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Dear Shay

KAITUNA, MAKETŪ AND PONGAKAWA WMA WETLAND MAPPING

1.0 Introduction

In response to your request, Pattle Delamore Partners Ltd (PDP) is pleased to provide Bay of Plenty Regional Council (BOPRC) with the Kaituna (Kaituna, Maketū and Pongakawa) Water Management Area (WMA) wetland map. The objective of this project was to map wetlands down to 0.05 ha size and to assist BOPRC in updating and completing their inventory of natural wetlands.

Based on this we have provided what we assess to be the optimal mapping output balancing wetland mapping accuracy, outputs, cost and programme.

1.1 Project Objectives

The scope of this project included the update and completion of the mapping of wetlands in the Kaituna WMA.

- This mapping will help BOPRC to achieve the requirements of the 2020 National Policy Statement for Freshwater Management (NPS-FM) to identify and map natural inland wetlands ≥0.05 ha (≥500 m^2).
- It will also provide BOPRC with a basis for prioritizing wetlands at risk of loss of extent or values and an inventory to consult for resource consent applications.
- It will provide BOPRC with information on the extent, class and vegetation structure of wetlands within the WMA.
- It will provide BOPRC with information on confidence of the mapping and help to determine areas where there is a need to prioritise ground truthing work.

1.2 Approach

Our approach included a first phase (Phase I) with desktop wetland identification, extent digitisation and classification utilising Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM), high-resolution Red-Green-Blue (RGB) aerial imagery, Sentinel-2 multi-spectral level-2A satellite imagery, Sentinel-1 SAR (Synthetic Aperture Radar) imagery, BOPRC supplied oblique imagery (where available) and supplementary data (GIS and environmental data) for our wetland specialists to digitise wetland location, extent, and class. Various topographic and optical wetland predictors were used in combination with the aerial imagery and oblique imagery to identify and characterise the wetlands in the WMA. The combination of the data inputs enabled our remote sensing scientists and wetland specialists to complete targeted identification and digitisation which minimised the opportunity to overlook wetlands in the study area compared to completion of digitisation on its own.

Phase II included a wetland class assessment (classification) as per Johnson and Gerbeaux 2004. The final phase (Phase 3) included a GIS post processing and review process to produce the Kaituna WMA wetland map.

The specific steps of our methods are described in detail in section 2.0 below.

2.0 Methods

Our methodology included multi-step methodology as outlined in Figure 1 and described below.

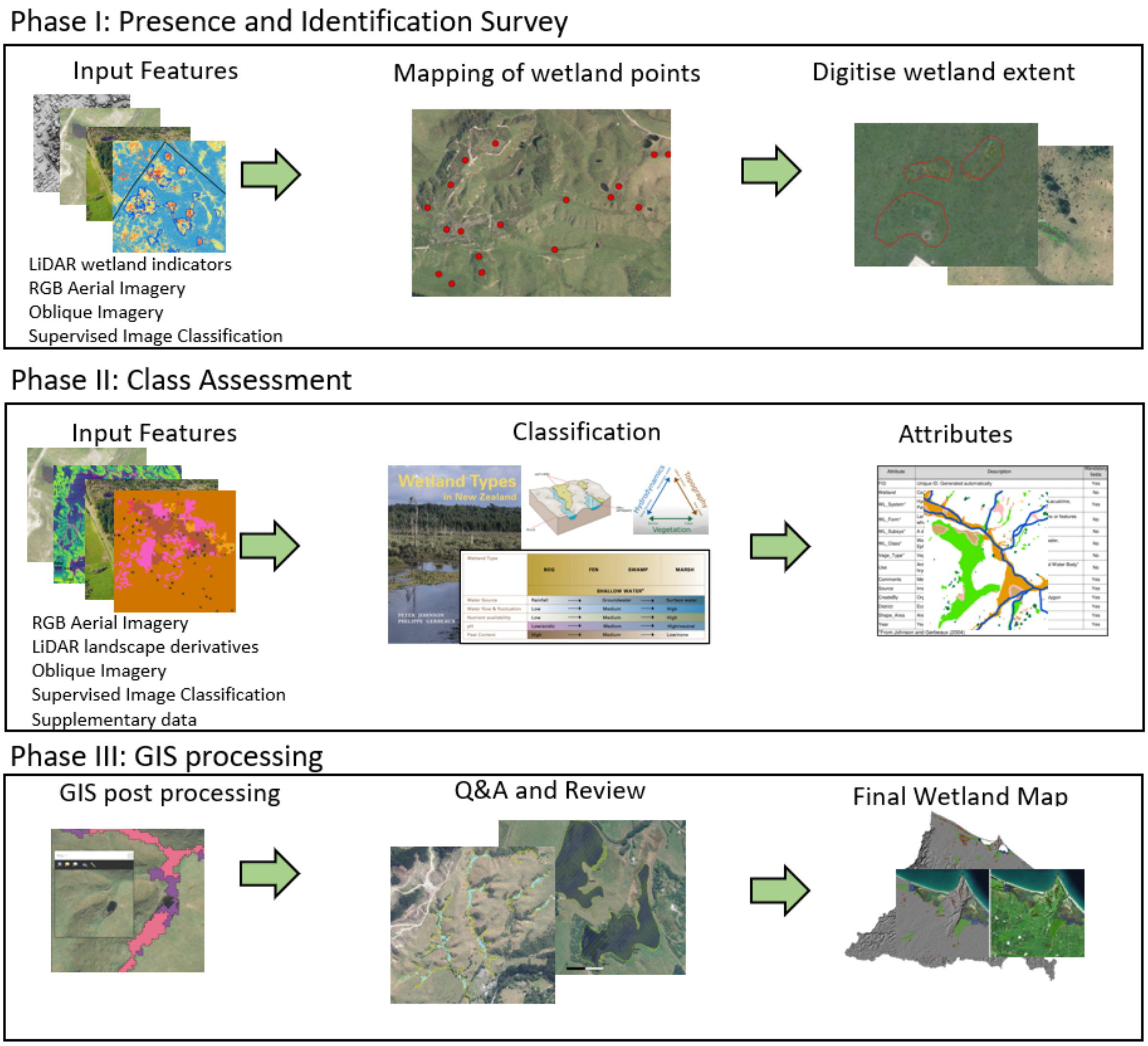

Figure 1: Methodology

Phase I:

1. Data assembly – This initial task involved building a database of fundamental data for the mapping work. We first assembled all data inputs and tiled the imagery into processing units and setup the feature classes for digitisation. The main data inputs included the latest high resolution digital topographic data (LiDAR derived digital terrain model), optical imagery (aerial and satellite), SAR and oblique imagery (if available). The data sets used for this project are summarised in Table 1.

Table 1: Input Data

Data Set	Description
LiDAR DEM	LiDAR Digital Elevation data: 2019-2022 Bay of Plenty LiDAR 1m DEM (LINZ) 2011 Bay of Plenty LiDAR 2m DEM (BOPRC)
Red-Green-Blue (RGB) aerial imagery tiles	Regional aerial imagery made available by LINZ: 2020 0.1m Urban Aerial Imagery 2021 0.3m Rural Aerial Imagery 2021-2022 0.3m Rural Aerial Imagery
Oblique imagery	2022 BOPRC imagery supplied and accessed through Photoblique software.
Sentinel-2	COPERNICUS Multi-spectral level-2A satellite imagery: 2022 10m cloud free median composite (image collection of 106 images with a date range between 1 January – 30 September 2022) 2022 10m Spring composite (image collection of 6 images ranging from 3 to 13 August 2022)
Sentinel-1 SAR	2022 10m C-band Synthetic Aperture Radar Ground Range Detected (image collection of 34 images with a date range between 15 June-23 August 2022)
Reference data	Existing BOPRC wetland inventory (BOP freshwater and maritime wetland database including 2018 Landcare Research Wetland extent database)
Supplementary data	BOPRC Land Use and Land Cover 2021
Regional GIS data	Short rotation cropland and vineyard and orchard land use classes (using LCDB5). 2021 Department of Conservation Ecological Districts Polygon layer.

Wetland identification and delineation – Our wetland specialists generated wetland points and digitised wetland extents appropriate to the study area. We aimed to identify and map wetlands down to approximately ≥0.05 ha (≥500 m^2). We split the Kaituna WMA project area up based on the Department of Conservation (DOC) ecological zones (2021). The northern part of the project area consisted of the Tauranga Ecological district and the southern project area the Otanewainuku Ecological District (Figures 2 and 5). This allowed us to focus our mapping on a particular characteristic landscape in terms of topography, geology, climate, soil and biological features, broad cultural patterns, and range of biological communities (Department of Conservation, 1987). We assembled a dedicated ArcGIS wetland mapping web application for the wetland ecologists to complete the wetland mapping (Figure 2). The main layers included aerial imagery mosaics (Table 1), ESRI NZ imagery basemap, a LiDAR DEM hillshade and topographic wetland indicators. Potential wetlands identified with low confidence levels were verified using the oblique imagery where possible (Figure 3). We used the regional imagery, Google Earth time interval imagery and spring Sentinel 2 imagery in combination with topographic wetland variables for our assessment of 'pasture looking wetlands' or 'rushland habitat'.

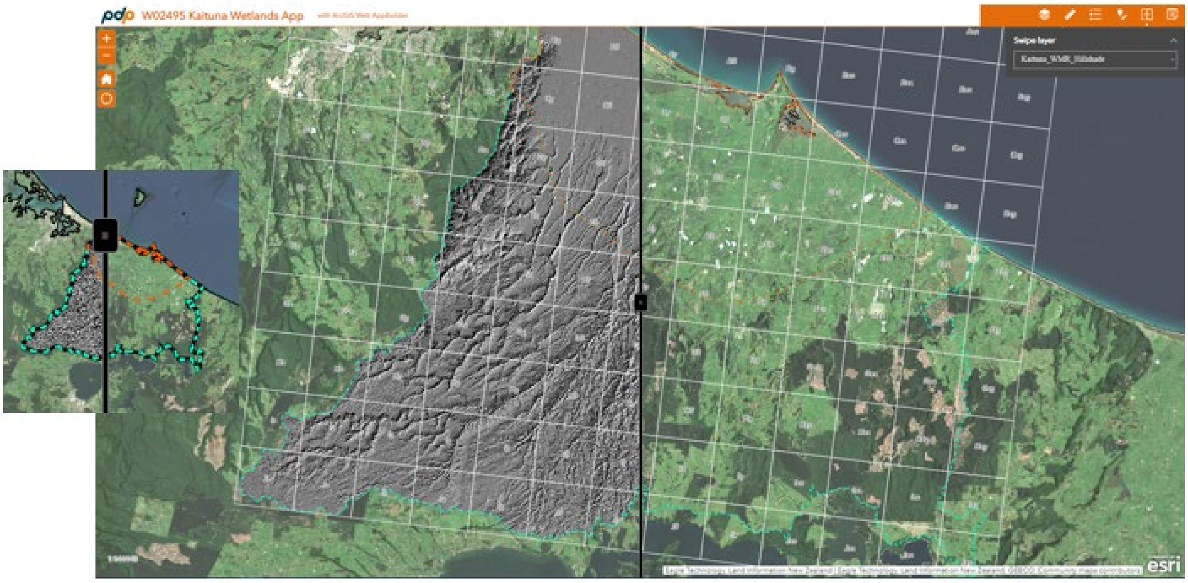

Figure 2 Kaituna Wetland Mapping Web Application (the insert shows the ecological districts).

In addition to the methodology described above we also used a supervised image classification to enhance our understanding of wetland location, presence, extent, and class. Optical (regional aerial and sentinel-2 satellite), topographic (DEM derived topographic wetland indicators) and radar (Sentinel-1 SAR) imagery) were used for the classification of wetland extent and class. A combination of the visible bands, near-infrared spectral indices, topographic indicators, and radar input variables (Figure 4) were derived from the imagery. The Sentinel 1 and 2 input variables included spring imagery to capture seasonal wetland signatures. The use of the image classification in combination with the standard methodology provided the opportunity for the ecologists to complete targeted mapping.

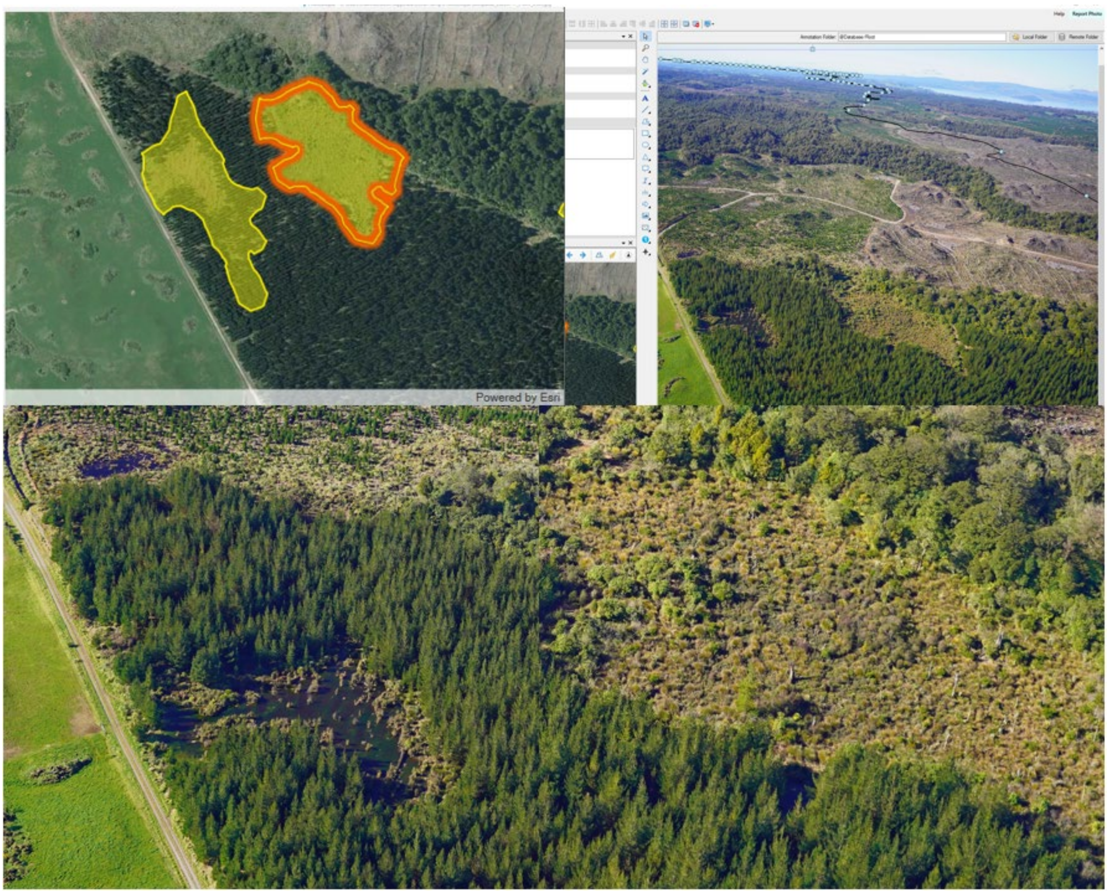

Figure 3 Example of oblique imagery showing two Bog wetlands dominated with sedges.

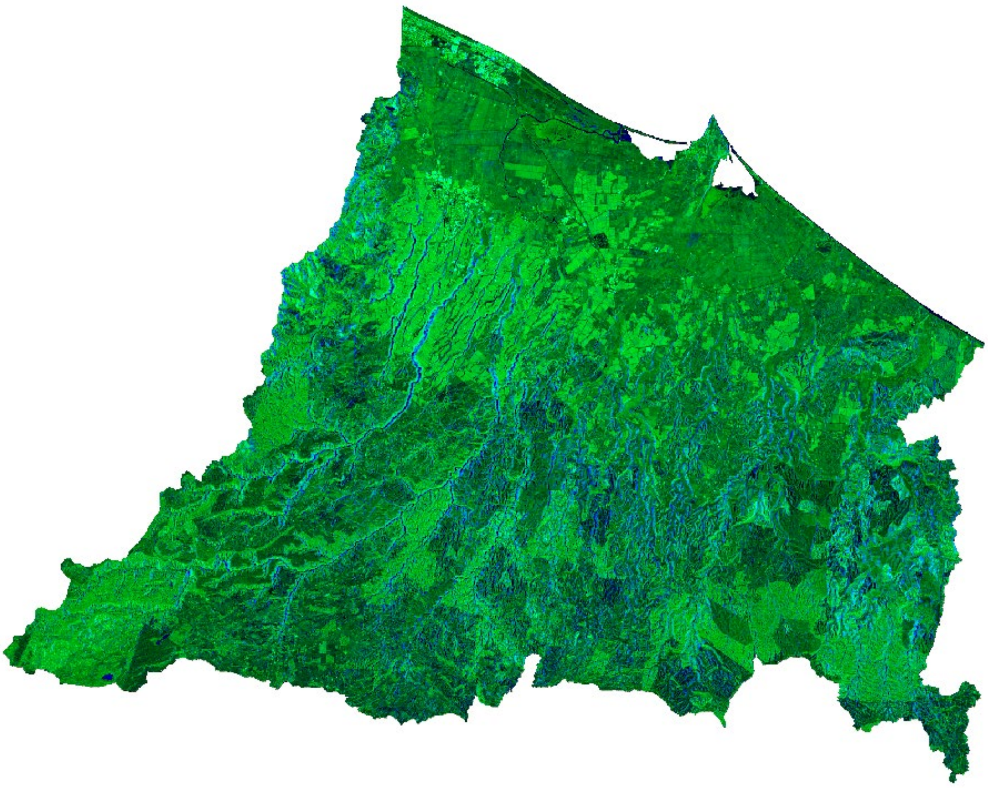

Figure 4: Sentinel 1 SAR input variables presented in a composite image.

Phase II:

2. Class Assessment – We used the RGB aerial imagery, LiDAR landscape derivatives, the existing wetland dataset, recent landcover, oblique imagery (where available) and other relevant information (ancillary data) as reference material, where suitable, to complete the class assessment. This step included a combination of specialist image interpretation and wetland ecological interpretation to assign the relevant attribute information. The classification was completed in accordance with the classification by Johnson and Gerbeaux, 2004.

   We have incorporated the following attributes as requested:

   - Hydrosystem as per Johnson and Gerbeaux 2004
   - Wetland class as per Johnson and Gerbeaux 2004
   - Structural class as per Johnson and Gerbeaux 2004
   - Status (whether the wetland is likely to meet the NPS-FM definition of a natural wetland. Divided into the following categories: Natural, Pasture Exclusion, Artificial, Induced).
   - Confidence (low, medium, high)
   - Confidence Reason
   - Notes

   Table 2 summarises the schema used for the wetland mapping attributes, the definitions used for wetland status and a description of the confidence reasons.

Table 2: Input Data

Attribute	Field Name	Pick List
Object Identification	OBJECTID	N/A
Hydrosystem	HydroSyste	Palustrine, Riverine, Lacustrine,
Wetland class	WetlandCla	Bog, Fen, Swamp, Marsh, Seepage, Shallow water, Ephemeral wetland, Saltmarsh
Structural class	WetlandStr	Forest, Treeland, Scrub, Shrubland, Flaxland, Tussockland, Fernland, Reedland, Rushland, Sedgeland, Grassland, Cushionfield, Herbfield, Turf, Mossfield, Lichenfield, Algalfield
Wetland status	WetlandSta	Natural, Pasture Exclusion, Artificial, Induced[1]
Confidence level	Confidence	Low, Medium, High
Confidence reason	ConfidReas	Probable wetland, Possible Wetland, Probable artificial, Known wetland, Indeterminant[2]
Notes	Notes	N/A

Notes:

1. *Wetland status definitions:*
   Natural wetland. This is an abbreviation of 'Natural inland wetland' which was applied to inland freshwater wetland.
   Natural estuarine wetland. This was applied to wetlands that were in the estuarine hydrosystem.
   Natural (modified) wetland. Natural wetland but with some human modifications such as weirs and drains.
   Pasture Exclusion. Either 'pasture looking wetlands' or 'rushland habitat'.
   Artificial constructed wetland follows the explanation from the Ministry for the Environment (2021) and include stock water dams, water storage ponds, ponds made for duck shooting and open drainage channels.
   Induced wetland in terms of Ministry for the Environment (2021). Wetlands that have been unintentionally induced as a consequence of human activities (for example, as a consequence of in-stream works such as culverts, or through the effects of increased sedimentation caused by deforestation). Induced wetlands are natural wetlands and regulated by the NES-F.

2. *Confidence reason definitions:*
   'Probable wetland' e.g. No site visit data but soil, drainage data, landforms, proximity to water sources and aerial imagery assessed by expert, all corroborate classification, = >90%
   'Possible wetland' e.g. No site visit data, abiotic data lacking to support designation but appears to be a wetland as assessed by an expert assessment of aerial images, >50%
   'Probable artificial' This means wetland habitat is present, but the wetland is probably man-made.
   'Known wetland' e.g. ecological data known from site, either council staff, presence on council layers or other qualified experts. = 100%
   'Indeterminant wetland' e.g. No site visit data, abiotic data lacking to support designation, expert assessment indeterminant, requires additional information such as site photo's, site visit, <50% Note: this criterion has been applied to either 'pasture looking wetlands' or 'rushland habitat' (Pasture Exclusion) including 'Forest wetlands' where topographic indicators, geomorphology, hydrological indicators, and aerial images indicate the presence of a wetland). Based on expert assessment some Forest wetlands were also assigned the 'Possible wetland' confidence reason.

Phase III

3. GIS processing – Post process tasks also included but were not limited to clip, dissolve, removal of overlap and attribution operations. The final attributed data were post-processed in Esri ArcGIS Pro Release 3.0.0 (Esri 2022) using Modelbuilder containing Repair Geometry, Clip, Calculate Field, and Append tools." The GIS processing step were conducted simultaneously with the step 5 review process.

4. Human Specialist Review – This step involved the review and finalisation of the GIS output. Recommendations was provided to the post -processing team until a satisfactory result had been achieved.

3.0 Results

We mapped a total number of 1002 separate wetland polygons. This equates to 1597 ha or 1.49 % of the 107,208-ha Kaituna WMA.

A variety of different imagery sources (Table 1) and derived wetland indicators were considered during the wetland identification, presence and classifications phases through specialist image and wetland characteristics interpretation. This ensured that even wetlands that are difficult to identify, rare, or not included in the current BOPRC inventory such as seeps, coastal wetlands, forest swamps, bogs and shallow water have been identified and mapped. Table 3 indicates the number of wetland polygons and area covered grouped by wetland class. Figure 5 present a spider chart of the area covered with wetlands based on wetland status. The Natural wetland status included the largest part of the WMA (approximately 1416 ha). Swamp wetlands cover the largest part of this area followed by Marsh, Bog, Saltmarsh, Seepage, Shallow Water and Fen. Approximately 146 ha of the wetland area within WMA was classified as Pasture Exclusion. Marsh dominated the pasture exclusion, followed by Swamp and Seepage. A small percentage of the wetland area was classified as artificial and induced. Figure 6 presents a map of the distribution and coverage of wetlands based on wetland class within the WMA. The coverage correlates with the information presented in Table 3. The Palustrine class dominate wetland coverage based on hydrosystem followed by riverine and estuarine (1122.4, 339 and 135.4 ha respectively).

Section 3.1 and 3.2 provides a summary of the results for each Ecological District with focus on the vegetation structural class.

Table 3: Number of polygons and area covered grouped by wetland class

Wetland class	Number of polygons	Area in hectares (ha)
Swamp	483	681.17
Marsh	306	515.67
Bog	36	181.42
Saltmarsh	31	137.23
Seepage	102	40.5
Shallow Water	43	25.67
Fen	1	15.37

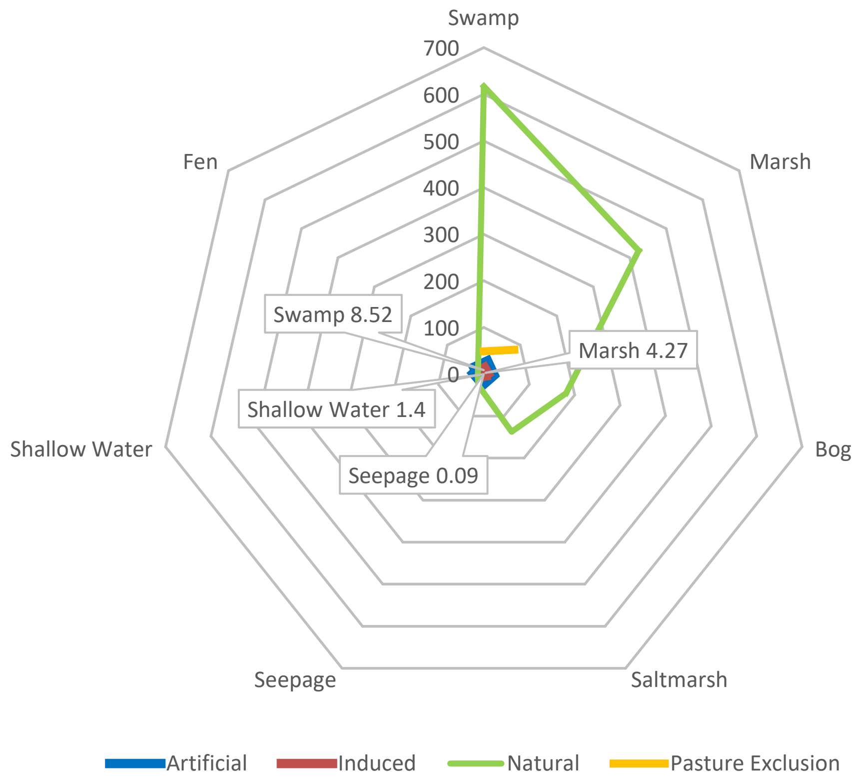

Figure 5: Spider chart of wetland area (ha) based on wetland status (the call outs indicate the induced wetland status class which covers the smallest area)

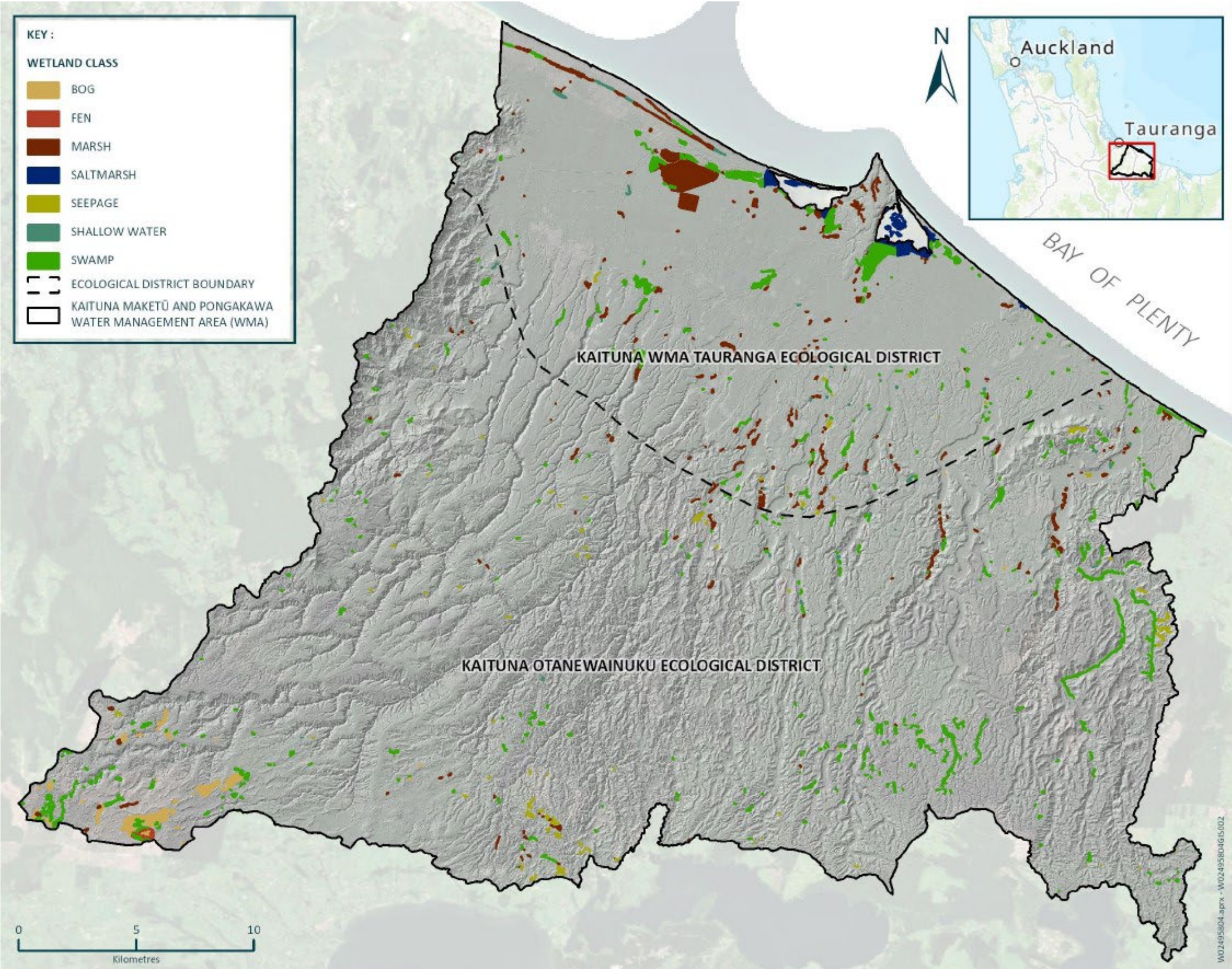

Figure 6 The Kaituna WMA Wetland Map indicating the distribution of wetlands in project area based on wetland class.

3.1 Tauranga Ecological Distict

Coastal plains, sand dunes and swamplands, long strait beaches, the large shallow harbour with estuaries and low hills near Maketu dominate the Tauranga Ecological District project area. Much of the former forests were cleared which included extensive flax swamps, fern and scrub. The tidal inlets include mangroves. Much of the district were modified through farming, horticulture and exotic forests (Department of Conservation, 1987). We mapped a total number of 392 separate wetland polygons within this ecological district.

The most widespread vegetation structure (based on area covered of the wetlands in the ecological district is Herbfield followed by Treeland, Shrubland and Grassland. Herbfield was difficult to separate from other similar looking vegetation structures and therefore some misidentification may have occurred. Grassland vegetation was identified mostly for pasture looking wetlands (pasture exclusion status). Rushland was the fifth most common vegetation followed by Sedgeland. The least common vegetation included Forest, Reedland and Scrub. Figure 7 indicates that the number of polygons and Area (ha) for Forest, Grassland, Herbfield, Reedland, Rushland and Scrub followed a very similar trend whereby Sedgeland and especially Shrubland and Treeland had an opposing trend. The indication is that there is only a limited number of Shrubland and Treeland wetlands although they cover larger extents.

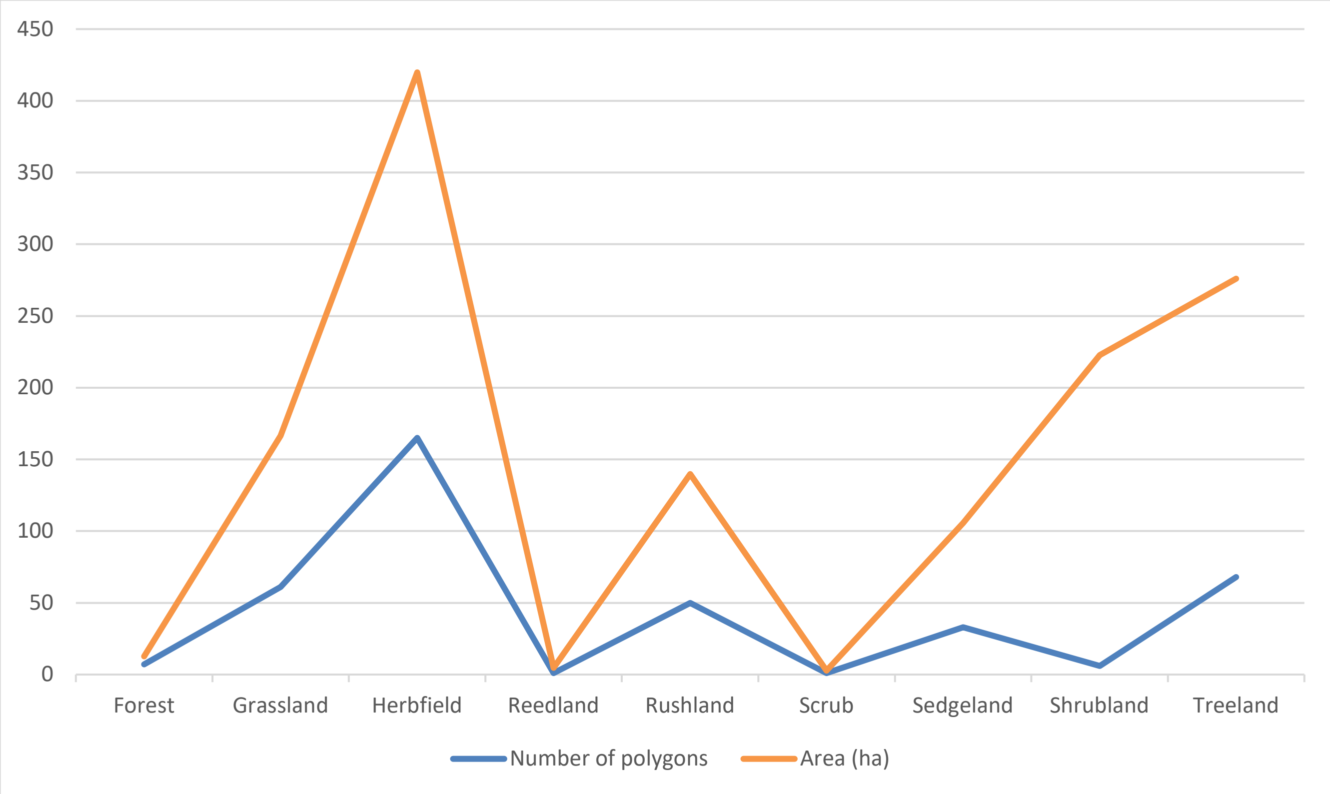

Figure 7 The vegetation structure of the wetlands mapped in the Tauranga Ecological District

3.2 Otanewainuku Ecological District

The Otanewainuku Ecological District includes plateaux ranging from 300 to 600 m.a.s.l. sloping eastwards and northwards. Native vegetation in the ecological district is dominated by podocarp-hardwood forests. Most of the native plateau forests were logged and replaced with exotic forests and some areas cleared for farming (Department of Conservation, 1987). We mapped a total number of 610 separate wetland polygons within this ecological district.

The most widespread vegetation structure (based on area covered) of the wetlands in the ecological district is Forest followed by Treeland and Shrubland (Figure 8). These wetlands can be difficult to separate from other similar looking terrestrial vegetation structures and therefore some misidentification may have occurred although we have used various hydrological and topographical indicators to help with the identification and classification of these wetlands. The identification of these wetlands using the aerial and oblique alone still provide only limited results. Figure 9 provides an example of a swamp forest as seen by oblique imagery. Based on this image stands of Kahikatea (*Dacrycarpus dacrydioides*) trees can be seen in a surface depression. The use of DEM derived topographical and hydrological including radar derived hydrological indicators made it possible to improve confidence levels in mapping of these wetlands. An 'Indeterminant wetland' confidence reason was assigned for some Forest wetlands where the expert assessment was uncertain (indetermined). Sedgeland followed by Herbfield and Rushland vegetation structures followed the woody vegetation structures in term of area coverage. The Herbfield class have a high number of polygons although proportionally cover a relatively small area which indicate that individual wetland areas are relatively small. The remainder of the wetlands consisted of Scrub, Reedland, Fernland and a rare Turf wetland.

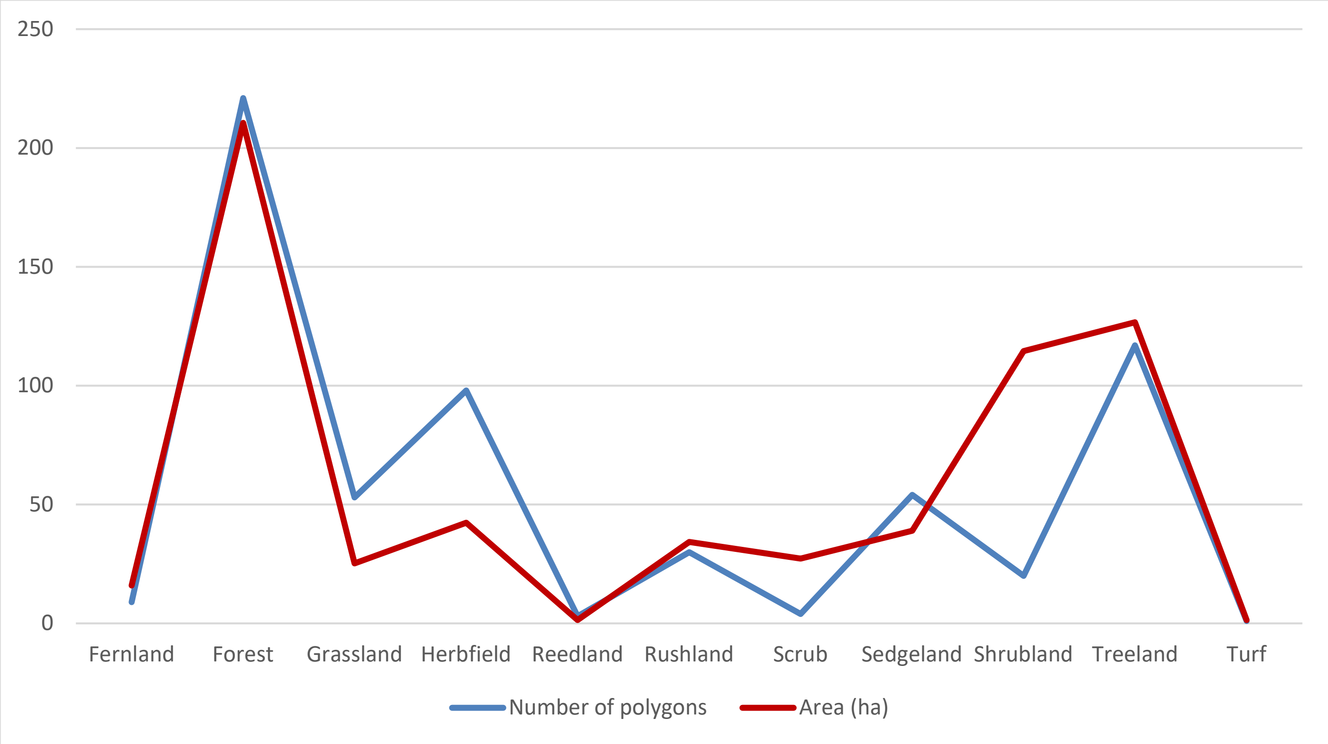

Figure 8: The vegetation structure of the wetlands mapped in the Otanewainuku Ecological District

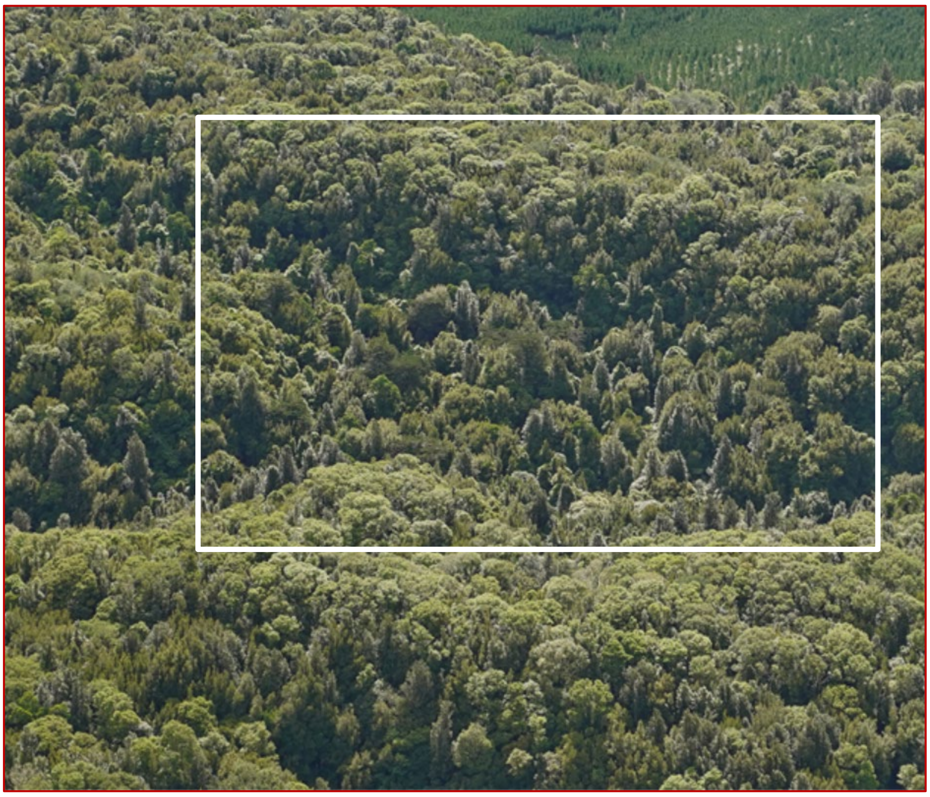

Figure 9: Example of a swamp forest as seen by oblique imagery. Based on this image stands of Kahikatea (Dacrycarpus dacrydioides) trees can be seen in a surface depression

4.0 Conclusions and Discussion

We have identified and mapped many new wetlands not included in the current BOPRC inventory some of these are rare, such as seeps, coastal wetlands, forest swamps, bogs and shallow water.

We followed an integrated approach to map the wetlands in the Kaituna WMA. This involved using the expertise of wetland botanists and specialists mapping wetlands in a desktop environment using a user-friendly designed web interface. The web interface was designed with the aim to ensure that the wetland mapping can be completed as efficiently as possible including providing adequate information layers for the identification, extent digitisation and classification of wetlands. These included aerial imagery mosaics, ESRI NZ imagery basemap, a LiDAR DEM hillshade and topographic wetland indicators such as probability of depression and curvature. We utilised the oblique imagery for targeted identification and classification (when information in the web interface was insufficient) of wetlands in the WMA, since the process of viewing the oblique imagery are very time consuming. The oblique imagery also did not cover some of the southern sections of the WMA. The integrated approach involved remote sensing expertise in the form of providing and interpreting the wetland the indicators for the web interface. Additionally supervised image classification using optical, topographic and radar imagery was used to enhance and speedup the mapping. In conclusion, this approach also ensured targeted identification and digitisation which minimised the opportunity to overlook wetlands in the WMA compared to completion of digitisation on its own.

We aimed to identify and map wetlands down to approximately ≥0.05 ha (≥500 m^2) although the mapping and classification of wetlands under 2000m^2 requires meticulous interpretation, is very time consuming and seasonal wetland signatures tend to be more important for accurate mapping. A total of 15.8% of the wetlands mapped was between 0.05 and 0.2 ha and 4.2% of our mapping output included wetlands under 0.05 ha.

5.0 Recommendations

- We found that this integrated specialist mapping approach using an easy-to-use web interface in combination with remote sensing techniques to enhance and speedup mapping very worthwhile in terms of the quality of the output compared to other mapping approaches we have used in the past.
- The identification of wetlands using oblique imagery alone provided limited results. It is very time-consuming and labour intensive and it is difficult to accurately identify the location of a wetland from the oblique imagery and pinpoint the location on the regional aerial imagery. It requires a trained eye and someone with an understanding of the position of a wetland in the landscape. Where wetlands are located far from the flight path the usage of this imagery is further limited. This imagery does provide good value for the confirmation of wetland presence, including providing classification and vegetation structure information. We found that it is best used for targeted identification and classification.
- Wetlands with 'Indeterminant wetland' including to a lesser degree 'Possible wetland' confidence reasons (Table 2) need to be prioritised for ground truthing. This would provide the opportunity to refine the extent, class and vegetation structure.
- The near infrared (NIR) band of the aerial imagery was not available for the entire study area and we therefore decided not to use it. Acquiring NIR imagery for the entire BOPRC area will improve future mapping efforts. By comparing reflectance of an area to the reflectance of other land cover types, it is possible to identify wetlands with a high degree of accuracy (open vegetation types).

6.0 Limitations

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Bay of Plenty Regional Council Toi Moana and others (not directly contracted by PDP for the work). PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

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7.0 Acknowledgements

Our thanks go to Shay Dean (Bay of Plenty Regional Council Toi Moana) for providing access to the Council data used in this project and to Andrew Macdonald for assistance and guidance using and the Photoblique platform.

Yours faithfully

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