Motutangi Stream and Ngārui-o-te-Marangai / East Beach. It is also frequent on the margins of the wetland and on dune ridges within the wetland.

In terms of percent canopy cover, this forest type is often dominated by the exotic tree Sydney golden wattle. There are extensive areas of Sydney golden wattle forest (and scrub) where other canopy species are either entirely absent or are a minor component of the canopy (Photo 2, Appendix 3) (these areas have classified as Sydney golden wattle forest and scrub). In other places, for example parts of the dune system between Motutangi Stream and Ngārui-o-te-Marangai / East Beach, kanuka is the dominant species in this forest type. Manuka is also a component of this vegetation type in places, particularly within the ecotone between this dryland vegetation community and wetland vegetation.

Other species associated with this vegetation type include black wattle, prickly hakea and woolley nightshade in the canopy and manuka, bracken, gorse, taihao, bog schoenus and *Machaerina* spp. in the understorey.

5.6.2 Manuka scrub and shrubland

Manuka scrub and shrubland occurs throughout the wetland and is most common in bog and gumland wetland classes. It occurs extensively as low shrubland and scrub, (Photo 3, Appendix 3) but in a few locations grows as taller scrub (estimated to be up to 4 m tall). There are extensive areas of manuka scrub where manuka is the dominant canopy cover, but manuka also occurs frequently in association with bog schoenus and tangle fern. In wetter bogs manuka grows amongst wire rush and *Machaerina* spp. Manuka also occurs in association with raupo in areas of higher nutrient status, while on drier dune ridges it grows in association with kauri sedge.

5.6.3 Tangle fern fernland

Tangle fern fernland covers extensive areas of the wetland. It is most abundant within seasonally dry gumland on the western side of the wetland where it grows in association with bog schoenus and manuka. It is also present on the margins of standing water in the northern side of Motutangi Swamp where it grows in association with manuka, wire rush, *Machaerina* spp. and club moss.

5.6.4 *Machaerina* spp. rushland and reedland

Machaerina species occur as reedlands where they grow in standing water within the wetland (Photo 4, Appendix 3) and as rushlands (Photo 5, Appendix 3) elsewhere. Both *Machaerina* rushlands and reedlands cover extensive areas within the wetland. Several species of *Machaerina* are present the Kaimaumau-Motutangi Wetland including tussock swamp twig rush (*M. juncea*), *M. teretifolia, M. arthrophylla*, jointed baumea (*M. articulata*) and *M. rubiginosa*. Except for jointed baumea, it was not possible to confidently distinguish between the *Machaerina* species from the reconnaissance helicopter survey, or from the drone footage taken during the field validation work. As a result, these species were grouped and classified as *Machaerina* spp.

Machaerina teretifolia appeared to be the most abundant of the *Machaerina* species and was common in bogs and standing water throughout much of the wetland, where it often grew in association with manuka and bog schoenus in wet hollows. *Machaerina arthrophylla* appeared to be less common and restricted to areas of standing water. Tussock swamp twig rush grows in association with oioi at the palustrine / estuarine boundary inland of Kuaka Point where the saline influence is stronger. Tussock swamp twig rush also covers a large area inland of this estuary and is common in Lake Waikaramu. Jointed baumea was observed in standing water, particularly in dune hollows nearer the coast, and in riverine habitats. *Machaerina rubiginosa* did not appear to be common and had a patchy distribution.

5.6.5 Bog Schoenus rushland

Bog schoenus is very common within the Kaimaumau-Motutangi Wetland and is distributed widely throughout the wetland in gumlands and bogs. It forms large areas of rushland in places (Photo 6, Appendix 3), often in association with manuka, tangle fern and wire rush. It also grows in standing water in dune hollows in association with *Machaerina* species (particularly *M. teretifolia*).

5.6.6 Spinifex grassland

In total, there is approximately 115 ha of spinifex grassland (Photo 7, Appendix 3) on the young (seaward most) dunes along Ngārui-o-te-Marangai / East Beach. Spinifex is the dominant species on these dunes, but other prominent species are knobbly club rush and the nationally At Risk – Declining species sand coprosma, sand daphne and (infrequently) pingao. The sand daphne population on these dunes may represent a national stronghold for the species (A. Townsend *pers. comm.* 2018). The exotic herb catsear was also present in this vegetation type.

5.6.7 Oioi rushland

Oioi rushland (Photo 8, Appendix 3) occurs in the two estuarine saltmarshes at either end of the mapping area; there are localised patches at the mouth of Motutangi Stream at Houhora Heads, and more extensive rushlands within the inlet inland of Kuaka Point.

The most extensive areas of oioi rushland are in well drained marshes in dune hollows behind the young dunes along Ngārui-o-te-Marangai / East Beach (Photo 9, Appendix 3). These marsh systems support reasonably homogenous pampas grass/oioi rushlands. Other associated species in this vegetation type include trees and shrubs of Sydney golden wattle, manuka and gorse as well as localised lowland flax.

5.6.8 Kanuka-manuka scrub and shrubland

There are low stature scrub and shrublands of kanuka and manuka (Photo 10, Appendix 3) on raised dune ridges within the wetland. Associated species include prickly hakea, gumland grass tree, tamingi, taihao, kumarahou and the club moss *Lycopodium deuterodensum*. Taller areas of kanuka-manuka scrub are present on raised dunes, where Sydney golden wattle is often present in the canopy cover. Kanuka and manuka scrub and shrublands also grow in drier gumland on the western side of the wetland in association with prickly hakea, tangle fern, *Lycopodium deuterodensum* and bog schoenus.

5.6.9 Raupo reedland

Raupo reedland (Photo 11, Appendix 3) is of restricted extent within the Kaimaumau-Motutangi Wetland. Raupo is present at the eastern and western sides of the wetland, and there are a few small patches along Te Kahuna Stream and where the wetland is adjacent to Far North Road, north of the settlement of Motutangi. Raupo rows as dense patches of reedland in some areas, but also as a diffuse reedland amongst other species including *Machaerina* species, bog schoenus, manuka and wire rush.

5.6.10 Weed Species

Sydney Golden Wattle

The distribution of Sydney golden wattle within the wetland was able to be mapped with a high level of confidence.

As described in Section 5.6.1, Sydney golden wattle occurs as forest and scrub on terrestrial dune and dryland habitats throughout the mapping area. It frequently occurs with kanuka and manuka, but there are also extensive areas of Sydney golden wattle forest and scrub where other canopy species are either entirely absent or are only a minor component of the canopy.

Sydney golden wattle is the dominant tree species on most of the extensive dune system between Kaimaumau-Motutangi Wetland and Ngārui-o-te-Marangai / East Beach, surrounding Lake Waikaramu (including a large area on the dune ridge on the western side of the lake), and on Ngai Takato owned land (formerly Sovereign Station) south and west of Lake Waikaramu (where it has rapidly invaded following vegetation clearance). It is also frequent on raised dune ridges throughout the wetland and on its margins. In areas of gumland, particularly at the western margin of the wetland, it has established in several places but then died during wetter periods.

Prickly Hakea

Prickly hakea occurs within terrestrial forest and scrub, and drier areas of gumland within the mapping area. It is locally frequent in some vegetation communities, for example in association with Sydney golden wattle, kanuka and manuka. Although locally frequent, it almost always occurs as scattered individual shrubs amongst other tree and shrub species. As a result, it was never observed to be a dominant species, and due to its scattered nature was not able to be identified and mapped from the aerial imagery.

Gorse

Gorse scrub was identified and mapped with a high level of confidence where it occurred as dense shrubland or scrub.

The main areas of gorse shrublands and scrub are on the western side of Motutangi Stream, in the two wetland areas adjoining Far North Road and near Kuaka Point at the end of Kaimaumau Road. Gorse was also observed during the helicopter reconnaissance flight amongst the mosaic of Sydney golden wattle, kanuka and manuka forest and scrub on the dune system on the eastern side of the wetland, where it was most abundant between Te Kahuna Stream and Otiaia Point. This gorse could not be identified and delineated with enough certainty to map it. However, where it was observed during the field work or from the aerial imagery, wherever possible, its presence was noted in the comments field of the attribute table of the wetland and vegetation layer.

Pampas Grass

Because of its distinctive form and colour, pampas grass was able to be mapped with a high level of confidence.

The main areas of pampas are within the oioi rushlands in the dune hollows behind Ngārui-o-te-Marangai / East Beach, along the margins of Motutangi Stream, in the wetland area adjoining Far North Road (north of the settlement of Motutangi) and near Kuaka Point at the end of Kaimaumau Road.

6.0 Mapping Constraints

6.1 Aerial Imagery

6.1.1 Quality

The accuracy of the vegetation mapping and wetland classification relies heavily on the resolution and quality of the aerial imagery. During the project scoping stage, before mapping commenced, all the recent aerial imagery of the wetland was examined. The NRC imagery was the most recent, best quality imagery available. This imagery was examined and determined that the most appropriate resolution for mapping using this imagery was 1: 2,000. The option of acquiring better resolution imagery was discussed with DOC, but it was agreed that mapping would proceed using the NRC imagery, acknowledging that mapping would be constrained to some extent, by the quality of the imagery.

The resolution and quality of the imagery also made it difficult to identify and map weed species. Sydney golden wattle and pampas were generally easy to identify and have been mapped with a level of confidence. Gorse was relatively easy to identify in areas where it was the dominant species in the canopy but was not able to be identified easily where it grew amongst other tree and/or shrub species. Hakea was not able to be identified from the imagery at all. This species occurred frequently in terrestrial vegetation communities in several the areas visited during the reconnaissance and field validation surveys but was never dominant.

6.1.2 Aerial imagery as a 'point in time'

Aerial images represent a point in time. As discussed in Section 2.3 the most up-to-date aerials available at the start of the project were used for mapping. However, as expected, comparison of this imagery with the more recent Google Earth imagery showed some changes in wetland extent and vegetation community composition.

Only minor changes in wetland extent were evident. The most noticeable change was a result of recent vegetation clearance for an avocado orchard on the wetland's margin near the end of Norton Road.

The composition of vegetation communities also changes over time. Some noticeable changes were already evident between the NRC imagery and more recent Google Earth imagery from mid-August 2018. The most obvious examples of this were: vegetation recovery (particularly Sydney golden wattle-manuka scrub) following vegetation clearance in the southern part of the wetland on Ngai Takato owned land; and the continued expansion of Sydney golden wattle into terrestrial habitats and gumland that are only infrequently wet.

The water table fluctuates regularly, for example seasonally, but also in response to rainfall events. The water table was lower in the NRC imagery than when the reconnaissance survey and field validation work was undertaken. This was particularly evident in areas of ephemeral shallow water within more extensive areas of gumland. These areas were dry siltfield at the time the imagery was acquired but were found to be full of water when the field work was undertaken.

6.2 Wetland Class

Wetland class proved difficult to map remotely using the data available because most of the characteristics used to define these classes (i.e. water flow, drainage, water table, water fluctuation, periodicity, substrate, nutrient status and pH) cannot be determined from aerial photographs. In addition, the only data available for the study area that provided information on the gradient, or slope, is 20 m Topo50 contour data. For small scale wetland features, 20 m contour data is of insufficient resolution. The Freshwater Environments of New Zealand (FENZ) "wetlands current typology" geospatial layer (Leathwick et al. 2010), although considered as part of the decision-making process, is broad scale and not very useful at the finer resolution where different wetland systems can occur at small scales. It is possible to use vegetation type as a proxy, although only up to a point. Johnson and Gerbeaux (2004) are clear that wetland class should be assigned based on function and not differentiated by the situations they occupy or the vegetation they contain. Further, vegetation types tend to overlap considerably between wetland classes. Soil type and hydrological regime information would be useful, but soil type data is often not of high enough resolution and data on hydrological regimes are generally not able to be assessed remotely.

The reconnaissance survey was undertaken following an unusually heavy rainfall event and water levels in the wetland were observed to be very high. As a result, the hydrological conditions within the wetland may not have been representative of the 'usual' hydrological state of the wetland at the time the reconnaissance survey was undertaken. In addition, only limited field validation was possible following the initial mapping and classification, and the field validation was largely undertaken remotely by drone. Because water flow, drainage, water table position in relation to the ground, water fluctuation and periodicity are all important distinguishing features of wetland class (Johnson and Gerbeaux 2004), the atypical hydrological conditions at the time of the reconnaissance survey added to the challenges of accurately determining wetland class.

For some areas of the wetland determining wetland class proved to be difficult from the information available and there was not always a good ‘fit’ with the Johnson and Gerbeaux (2004) system for classifying wetland class. Based on the vegetation communities and observations made during the reconnaissance and field validation surveys, extensive areas of the wetland that have peat substrates appear to have a very low nutrient status and pH, with slight water fluctuation and nil to very slow water flow. These are distinguishing features of bogs. However, in these areas the water table is frequently above the surface of the ground, which is a distinguishing feature of swamps. The water origin (rain, groundwater or surface water) was not able to be determined with confidence. Only a small proportion of the wetland was classified as swamp, and this was largely based on the presence of vegetation communities’ indicative of higher nutrient status (e.g. raupo, lowland flax and, in a small number of localised areas, cabbage trees) and likely higher water flow.

Distinguishing between terrestrial communities and some areas of gumland was also difficult, particularly in drier parts of the wetland or where vegetation had been cleared and the soil profile had been altered. For example, some of the Ngai Takato owned land at the south-western corner of the wetland, which was almost certainly formerly gumland, is now dominated by Sydney golden wattle. This species is indicative of drier conditions, but it was unclear as to whether these areas were terrestrial or gumland. Where there was uncertainty about whether an area was terrestrial or gumland, the polygon’s habitat type, hydrosystem and wetland class were classified as “wetland?”, “palustrine / terrestrial?” and “gumland”, respectively.

Because of the constraints discussed above, wetland class mapping is unlikely to be repeatable using remote mapping techniques. However, the wetland class maps do provide a baseline against which to measure future change.

6.3 Mapping Waterways

The Topo50 vector river polyline (river centreline) was used to assist the identification of waterways with the wetland extent. Other waterways, were difficult to identify because:

1. Natural waterways, such as streams within the wetland, were small and narrow and covered by vegetation, making them difficult to identify from aerial imagery. This was also likely to also be the case for smaller drains.
2. Drains were difficult to identify and map with certainty. In many cases, drains could not be confidently distinguished from other linear features, such as lines of cleared vegetation and vehicle tracks.

6.4 Field Validation

Field validation was constrained by the amount of time available to undertake the field validation work and access within the wetland.

The available budget for the project restricted the field validation period to two days. The limited amount of time for ground-based field validation, in conjunction with access difficulties (discussed below), meant that only a limited area of the wetland could be ground-truthed (i.e. the number of polygons and vegetation communities), and limited the type of information that could be collected. More time (and resources) would have allowed more vegetation communities and polygons to be checked, resulting in a higher overall level of confidence in the final maps.

Access was a significant constraint to the field validation work. Some of the tracks within the wetland could not be used either because landowners could not be contacted to gain access, or because sections of the tracks were impassable (due to deep standing water or mud). The vegetation within the wetland is also difficult and time-consuming to move through on foot, which limited ground surveys to polygons adjacent to, or near, the wetland's margin, or along the 4WD tracks within the wetland.

Using a drone to acquire imagery for validation purposes allowed a much greater area of the wetland to be viewed than could have been surveyed on foot in the time available. However, much of the drone survey work was restricted to the margins of the wetland (Figure 4), except where 4WD vehicle tracks allowed access further into the wetland. Use of the drone was also constrained by battery life (approximately 18 mins)[4] and legal constraints that mean the pilot cannot fly the drone beyond the line of site.

[4] Following the field validation work BML purchased a new drone with a 27-minute battery life (and a higher resolution camera).

7.0 Recommendations

This section makes recommendations to improve future wetland mapping and classification work based on the constraints identified during the wetland mapping and field validation stages.

- A helicopter reconnaissance survey prior to desktop mapping is recommended for mapping and classification projects of this scale. The helicopter survey increased the understanding of the vegetation patterns in relation to drainage, waterways and to a certain extent, wetland class. It also enabled the person undertaking the mapping to familiarize themselves with the vegetation communities and relate these back to the aerial photographs. This is important as the colour and quality of the different imagery can make some vegetation types appear very different.
- It is recommended that, where available, local knowledge is used for projects of this type. Several people with local knowledge of the Kaimaumau-Motutangi Wetland assisted with the reconnaissance and field validation surveys. This local knowledge was extremely helpful. Kaio Hooper and other Kaitaia DOC staff were able to arrange access across private land and had a good knowledge of the 4WD tracks within the wetland. Andrew Townsend’s knowledge of the wetland’s flora was also very helpful during the field validation survey.
- When undertaking field validation in wetlands where access is difficult, and the use of a helicopter is too expensive, using a drone as an alternative is recommended. The drone proved to be valuable for field validation purposes, particularly due to the difficulties accessing enough of the wetland on foot in the time available. Using a drone to acquire imagery for validation purposes allowed a much greater area of the wetland to be viewed than could have been surveyed on foot in the time available. It was also possible to gain remote footage of the more inaccessible areas within the wetland. Using a drone with a longer flight time is also recommended for future work to allow better access to central parts of the wetland.
- It is recommended that future wetland classification projects that use drones for field validation use the ArcGIS Full Motion Video (FMV), or similar software. The FMV extension proved to be a very useful tool for viewing the drone video footage and editing the spatial layers in ArcGIS.
- Where funding permits, allowing more time for field validation is recommended. For this study, due to budgetary constraints, field validation was limited to two days. More time for field validation would increase confidence in the wetland and vegetation maps, particularly in the wetland class attribute and would allow more detailed sampling, such as analysis of substrate types, nutrient status and pH. Ultimately allowing more time for field validation would result in a higher overall level of confidence in the final maps.
- As was recommended for the Ō Tu Wharekai wetland mapping (Boffa Miskell 2015), we recommend DOC consider creating a ‘live’ copy of the geospatial layers and updating the vegetation maps as further research and field validation work is undertaken. This is particularly relevant because of the limited amount of ground-truthing that was possible during this study.

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Appendix 1: Common and Scientific Names of Plants Mentioned in the Report

Common Name	**Scientific Name**
Bog schoenus	*Schoenus brevifolius*
Cabbage tree	*Cordyline australis*
Clubmoss	*Lycopodium deuterodensum*
Gorse	*Ulex europaeus*
Gumland grass tree	*Dracophyllum lessonianum*
Jointed baumea	*Machaerina articulata*
Kanuka	*Kunzea linearis*
Kauri sedge	*Schoenus tendo*
Kikuyu grass	*Cenchrus clandestinus*
Knobby club rush	*Ficinia nodosa*
Kuawa	*Schoenoplectus tabernaemontani*
Kumarahou	*Pomaderris kumeraho*
Kutakuta	*Eleocharis sphacelata*
Lowland flax	*Phormium tenax*
Machaerina arthrophylla	*Machaerina arthrophylla*
Machaerina spp.	*Machaerina spp.*
Machaerina teretifolia	*Machaerina teretifolia*
Macrocarpa	*Cupressus macrocarpa*
Mangrove	*Avicennia marina*
Manuka	*Leptospermum scoparium var. incanum*
Oioi	*Apodasmia similis*
Pampas grass	*Cortaderia selloana*
Pingao	*Ficinia spiralis*
Prickly hakea	*Hakea sericea*
Radiata pine	*Pinus radiata*
Raupo	*Typha orientalis*
Sand coprosma	*Coprosma acerosa*
Sand daphne	*Pimelea villosa*

Spinifex	*Spinifex sericeus*
Sydney golden wattle	*Acacia longifolia*
Taihoa	*Cassytha paniculata*
Tamingi	*Epacris pauciflora*
Tangle fern	*Gleichenia dicarpa*
Tussock swamp twig rush	*Machaerina juncea*
Wire rush	*Empodisma robustum*
Woolly nightshade	*Solanum mauritianum*

Appendix 2: Dominant Species - Summarised Data

Table A2.1: *The number of polygons and area (in ha) of each of the dominant species classes mapped within the mapping area.*

Dominant Species	Count	Area (ha)
Sydney golden wattle-Kanuka	100	796.8
Manuka	275	472.6
Machaerina spp.	445	391.2
Sydney golden wattle	180	339.7
Sydney golden wattle-Kanuka-Manuka	28	267.0
Sydney golden wattle-Kanuka/Manuka	50	230.0
(blank)	50	97.9
(Knobby club rush)/Spinifex	10	97.3
Manuka/Bog schoenus-Tangle fern	39	96.7
(Manuka)/Bog schoenus-Tangle fern	11	96.0
Bog schoenus-Tangle fern	58	94.9
Sydney golden wattle-Manuka	59	89.4
Machaerina spp.-Bog schoenus	126	87.5
Manuka-Bog schoenus	43	64.5
Manuka/Bog schoenus-Machaerina spp.	27	64.5
Tangle fern-Bog schoenus	20	61.5
(Radiata pine)/Sydney golden wattle-Kanuka	10	61.1
Manuka/Tangle fern	32	56.6
(Manuka)/Machaerina spp.	32	54.9
Machaerina spp.-Wire rush/Clubmoss	3	53.0
Manuka/Machaerina spp.	101	47.5
Pampas grass/Oioi	36	46.5
Sydney golden wattle/Manuka	83	41.6
(Manuka)-Bog schoenus-Machaerina spp.	12	37.4
Manuka/Tangle fern-Bog schoenus	18	36.5
Manuka/Machaerina spp.-Bog schoenus	30	33.3

(Sydney golden wattle)/Manuka	37	33.2
Manuka/Bog schoenus-Machaerina spp.-Wire rush	1	29.6
Bog schoenus-Machaerina spp.	64	29.2
Gorse	16	28.4
Machaerina spp.-Bog schoenus-Tangle fern	11	27.3
Bog schoenus-Machaerina spp.-Wire rush	25	25.7
Kikuyu grass	36	25.4
Manuka/Wire rush-Tangle fern	11	24.2
(Sydney golden wattle)/Pampas grass/Oioi	4	23.8
(Radiata pine)/Manuka-Tangle fern	4	23.7
(Sydney golden wattle)-Kanuka/Manuka	4	21.1
Manuka-Bog schoenus-Tangle fern	9	20.9
(Manuka)/Bog schoenus-Tangle fern-Machaerina spp.	7	20.2
Manuka-Bog schoenus-Machaerina spp.	5	20.0
(Radiata pine)/Manuka	4	19.5
Kanuka	20	18.9
Kanuka-Manuka	59	18.8
Manuka-Kauri sedge	3	17.6
Bog schoenus-Tangle fern-Machaerina spp.	2	17.3
Manuka-Tangle fern-Bog schoenus	7	16.9
Kanuka-Manuka/Tangle fern	7	16.8
Machaerina spp.-Bog schoenus-Wire rush	23	16.0
Woolly nightshade	15	15.6
Tangle fern	46	13.5
(Sydney golden wattle)/Pampas grass/Knobby club rush	2	13.5
(Knobby club rush)/Spinifex -Sand daphne	1	13.4
(Manuka)/Bog schoenus	6	13.3
Machaerina spp.-Wire rush	36	12.7
(Radiata pine)/Sydney golden wattle-Kanuka-Manuka	3	12.5
Manuka-Machaerina spp.	23	12.4
(Sydney golden wattle-Kanuka)/Manuka	6	12.1
(Sydney golden wattle)/Kanuka-Manuka	7	11.5
Raupo	15	11.4
Radiata pine/Sydney golden wattle-Kanuka	8	11.2

(Kanuka)-Manuka/Tangle fern	1	11.2
Raupo/Machaerina spp.	24	10.0
(Radiata pine)/Manuka-Bog schoenus-Tangle fern	1	10.0
(Manuka)/Bog schoenus-Machaerina spp.	6	10.0
Radiata pine	8	9.8
Kanuka/Tangle fern	5	9.6
Mangrove	3	8.9
(Manuka)/Tangle fern	7	8.6
Oioi	36	8.6
Kanuka-Sydney golden wattle/Woolly nightshade	1	8.5
(Manuka)/Tangle fern-Bog schoenus	4	8.4
Bog schoenus-Machaerina spp.-Tangle fern	7	8.2
Manuka-Machaerina spp.-Bog schoenus-Wire rush	1	7.5
Machaerina spp.-Wire rush-Tangle fern	3	6.6
Manuka-Wire rush-Tangle fern	1	6.3
Bog schoenus-Wire rush	21	6.1
(Sydney golden wattle)/Manuka/Machaerina spp.-Bog schoenus	1	6.0
(Kanuka)/Bog schoenus-Tangle fern	1	6.0
Jointed baumea	9	5.9
Woolly nightshade-Gorse	7	5.9
Exotic grass	10	5.4
Raupo/Machaerina spp.-Bog schoenus	4	5.4
Sydney golden wattle-Kanuka-Manuka/Tangle fern	1	5.3
Knobby club rush/Spinifex -Sand coprosma	1	5.2
Bog schoenus	26	5.2
Radiata pine/Manuka/Tangle fern	4	5.0
Manuka/Bog schoenus-Machaerina spp.-Tangle fern	5	4.9
Radiata pine/Manuka	9	4.5
Sydney golden wattle/Manuka/Knobby club rush	2	4.4
Pampas grass-Gorse	2	4.2
(Sydney golden wattle)/Manuka-Bog schoenus-Tangle fern	6	3.7
Sydney golden wattle-Manuka/Machaerina spp.-Bog schoenus-Tangle fern	2	3.7
Radiata pine/Sydney golden wattle	2	3.6

(Sydney golden wattle)/(Pampas grass)/Exotic grass	1	3.5
Kanuka-Manuka/Machaerina spp.-Bog schoenus-Tangle fern	2	3.5
Manuka-Machaerina spp.-Bog schoenus	5	3.5
(Raupo)-Machaerina spp.	8	3.0
Tangle fern-Wire rush-Machaerina spp.	1	2.9
(Kanuka)/Tangle fern	2	2.9
Oioi-Tussock swamp twig rush	2	2.9
Tussock swamp twig rush	6	2.8
Manuka/Wire rush	9	2.7
Radiata pine/Sydney golden wattle-Kanuka-Manuka	1	2.7
Raupo-Manuka	6	2.7
Kanuka/Tangle fern-Bog schoenus	7	2.6
(Sydney golden wattle)/Kikuyu grass	2	2.5
(Radiata pine-Sydney golden wattle)/Manuka-Tangle fern	1	2.4
(Manuka)/Kauri sedge	11	2.4
Gorse/Kikuyu grass	2	2.4
Manuka-Raupo	3	2.2
Eucalypt sp.	1	2.1
Sydney golden wattle/Kanuka	1	2.1
Jointed baumea-Machaerina spp.	3	2.0
(Sydney golden wattle)/Manuka-Bog schoenus	2	2.0
(Radiata pine)/Kanuka-Manuka	1	1.9
Sydney golden wattle/Knobby club rush-Sand coprosma	1	1.9
Manuka/Bog schoenus-Wire rush	8	1.8
Woolly nightshade-Pampas grass	3	1.8
Manuka-Bog schoenus-Kauri sedge	1	1.8
Manuka/Machaerina spp.-Bog schoenus-Tangle fern	6	1.8
Oioi?	5	1.7
Pampas grass	8	1.6
Raupo/Wire rush	2	1.6
Manuka-Tangle fern	3	1.5
Sydney golden wattle-Kanuka/Kikuyu grass	2	1.5
Pampas grass-Lowland flax-Coprosma sp./Exotic grass	3	1.4
Manuka/Tussock swamp twig rush	4	1.4

Sydney golden wattle-Manuka/Bog schoenus-Tangle fern	1	1.3
Kanuka-Manuka-Kauri sedge	1	1.3
Tangle fern-Wire rush-Bog schoenus	2	1.3
Manuka/Bog schoenus-Tangle fern-Wire rush	1	1.2
Tussock swamp twig rush-Jointed baumea	2	1.2
(Sydney golden wattle)-Kanuka	3	1.2
Sydney golden wattle/Woolly nightshade-Gorse	1	1.1
Sydney golden wattle-Manuka/Machaerina spp.-Bog schoenus	2	1.1
Manuka-Gorse	1	1.0
Sydney golden wattle-Kanuka/Knobby club rush-Sand coprosma	1	1.0
Wire rush-Tangle fern	11	1.0
?	5	1.0
Manuka/Wire rush-Bog schoenus	4	1.0
Sydney golden wattle/Tangle fern	4	0.9
Manuka-(Kauri sedge)	1	0.9
Radiata pine/Woolly nightshade-Gorse	1	0.9
Lowland flax/Oioi	2	0.9
(Manuka-Gorse)/Juncus spp.-Kikuyu grass	1	0.9
Sydney golden wattle/Gorse	2	0.8
Manuka/Oioi	5	0.8
(Lowland flax)-Manuka/Wire rush	1	0.8
(Sydney golden wattle-Kanuka)/Gorse	1	0.8
(Radiata pine)/Woolly nightshade-Gorse	1	0.7
Manuka-Lowland flax	1	0.7
(Sydney golden wattle)/Manuka-Taihoa	1	0.6
Raupo-Manuka-Machaerina spp.	3	0.6
Machaerina spp.-Wire rush-Raupo	1	0.6
Knobby club rush-Sand coprosma	2	0.6
Manuka/Machaerina spp.-Wire rush	2	0.6
Sydney golden wattle-Coprosma sp.-Lowland flax-Pampas grass	1	0.6
(Pampas grass)-Manuka	2	0.6
(Sydney golden wattle)/Manuka-Tangle fern	1	0.6
Manuka-Bog schoenus-Wire rush	1	0.6

Radiata pine/Bog schoenus-Tangle fern	2	0.5
Kauri sedge-Manuka	1	0.5
(Lowland flax)-Pampas grass/Oioi	1	0.5
Juncus spp./Kikuyu grass	1	0.5
(Raupo)-Machaerina spp.-Bog schoenus	2	0.5
Tangle fern-Wire rush	2	0.5
Sydney golden wattle-Kanuka/Woolly nightshade	1	0.5
Woolly nightshade-Gorse/Kikuyu grass	1	0.5
Manuka/Machaerina spp.-Bog schoenus-Wire rush	2	0.5
Manuka-(Lowland flax)/Machaerina spp.	1	0.5
Sydney golden wattle-Kanuka/Gorse	1	0.5
Juncus spp./Exotic grass	1	0.5
Juncus spp.-Oioi	2	0.4
Kauri sedge-Tangle fern-Manuka	1	0.4
Lowland flax-Manuka/Oioi-Machaerina spp.	1	0.4
Macrocarpa	1	0.4
Raupo-Jointed baumea	1	0.4
(Sydney golden wattle)/Manuka-Kauri sedge	1	0.4
(Kanuka-Manuka)/Exotic grass	1	0.4
Coprosma sp.-Lowland flax-Pampas grass	1	0.4
Sydney golden wattle/Manuka-Taihoa	4	0.4
Raupo/Oioi	2	0.4
Knobby club rush	1	0.3
Machaerina spp.-Tangle fern	1	0.3
(Manuka)/Machaerina spp.-Tangle fern	1	0.3
Sydney golden wattle/Manuka-Machaerina spp.	1	0.3
Exotic grass-Cyperus spp.-Machaerina spp.	1	0.3
(Lowland flax-Manuka)/Oioi	2	0.3
Manuka-Pampas grass/Kikuyu grass	1	0.3
Cyperus spp.-Exotic grass	1	0.3
Manuka-Taihoa	3	0.3
Pampas grass-Manuka	2	0.2
Sydney golden wattle-Kanuka-Manuka/Bog schoenus-Tangle fern	1	0.2
Kanuka-Manuka/Bog schoenus-Machaerina spp.	1	0.2

Kanuka-Manuka/Machaerina spp.-Bog schoenus	1	0.2
Sydney golden wattle-Manuka-Pampas grass/Kikuyu grass	1	0.2
Sydney golden wattle-Kanuka/Manuka-Taihoa	1	0.2
Kauri sedge-Tangle fern	1	0.2
Kanuka-Manuka-Taihoa	1	0.2
Sydney golden wattle-Manuka/Knobby club rush	1	0.2
(Radiata pine)/Sydney golden wattle-Manuka	1	0.2
Sydney golden wattle/Kikuyu grass	2	0.2
Pampas grass/Machaerina spp.	2	0.2
Sydney golden wattle-Manuka/Machaerina spp.	1	0.2
Sydney golden wattle/Bog schoenus-Tangle fern	2	0.1
Radiata pine/Kanuka-Manuka	1	0.1
(Manuka-Pampas grass)-Oioi	1	0.1
Cabbage tree/Oioi	1	0.1
Pampas grass/Exotic grass	1	0.1
Kuawa	2	0.1
(Manuka)/Wire rush-Tangle fern	1	0.1
Sydney golden wattle-Manuka/Exotic grass	1	0.1
(Sydney golden wattle)-Manuka	1	0.1
Pampas grass-Lowland flax	1	0.1
Raupo-Machaerina spp.	1	0.1
Manuka-Kauri sedge-Taihoa	1	0.1
Sydney golden wattle/Manuka-Tangle fern	1	0.1
(Manuka)-Lowland flax-Pampas grass/Oioi	1	0.1
Kanuka-Bog schoenus-Machaerina spp.	1	0.1
Manuka/Machaerina spp.-Tangle fern	1	0.1
Sydney golden wattle/Kanuka-Manuka	1	0.1
Shallow water	2	0.1
(Lowland flax)/Carex sp.	1	<0.1
Sydney golden wattle/Bog schoenus-Wire rush	1	<0.1
Wire rush-Tangle fern-Machaerina spp.	1	<0.1
Cabbage tree/Lowland flax	1	<0.1
Coprosma sp.	1	<0.1

Appendix 3: Photographs of Vegetation Communities

Photo 1: Sydney golden wattle-kanuka forest between Motutangi Stream and Ngārui-o-te-Marangai / East Beach

Photo 2: An extensive area of monoculture Sydney golden wattle forest in the south-western part of the wetland

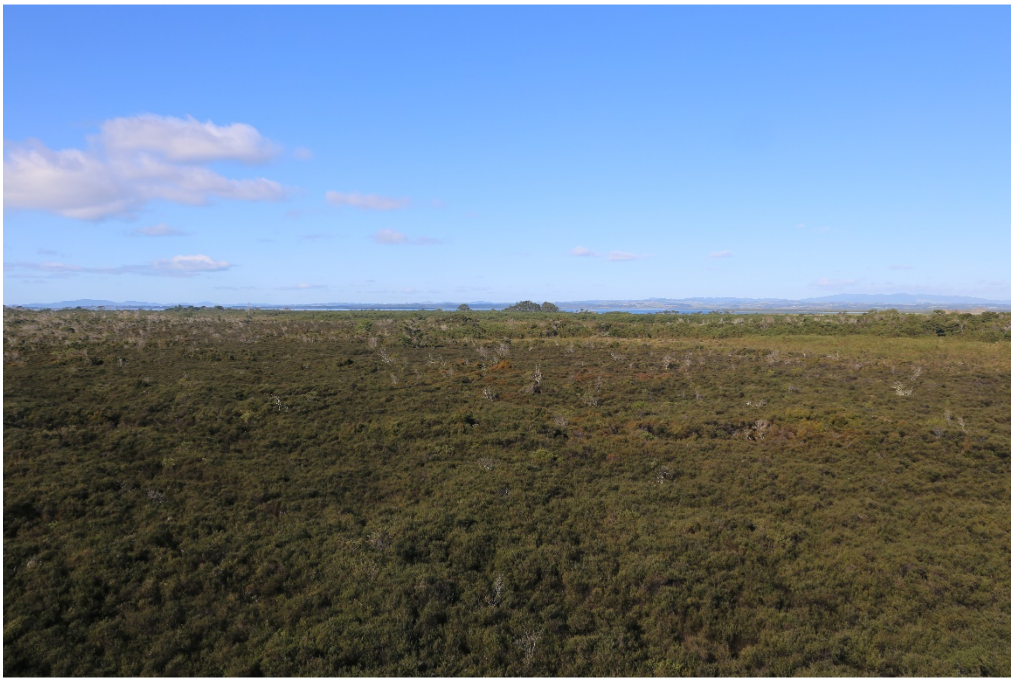

Photo 3: Low stature manuka scrub

Photo 4: *Machaerina teretifolia M. arthrophylla* reedlands in standing water

Photo 5: *Machaerina* (and bog schoenus) rushland

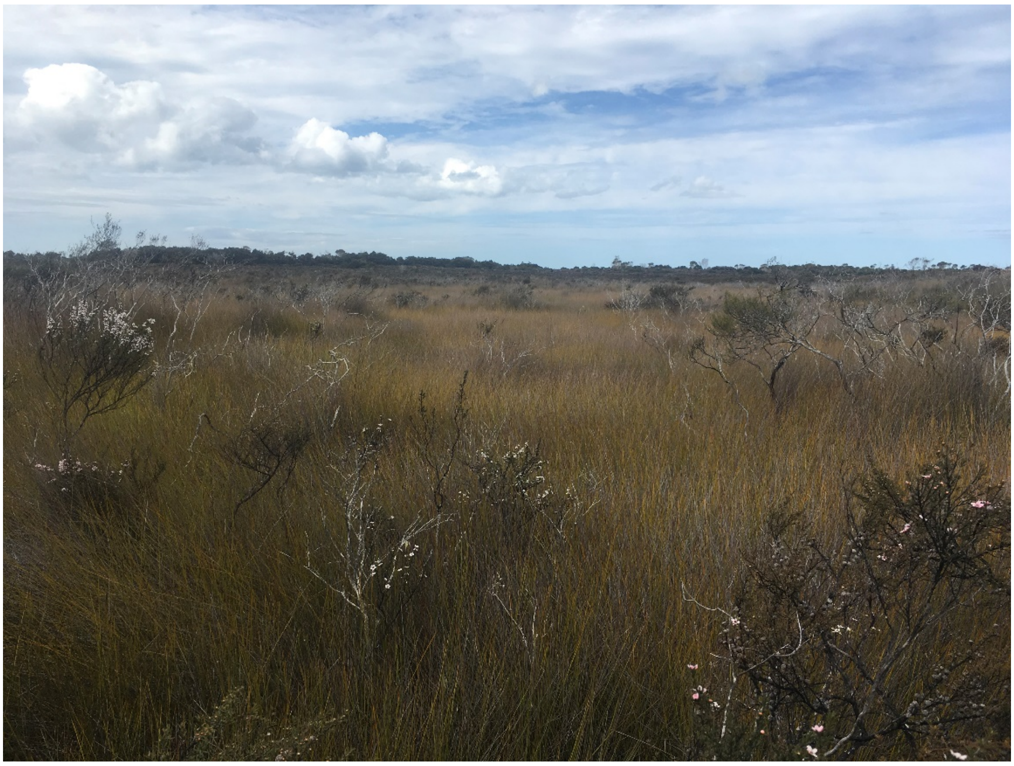

Photo 6: Bog schoenus rushland growing in association with manuka

Photo 7: (Knobbly clubrush)/spinifex with several large sand daphne. Catsear is present in the foreground

Photo 8: Oioi rushland within the estuarine saltmarsh inland of Kuaka point

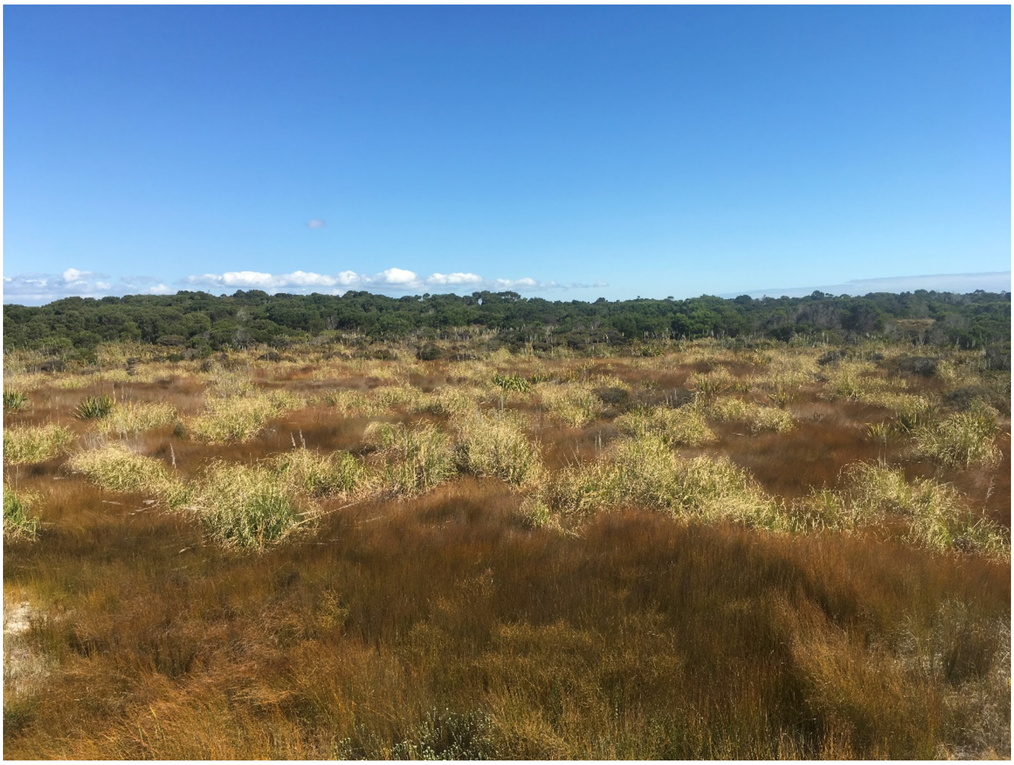

Photo 9: Pampas grass/oioi rushlands in well drained marshes in dune hollows behind the young dunes along Ngārui-o-te-Marangai / East Beach

Photo 10: Low stature scrub and shrublands of kanuka and manuka on a raised dune ridge

Photo 11: A small patch of raupo reedland on the eastern side of the wetland

About Boffa Miskell

Boffa Miskell is a leading New Zealand professional services consultancy with offices in Auckland, Hamilton, Tauranga, Wellington, Christchurch, Dunedin and Queenstown. We work with a wide range of local and international private and public sector clients in the areas of planning, urban design, landscape architecture, landscape planning, ecology, biosecurity, cultural heritage, graphics and mapping. Over the past four decades we have built a reputation for professionalism, innovation and excellence. During this time we have been associated with a significant number of projects that have shaped New Zealand's environment.

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