Remapping the Extent of Auckland's Wetlands: Methods and Summary

September 2017

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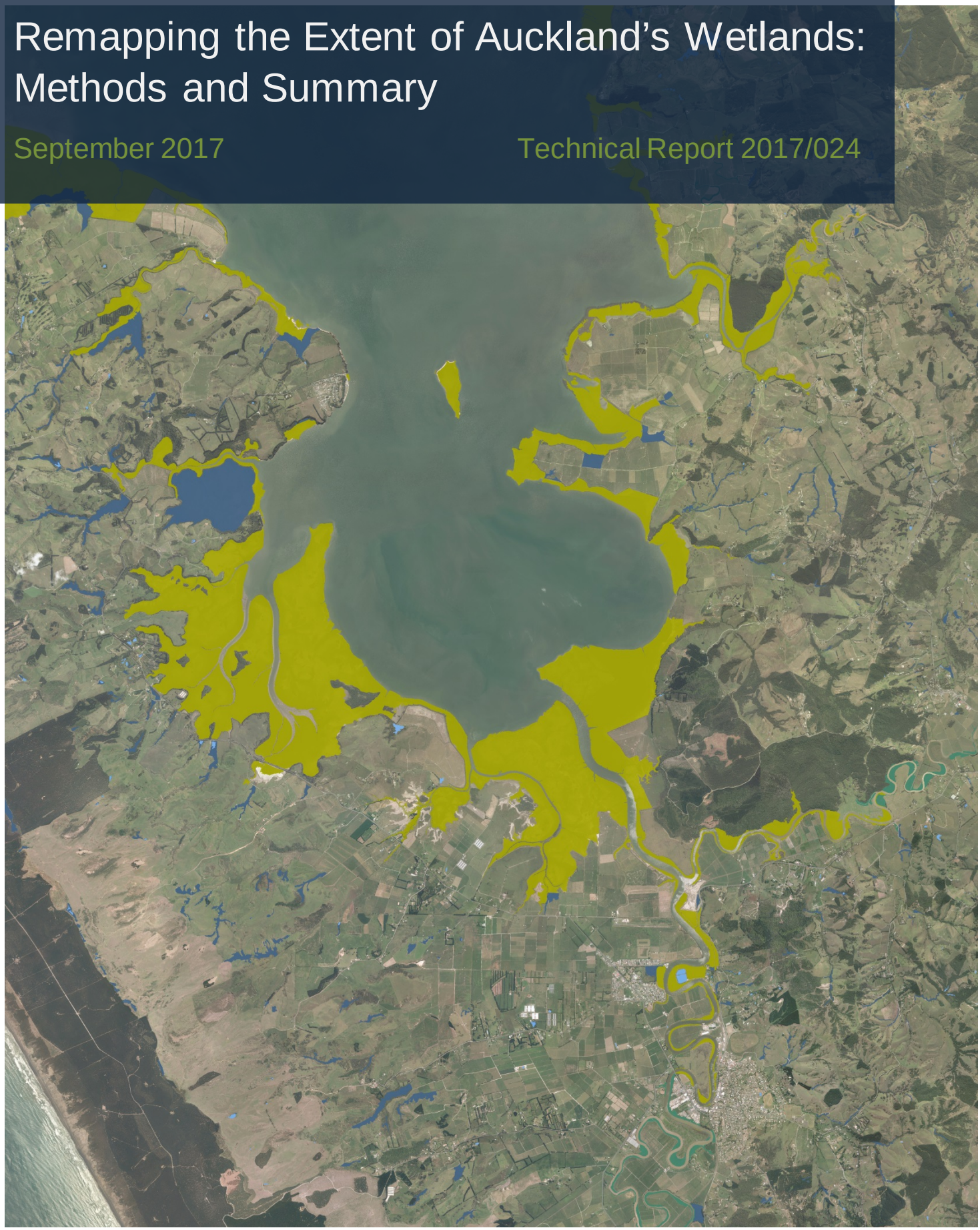

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Executive summary

There is a need to inventory wetlands for the purpose of tracking the status and trends of wetland resources through time and to inform strategy, policy, and wetland management operations.

Typically, wetland inventories have been collated from a range of sources and include data collected at various spatial and temporal scales, and for different purposes. As a consequence pre-existing spatial inventories of wetlands for the Auckland region contained mapping errors, old data, inaccurate extents and missing wetlands. The Auckland Council's Research and Evaluation Unit (RIMU) encountered these issues when establishing wetland field plots as part of the biodiversity monitoring programme and began work on an updated regional Auckland wetland layer.

This project remapped the extent of Auckland's wetlands by digitizing the 2010-2011 aerial imagery, as a baseline for further work to monitor change in wetland area over time. It involved using various spatial datasets and aerial imagery to identify and delineate wetland boundaries and classify wetlands by hydrological function (e.g. palustrine, estuarine etc.). A desktop method was chosen for the project as field surveys and remote sensing approaches were considered too intensive and less accurate for small wetlands.

The Auckland Wetland Layer dataset was created as a one-off, 'snapshot in time' of Auckland's wetlands and is primarily composed of original wetland polygons. Over 11,500 wetland polygons were mapped across the Auckland region with a total area of approximately 17,250ha. The majority of wetlands mapped were small and/or modified wetlands that had not been accounted for in previous layers. Estuarine and palustrine wetland are the two most extensive hydrosystems in the Auckland region making up 65 per cent and 22 per cent respectively of all current wetland area. Riverine and lacustrine wetlands are the rarest form of wetlands.

Overall, there were a large number of previously unmapped wetlands now delineated in the new Auckland Wetland Layer and the majority of pre-existing wetland delineations present in the 2010-2011 imagery now have updated boundaries. The near complete re-digitization of pre-existing wetland extents and the mapping of previously un-mapped wetlands has resulted in a single dataset for the Auckland region that has a consistent mapping scale, mapping resolution, delineation method and classification methodology, a first for the Auckland region.

The outcomes of this project will inform regional wetland, freshwater and land management for Auckland Council and contribute to national monitoring and reporting.

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1.0 Introduction

1.1 Background

Wetlands are important for the wide range of environmental, economic, biodiversity and cultural benefits they provide (MfE, 2007). However despite this, historical loss of wetland habitat has been very high in many parts of New Zealand and although wetland loss and degradation is still occurring, national and regional rates of loss are not currently reported (Myers et al. 2013). Auckland Regional Council (2010) provides estimates of the proportion of Auckland region wetlands lost, to draining and clearance. On average only around 4 per cent of Auckland's freshwater wetland ecosystems remain (ibid.). However, as shown by the results presented in this report, the proportion of wetland habitat remaining varies widely between different types of wetlands and various landscapes.

Regional and district councils have responsibilities to implement legislation and develop policies and regulations to protect wetlands and prevent their damage and degradation. In recognition of the important values and highly threatened status of wetlands (MfE 2007, Williams et al. 2007, Myers et al. 2013) the Auckland Council undertakes a regional wetland monitoring programme. This programme, started by the Auckland Regional Council in February 2010, has been continued by the Auckland Council following Auckland local government amalgamation on 1 November 2010. An outline of the regional wetland monitoring programme is provided in Appendix G.

The monitoring programme used existing (i.e. 2008 and prior) spatial data on wetland location and size to randomly select wetlands and plot locations for sampling. However, during the 2nd and 3rd years (2011-2012) of baseline plot measures it became apparent that the regional wetland layer was not fit for purpose as an automated selection tool. A high percentage of wetland polygons in the layer were incorrect (i.e. no wetland vegetation at that location) or had highly inaccurate boundaries. Many wetlands were also missing from the layer. The quality of information was particularly poor for certain classes of wetlands (e.g. dune deflation hollow and dune slacks); landcover types (e.g. wetlands in plantation forest) and landscapes (e.g. wetlands in intensively farmed rural landscapes without significant areas of native vegetation).

In November 2013 the Research and Evaluation Unit (RIMU) of Auckland Council began work on an updated Auckland wetland layer. Re-mapping Auckland's wetlands was undertaken via desktop means and involved using various spatial datasets and aerial imagery to identify and delineate wetland boundaries. A manual digitization approach was chosen for the project, as field surveys and remote sensing approaches were considered too intensive and less accurate for small wetlands. The dataset was created as a one-off, 'snapshot in time' of Auckland's wetlands based on 2010-2011 aerial imagery; it also acts as a baseline for future monitoring efforts.

The new Auckland wetland layer is primarily composed of original wetland polygons, although some were collated from other datasets within Auckland Council where the mapping resolution was similar. The layer also includes updated polygons from several local, regional and national scale wetland datasets.

The aim for remapping the extent of Auckland wetlands is to improve the management, understanding and monitoring of wetland ecosystems in the Auckland region by:

1. Increasing the general knowledge and understanding of Auckland's wetlands;
2. Allowing a more accurate estimate of historical rates of wetland loss;
3. Providing a more accurate baseline against which to measure future changes in the total area and fragmentation of Auckland's wetland assets. Including changes for different types of wetlands and different parts of the region;
4. Allowing an accurate assessment of the level of statutory protection of wetland habitat on public and private land;
5. Providing an information base to help inform planning and policy decisions of Auckland Council and the wider community.

1.2 Report overview

This report summarises work to remap the extent of wetlands in the Auckland region and the creation of an updated wetland spatial layer. It focuses on methodology behind improving and redefining existing wetland GIS datasets and was developed between 2013 and 2015 by Grant Lawrence and Craig Bishop in the Environmental Research and Evaluation Team of RIMU.

The resulting output of the analysis is a spatial dataset; the Auckland Wetland Layer (AWL). Each wetland polygon is tagged with classifications derived from the imagery or other external, spatial or non-spatial datasets. The classification hierarchy was adopted from Johnson & Gerbeaux (2004) in order to group the results, based on categorisation of wetland types, for effective analysis. The classification of wetlands is complicated and any work to accurately identify wetlands types needs to account for these complexities.

A detailed description of the methodology and rules used to identify and digitize the wetland polygons is found in Section 2.0, including the results of a desk-top audit of the wetland layer.

Section 3.0 presents some rudimentary data analysis of the AWL. It includes a break-down of the proportions of different wetland types, their spatial distribution across the region, and an estimate of historical habitat loss for different wetland types and locations.

1.3 Auckland's wetlands

Auckland's current stocks of wetland assets are reflective of the regions diverse landforms and development history. The Auckland region's land area is quite varied in terms of its topography and geology. The region encompasses significant parts of four ecological regions[1] and 13 ecological districts[2]. The steeper parts of the Waitākere and Hunua Ranges have retained much of their native ecosystems, including wetlands. However, their rugged topography means that wetlands were never very common in these locations.

In pre-human times the gentler hill-country that characterises Rodney local board and the low hills surrounding the Hunua Ranges was rich in swamp forest and palustrine wetland ecosystems that filled the basins and flat bottomed valleys (Lindsay et al. 2009). Almost all (92%) of these wetlands are gone (Singers et al. 2017). Although some good examples of indigenous wetland ecosystems still remain in these areas, the remaining wetlands are much smaller, more fragmented and altered in composition, compared to the habitat they replaced.

The flat and fertile lowlands that fringe the Kaipara and Manukau harbours, and form the Auckland isthmus, have suffered the greatest loss and alteration of their wetland habitats. In pre-human times wetlands were a common ecosystem in these locations, but they have been almost totally removed (99.6% loss, Lindsay et al. 2009) to make space for farming and urban growth. The wetlands that remain are significantly altered; weedy, negatively impacted by run-off from nutrients and pollutants, and with highly modified hydrology. On the positive side, the Auckland urban area is undergoing a dramatic expansion in the use of constructed wetlands as part of water sensitive design approaches. In recent times these artificial wetlands have significantly increased the overall area of palustrine wetland habitat within the Auckland metro area.

One of the defining characteristics of the Auckland region is its coastal influences; almost the entire regional land area is < 8km from the coast. Our long and sinuous coastline, large harbours and estuaries, and myriad of islands within the Hauraki Gulf mean the region is relatively rich in estuarine, saline and brackish wetlands. Collectively these comprise more than two-thirds of the remaining wetland areas.

Another characteristic of Auckland's wetlands is the relatively low proportion of riverine or lacustrine types. The region contains few large rivers, and <1% of the total wetland area comprises riverine types. The region also has very few lakes; only six[3] natural lakes > 20ha in size. The two largest lakes in the region, Ototoa and Pupuke, collectively comprise almost half of the total area of natural lakes. However, the water supply reservoirs in Hunua and Waitākere provide significant areas (c. 650ha) of artificial open freshwater habitat.

[1] Including Eastern Northland, Kaipara, Auckland and Coromandel ecological regions

[2] Including Awhitu, Great Barrier (Aotea), Hunua, Inner Gulf Islands, Kaipara, Little Barrier (Hauturu), Manukau, Otamatea, Rangitoto, Rodney, Taranga, Tamaki, and Waitākere ecological districts

[3] In order of decreasing size these are Ototoa (115 ha), Pupuke (107 ha), Spectacle (40 ha), Kereta (30 ha), Kuwakatai (28 ha) and Pokurua (24 ha)

1.4 Notes and limitations of the dataset

There are a number of limitations of the methodology and the comprehensiveness of the AWL. The project focused on mapping the extent of wetlands in the Auckland region, using desktop methodology to delineate their extent and a broad hydro-system classification, using available datasets and the desktop methodology.

Only wetlands detectable in the aerial imagery are included in this inventory. Small wetlands less than 0.01ha in size were not included and some wetlands difficult to detect on the images may have been missed. Additionally there will inevitably be error in the data, particularly where the boundaries of wetlands are cryptic or obscured by other features in the imagery. Some wetland classes are inherently more difficult to identify using aerial and desktop methodology such as forested wetlands; classes such as this are naturally less common than other wetland types.

Additionally, the AWL does not include un-vegetated intertidal mudflats, or any saline ecosystems below the point in the tidal range where mangroves cease growing.

In particular, we draw the attention of AWL users to the following limitations with using the dataset or analysis based on the dataset.

- The dataset is static – it is a 'snapshot in time' view of the extent of wetlands at the time of the aerial imagery from which boundaries were extracted. The majority of the regional coverage was captured in the summer of 2010/11 and the remaining area was captured in the autumn of 2012 (referred to throughout as the 2010/11 aerials).
- The dataset does not map the extent of the hydrosystems; it maps the extent of the wetland features (e.g. vegetation) that are then embodied by the hydrosystem.
- Aerial imagery limits classification of wetlands at broad hydrosystems level.
- Wetlands are dynamic features of the landscape; continuously changing in extent in response to altered climate and hydrological patterns. At the microscale, the area of wetland vegetation at the margins of some sites may therefore expand or contract with environmental changes.
- The dataset does not include very small wetlands[4]. The minimum mapping size was approximately 0.05ha (500m^2) as wetlands smaller than this were difficult to identify, especially those surrounded by forest and scrub vegetation.
- While every attempt was made to identify all wetlands it is likely (based on audit data) that a small number of moderate sized (i.e. 2ha+) wetlands were also missed.

[4] However, we note that these small wetlands are a minority in terms of total wetland habitat extent within the Auckland region. 60% of the wetlands in the AWL are <0.2ha in size, but these comprise only 3% of the total wetland area.

2.0 Methodology

2.1 Overview

Auckland is the 19th largest region in New Zealand by land area, covering 494,000ha, 1.84 per cent of New Zealand's land area. The study area is defined by the extent of the region encompassing the Auckland metropolitan area, rural areas, and the off shore islands in the Hauraki Gulf.

To effectively assess existing wetland delineations and classifications, and to identify and delineate new wetlands, a systematic 5km x 5km grid approach was used along with a semi-hierarchical classification system. The data preparation and creation processes were undertaken in ArcGIS 10.1 desktop geospatial software. This section documents how each step in the process was undertaken and the rules used to create the Auckland wetland layer. The process of developing the wetland dataset involved an initial assessment of pre-existing wetland datasets (in)accuracies and the creation of the Auckland Wetland Layer (Including the interpretation of aerial imagery, delineation and classification of wetlands).

2.2 Pre-existing wetland data

An assessment of pre-existing wetland datasets for the Auckland region (Table 2-1) was undertaken for the purpose of identifying the availability of accurate wetland data. These datasets were derived from a range of sources such as satellite and aerial photography, from different organisations and for different purposes.

Table 2-1, shows the total area of wetlands in the Auckland region calculated using a range of pre-existing wetland datasets. The values are therefore dependant on the accuracy of the individual datasets. Estimates are based on a summary of the total wetland area within each dataset, which includes freshwater and saline wetlands and openwater bodies. It is evident from the wide range of figures in Table 2-1 – the highest figure is almost 50 times the lowest – that some more systematic assessment and classification of Auckland's wetland assets was required.

Table 2-1: Pre-existing wetland datasets

Dataset	Description	Source	Total wetland area (hectares)
Freshwater Ecosystems of New Zealand (FENZ)	*Data sources include LCDB2, QEII covenant, topographic maps, DOC surveys and 15m DEM.* Waters of National Importance (WONI)	*Landcare Research for Department of Conservations: Land Information New Zealand: LINZ Data Service*	*2,530*
Topo	*Topographic mapping conducted by Land Information New Zealand, including data sourced form Landcare research and others. Wetland layers include the Swamp, Lake, Mangrove polygons.*	*Land Information New Zealand: LINZ Data Service*	*9,570*
The Land Cover Database 2 - 4 (LCDB)	*Manual & Automated classification developed by Landcare Research.*	*Land Information New Zealand: LINZ Data Service*	*13,360 (12,930*)*
Natural Heritage Wetlands (Also "DOC Wetlands Layer")	*Auckland regional wetland dataset collated by the Department of conservation (Chris Wild). Data sources include DOC and Auckland Council surveys, LCDB and WERI.*	*Auckland Council GIS*	*18,172*
Waterbodies Datasets	*Auckland Council Dataset. Includes, freshwater, saline, marine and inland water bodies such as lakes, ponds and reservoirs.*	*Auckland Council GIS*	*23,940*
Wetlands of Ecological Representative Importance (WERI)	National Inventory of all types of wetlands in NZ, compiled late 1980's	*DOC*	*113,520*

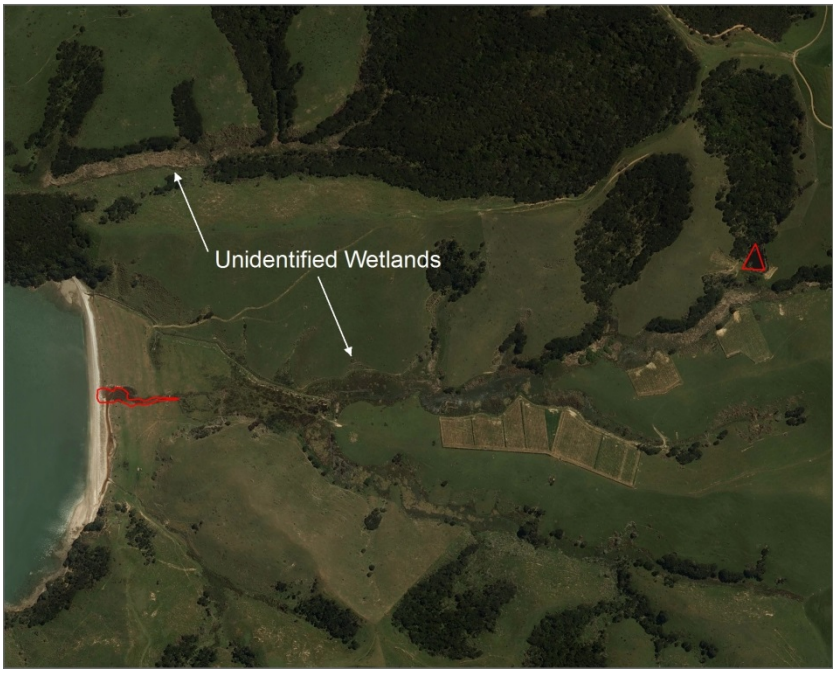
* LCDBv2, at the time of release the classification accuracies were much lower than that of LCDBv4. This was included as many of the other layers (Natural Heritage wetlands, Doc Wetlands) included polygons from LCDBv2 wetlands freshwater wetland classes only.

Several issues were identified within each of the datasets (e.g. Figure 1):

1. Inconsistencies in scale and inaccuracies in the extent of wetland boundaries.

2. Datasets contained artefacts or errors from older software or data capture processes and inherent errors arising from the merging of various layers.
3. Datasets contained old codes and classifications (and other attributes) no longer used.

Figure 1: Examples of pre-existing wetland datasets (taken from Natural Heritage / DOC Wetlands)



However, depending on the dataset, numerous mapped wetlands were audited at the time of collection, which included ground-truthing procedures, field inspections and reviews. Therefore, where appropriate it was possible to transfer spatial and attributes data into the new wetland layer if the characteristics were still consistent in the current aerial imagery. The pre-existing datasets were also an invaluable tool for locating potential wetlands for the purpose of remapping in the new wetland layer. The pre-existing wetlands were used

as a reference and polygons assessed based on current aerial imagery. A determination as to whether the polygon would be transferred into the new dataset or re-mapped was made. Re-mapping was achieved by manual digitization of wetland features using the most current aerial imagery.

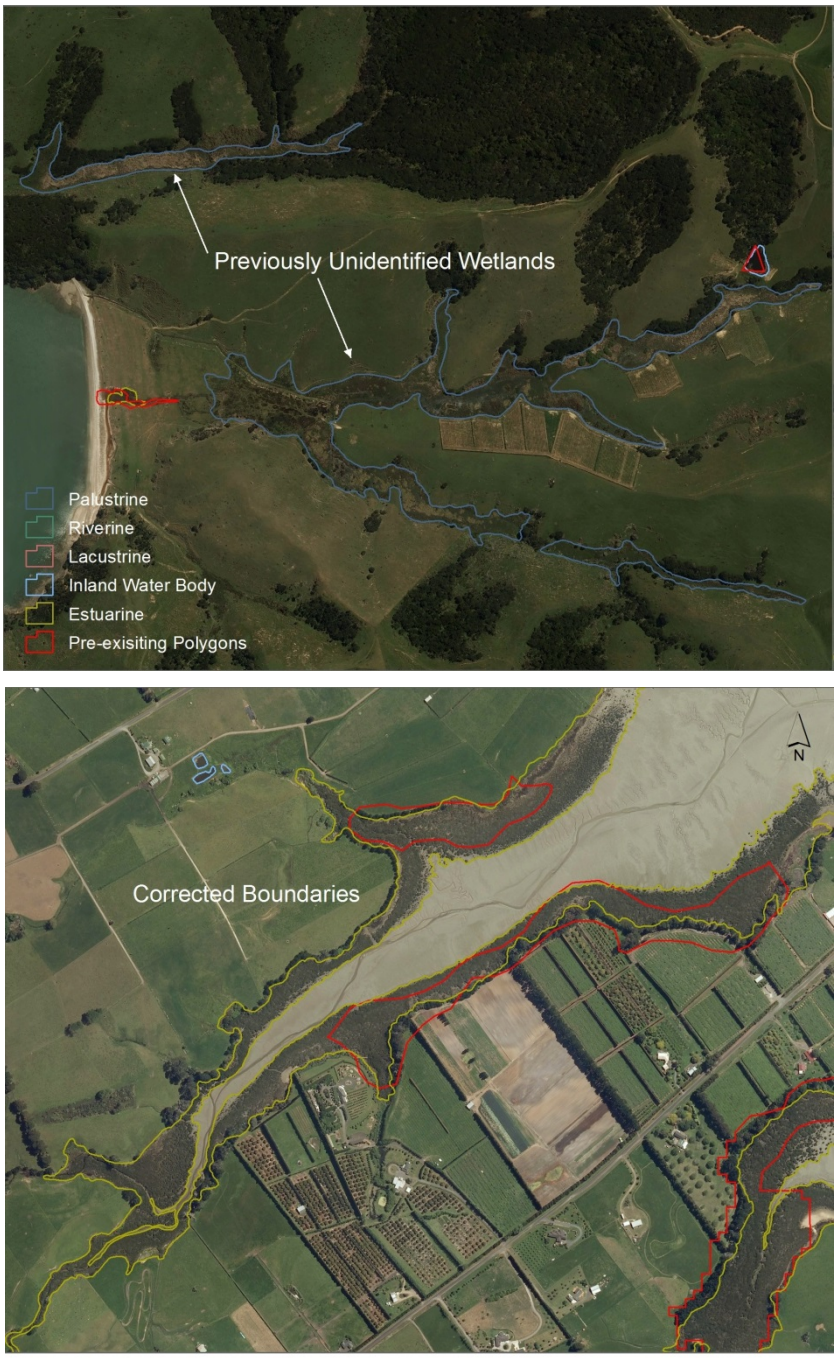
2.3 Wetland mapping

The Resource Management Act (1991) defines wetlands as including *"permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions"*. To accurately map wetlands using this definition has proved difficult and therefore a broader interpretation to include all, not just "natural" ecosystems, was adopted to delineate wetland boundaries. Another difficulty lies in determining where a wetland starts and finishes. Determining where to 'draw the line' is inherently challenging due to the ephemeral nature of wetlands in that wetland water and soil conditions tend to fluctuate. This was addressed by mapping vegetation, as vegetation cover and composition typically responds to longer term physical and chemical differences along a wetland to dryland gradient.

Our delineation of the current extent of wetlands improves on existing regional maps but is still an incomplete inventory as we were unable to depict ephemeral wetlands. This is an inevitable consequence of using imagery from a single time period. Aerial imagery favours depiction of wetlands with low stature vegetation like rush/reedland, whereas forested wetlands are difficult to separate from dryland forest. This was addressed by including the use of additional data to help locate known wet forested areas.

The primary source for wetlands for this project was the creation of original polygons (Figure 2). The new wetland layer also incorporates polygons from other datasets where the mapping resolution was equivalent. This includes the digitized field maps from the Auckland Council Wetland Monitoring Programme (400+ palustrine wetlands polygons) and wetland boundaries from targeted research programmes (e.g. Te Henga, Whatipu, Kaitoki). A significant portion of the estuarine wetland polygons were taken from work that tracked changes in mangrove extent in Auckland harbour (Carbines, 2016).

Figure 2: Examples of wetland updates included in the new 'Auckland Wetland Layer'



2.3.1 Search methodology

Each of the 5km x 5km grid tiles was searched for wetlands using the latest aerial imagery datasets (2010/11 and 2012). The Auckland's Territorial Boundary was used to define the study area.

The primary image layers were the rural and urban imagery datasets (Table 2-2), from which future aerial imagery and wetland delineations will be compared with. The imagery

was the latest imagery for the entire Auckland region at the time of completion and was captured in the summer of 2010/11 and autumn of 2012. Approximately 70 per cent of the region was captured in the 2010/11 and the remaining 30 per cent in 2012 (Appendix C and D). Google earth was also occasionally used to refine wetland extents. Mapping of wetlands involves locating and identifying wetland features in the landscape, and then spatial delineation (digitization) of the wetland boundary based on wetland features.

Table 2-2: Scale and resolution of the imagery used for the mapping

Year	Photo scale	Pixel resolution (m)
2010/11/12 Rural Catalogue	ortho-rectified RGB @ 1: 10,000	0.5
2010/11/12 Urban Catalogue	ortho-rectified RGB @ 1: 1,000	0.075

In cases where the interpretation of the aerial imagery was not clear, a number of secondary geospatial layers (Table 2-3) available to Auckland Council were useful in determining and refining wetland extents and classifications, this included a number of pre-existing wetland datasets and geology and hydrology datasets.

Table 2-3: Secondary geospatial layers

Dataset	Description	Source (Access date)
Freshwater Ecosystems of New Zealand (FENZ)	National extent of wetlands collated by Department of Conservation. Data sources include LCDB2, QEII covenant, topographic maps, DOC surveys and 15m DEM.	*Land Information New Zealand: LINZ Data Service (2013)*
The Land Cover Database 4 (LCDB)	Manual & Automated classification developed by Landcare Research.	*Land Information New Zealand: LINZ Data Service (08/2014)*
QEII	Polygon data showing boundaries of QEII covenants. Attribute data does not distinguish ecosystem types.	*Land Information New Zealand: LINZ Data Service (09/2013)*
Contours	2006 Rural 1m Contours. Created from the 2006 LiDAR data.	*Auckland Council (09/2013)*
Rivers	Auckland Regional Council River Numbers dataset (derived from NZMS260) created by consents team.	*Auckland Council (09/2013)*
Ecosystem Layers	Auckland Council Biodiversity Ecosystems Layers – current and historic extent of ecosystems.	*Auckland Council (03/2016)*
Topo	Various Topo50 layers: Lakes, Rivers, Wetlands, Lagoons, ponds. Update Annually	*Land Information New Zealand: LINZ Data Service (09/2013)*

2.3.2 Interpretation of aerial imagery

In theory, features can be identified using visual or automated methods. This project used visual methodology. Even with sophisticated computing techniques and improved algorithms, the brain is still better at processing the vast amounts of information required to identify fine scale wetland features in aerial imagery. The visual interpretative methodology associates features you see in an image with objects you are familiar with on the ground.

To identify wetlands, basic visual cues in the image were used; such as tone (colour), size, shape, texture, pattern, relative and absolute location and shadows to determine the identity of a particular feature. The primary image features used to delineate wetland boundaries was vegetation. This vegetation based system was used because water levels and soil conditions tend to fluctuate, whereas vegetation cover and composition typically respond to longer term physical and chemical differences along a wetland to dryland gradient. Many of these differences in vegetation cover can be identified in aerial imagery.

The most important visual cues for identifying wetland vegetation boundaries were colour, texture and pattern. Whereas the most important cues for interpreting and classifying wetland hydrosystem types was the location within the landscape using aerial imagery with the addition of secondary datasets such as contours and watercourse data.

Difficulties arose when attempting to define boundaries between geographically linked systems, i.e. where a single wetland system crossed multiple hydrosystems (the highest order classifications of wetlands). Boundary identification could be determined using visual cues such as a change in vegetation composition or changes in the clarity or colour of water adjacent to the wetland polygons, indicating a change in salinity. Other changes such as boundaries between lacustrine to palustrine, and riverine to palustrine were more difficult, although less frequent.

2.3.3 Delineation of wetlands

Manual digitization methods are often referred to as ‘heads-up’ or ‘on-screen’ digitizing since the interpreter is drawing boundaries on the computer screen. Manual delineation of wetland features took place during the interpretation of imagery and identification of wetlands features. The following general methods and procedures were applied;

- Delineation of the wetland feature to resemble the actual size and shape. No minimum mapping unit was established, however all objects that could identified as wetland features were mapped generally no smaller than 0.02 hectares (200m^2)
- Wetland polygons where digitized at 1:250 – 1:1,250 scale resolution depending on the aerial imagery dataset available for a given area (0.075 to 0.50m pixel resolution)
- Wetland boundaries were digitized around wetland features (e.g. vegetation canopy) visible in aerial imagery
- Polygons were smoothed using the polygon ‘smooth‘ tool at a maximum allowable offset of 0.01m
- In the case of obscured features in the aerial imagery caused by shadows and building etc., the boundary was drawn where vegetation is visible rather than making an estimate of where the wetland lies under the obstructing features (with the exception ‘Inland Water Body‘ class: ‘Ponds‘)

- Where wetland systems cover multiple hydrosystems, separate delineations are made and classifications applied accordingly

Each wetland polygon mapped had data entered for most (but not all) of the following attributes;

Table 2-4: Attribute data variables for wetland inventory shapefile

Attribute	Description	Mandatory fields
FID	Unique ID. Generated automatically	Yes
Wetland	Common wetland name (if available)	No
WL_System*	Hydrosystem class, the primary typology (Estuarine, Riverine, Lacustrine, Palustrine, Inland saline)	Yes
WL_Form*	Landforms wetlands occupy, forms which wetlands create, forms or features which wetlands contain	No
WL_Subsys*	A descriptive level relating to water regime	No
WL_Class*	Wetland Class (Bog, Fen, Swamp, Marsh, Seepage, Shallow water, Ephemeral wetland, Pakihi and gumland, Saltmarsh).	No
Vege_Type*	Vegetation structural class	No
Use	Anthropogenic activity or 'Natural' (generally assigned to "Inland Water Body" hrydrosystem)	No
Comments	Methods and Identification Source file name	Yes
Source	Imagery dataset the wetland polygon was digitized	Yes
CreateBy	Organisation, Department or Team who created the wetland polygon	Yes
District	Ecological District of the wetland polygon	Yes
Shape_Area	Area (Hectares) of the wetland polygon	Yes
Year	Year of polygon creation	Yes

*From Johnson and Gerbeaux (2004)

2.3.4 Wetland polygon classification

To describe the biological patterns in wetlands we adopted the existing, semi-hierarchical classification system defined in Johnson & Gerbeaux (2004). The uppermost unit of classification applied to wetland delineations is based on the hydrological function, considered to be a key characteristic dictating wetland physicality and ecology and describes basic wetland functions. This classification is based on broad hydrological and landform setting, salinity and temperature qualities and focused on the palustrine, lacustrine, riverine, estuarine and open water wetlands. In practical terms, hydrosystems are of relevance for grouping wetlands over relatively large areas and on a regional basis. Although hydrosystem boundaries cannot be expected to be clearly defined on the ground due inherent geological gradients, they do however provide an appropriate scale to begin the classification. For the purpose of classifying open water associated with inland wetlands, we have used an 'Inland Water Body' class to fulfil this need.

Table 2-5: Hydrological function definitions, taken from Johnson and Gerbeaux (2004)

Hydrosystem	Defining features
Estuarine	Saline wetlands associated with estuaries, tidal reaches and mouths of coastal rivers, coastal lagoons and open habitats where the soils are affected by sea salts. This includes areas of subtidal, intertidal and supratidal zones.
Riverine	Freshwater wetlands associated with rivers streams and other channels where the dominant function is the flow of water in open channels. The wetlands include the open flowing water and the bed and riparian margins.
Palustrine	All freshwater wetlands fed by rain, groundwater or surface water but not directly associated with lakes, rivers or estuaries.
Lacustrine	Freshwater wetlands associated with the margins of lakes and open water bodies large enough to be influenced by characteristic lake features and processes such as fluctuating water level, wave action, water deep and nil or only slow flow.
Inland water body	This includes areas of inland open water such as lakes and ponds and pooling surface water but excluding rivers and streams.

Where possible lower level classifications were also applied to wetland polygons (sub-system, wetland class, wetland form, structural class and dominant cover). Lower level classifications were only assigned where scale enabled this and/or where determinations based on interpretation of imagery and additional information aided an accurate classification. Where multiple wetland classes or other classes existed within one wetland polygon either the dominant type was assigned or no type was assigned at all.

All wetland polygons were saved within one shapefile (feature class) called the 'Auckland wetland layer' and stored within a Geodatabase located within Auckland Council folder structures.

2.3.5 Wetland to polygons

Defining wetland sites (whole systems) is problematic in a fragmented landscape such as Auckland's. In the absence of local information, there was a need to combine wetland fragments into single sites or a wetland complex. This is especially important when delineations are based on vegetation cover to define boundaries and not the underlying substrate. Until they are aggregated we cannot derive the total number of wetlands or wetland systems in Auckland region. Depending on the wetland type, the 'whole' system requires aggregation. For the purpose of identifying wetland systems in the Auckland region a set of aggregation criteria were defined (Table 2-6).

Aggregation of discrete wetland polygons is especially important for palustrine wetlands, where wetlands are disconnected by a physical feature, such as access ways and roads. One could argue that palustrine wetlands should be aggregated up to catchment level to establish a 'whole' system. In this project, palustrine wetlands were aggregated based on their proximity to capture potential interconnectedness. The proximity measure aimed at aggregating (but not physically connecting) wetland features. All palustrine polygons within 50m of each other were tagged with identical IDs, all unique IDs therefore become the

'wetland'. No physical join between features were made. However whether this approach is appropriate can only be assessed on a site by site basis.

Table 2-6: Polygon to wetland criteria

Hydrosystem	Aggregation criteria
Palustrine	Proximity measure: all palustrine wetlands within 50m of (25m buffer) the nearest neighbours are in the same wetland.

2.4 Quality checking

In order to increase the confidence in the wetland dataset an independent audit was carried out by experienced ecologists (Miriam Ludbrook – Wildland Consultants, Jade Khin and Craig Bishop – Auckland Council). Although other quality control measures were implemented during the interpretation, delineation and classification process, it is inevitable that not every wetland will be captured. The resources required to undertake a full assessment of the wetland layer and field verification of the wetland polygons was cost prohibitive for this project; therefore desktop analysis of a subset was randomly identified for QA.

Auditing the Auckland Wetland layer was a two-step process. The first steps were to quality check the positional and classification accuracy of polygons in the layer. The second step was checking the completeness of the layer.

A three percent target was established for both phases of wetland polygon audit. Phase one involved randomly selecting 3 per cent of the wetland polygons from each hydrosystem and assessing the accuracy and consistency of wetland delineations and classifications. The outcome of the audit was encouraging in that approximately only 6 per cent of randomly selected wetland required modification; of the 260 wetlands that were assessed, 1 was reclassified, 14 delineations were adjusted and 3 polygons were removed.

The second phase involved re-assessing 3 per cent of the Auckland land area using 500mx500m tiles covering the entire region and identifying all wetlands (captured as point features) to cross check against the wetland layer. Particular focus was given to assessing the freshwater wetlands as they are typically the most challenging wetlands to accurately delineate and classify using desktop methods.

3.0 Results

3.1 Total area of Auckland's wetlands

The new wetland layer is primarily composed of original wetland polygons. The entire Auckland region was mapped, using aerial imagery captured in the summer of 2010/11 and autumn of 2012. A total of 11,500 wetland polygons were mapped across the Auckland region with a total area of c.17,250 ha. The majority of wetland polygons mapped were small and/or modified wetlands that had not been accounted for in previous layers. The primary classifications assigned to the wetland polygons are summarised in Table 3-1 and Figure 3, and shown in Figure 4.

Estuarine and palustrine wetlands are the two most extensive hydrosystems in the Auckland region making up 65 per cent and 22 per cent respectively of all current wetland area. Riverine and Lacustrine wetlands are the rarest forms of wetlands.

Table 3-1: Summary of Auckland wetland polygons mapped

Hydrosystem	Wetland polygons (count)	Area of wetland polygons in hectares (portion of total)
Estuarine	2,892	11,290 (65%)
Riverine	140	180 (1%)
Palustrine	3,297	3,870 (22%)
Lacustrine	143	40 (0.2%)
Inland Water Bodies (including Natural Lakes)	5,121	1,890 (11%)
Total	11,593	17,250

Figure 3: Relative area of Auckland region wetland hydrosystem types

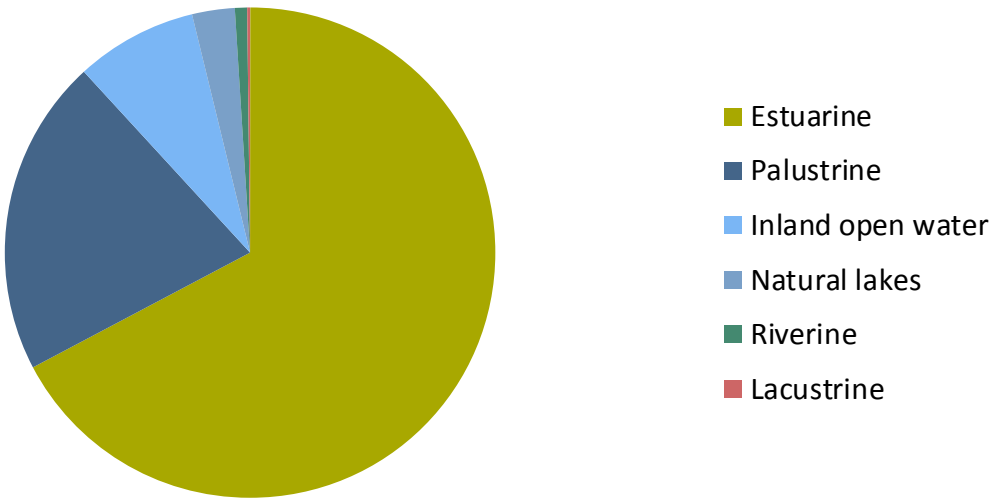
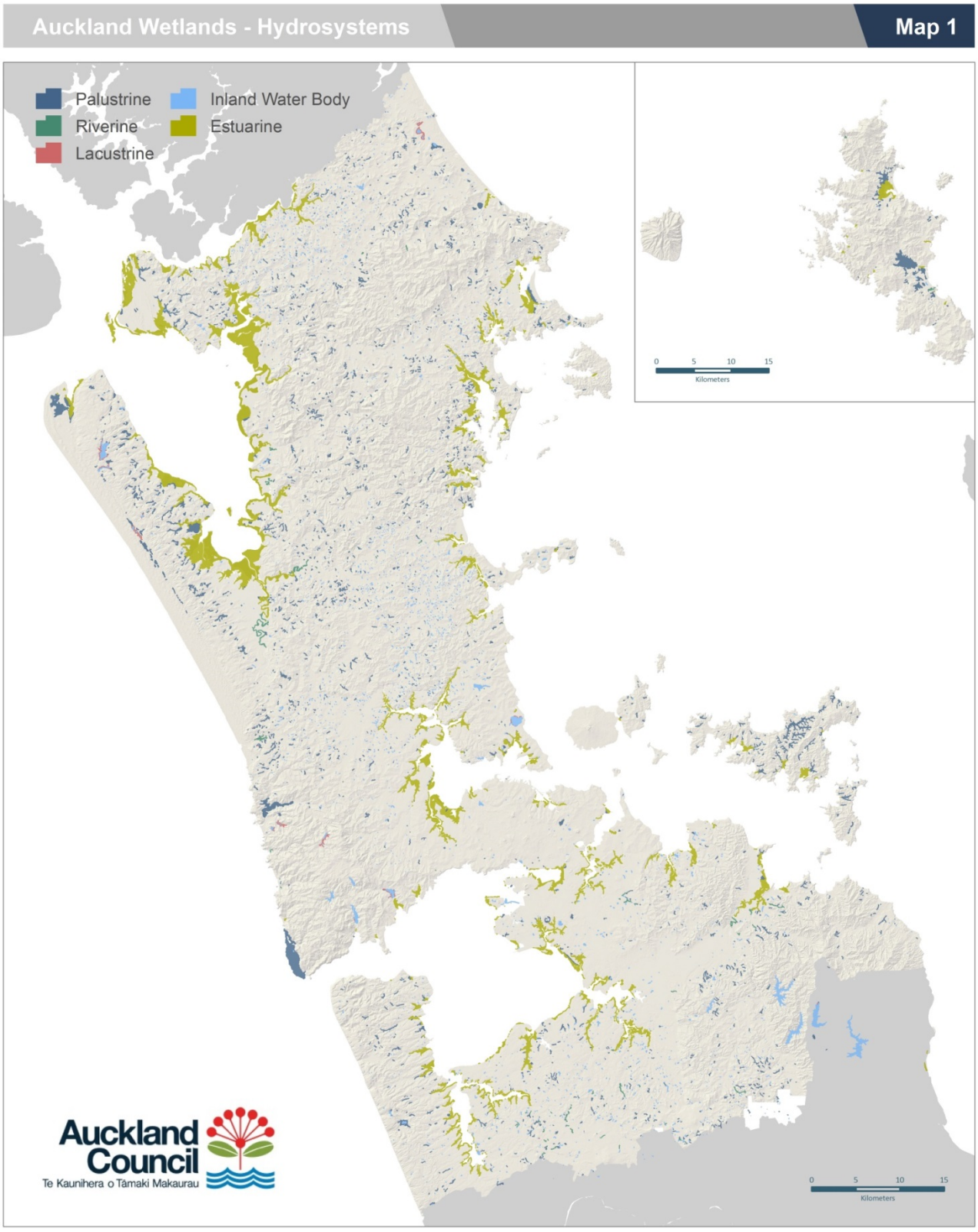


Figure 4: Auckland Wetland Layer



Unsurprisingly, there was a very wide variation in total area and type of wetlands between the regions ecological districts.

Table 3-2: Area (in ha) of wetlands by hydrosystem class for the regions 12 different ecological districts. Area totals are rounded to the nearest 10ha

Ecological district	Estuarine	Inland water body	Lacustrine	Palustrine	Riverine	Grand total
Awhitu	390	50	0	140	0	570
Great Barrier Island	270	10	0	590	20	870
Hunua	420	580	10	180	30	1,190
Inner Gulf Islands	150	10	0	250	0	410
Kaipara	4,180	260	20	980	100	5,510
Manukau	850	160	10	160	40	1,190
Otamatea	2,040	110	0	120	0	2,260
Rangitoto	10	0	0	0	0	10
Rodney	1,270	270	20	760	10	2,320
Tamaki	1,680	290	10	120	10	2,090
Waitakere	80	200	20	610	10	880
Grand total	11,290	1,890	40	3,870	180	17,250

Estuarine

Estuarine ecosystems comprise the largest area of wetland ecosystems in the Auckland region; 11,290 ha, or 65 per cent of the total wetland area. Estuarine ecosystems are overwhelmingly dominated by mangroves (91%) scrub and shrubland, although this general wetland class also includes much smaller areas of indigenous saltmarsh reedland, saltmarsh herbfield and salt meadow ecosystems. Estuarine ecosystems are found along much of the Auckland coastline, although they are less common on exposed parts of the western coast (Figure 4). Estuarine ecosystems are most dominant in harbours, especially the Kaipara Harbour, and the estuarine reaches of the larger rivers.

Inland water bodies

A total of 5121 inland water bodies (IWB) were mapped in the layer. Ninety-four per cent of these are <0.4ha in size. These small water-bodies are overwhelming artificial; constructed for the purposes of water supply, treatment or retention (Figure 5 and Figure 6). While Auckland is the most populated region in New Zealand, the land cover is still dominated by agricultural use which includes a myriad of small ponds and reservoirs dotting the landscape. In urban areas, stormwater ponds are an important contributor to this class.

Just 321 inland water bodies, 6 per cent of the total, are larger than 0.4 ha. These larger IWB were further sub-divided into four classes, depending on use. Of the larger IWB, 41 were natural features (13% of total and 32% of area) although many of the artificial lakes and reservoirs still provide important habitat for native birds and support indigenous wetlands around their margins.

Compared to other parts of New Zealand, Auckland has few large IWB. The total area of the 41 largest natural IWB in the region is approximately 470 ha. Almost half of this total area is provided by just two lakes; Lake Ototoa (115 ha) and Lake Pupuke (105 ha).

Figure 5: Size frequency distribution of different classes of open water bodies 0.4+ha in size

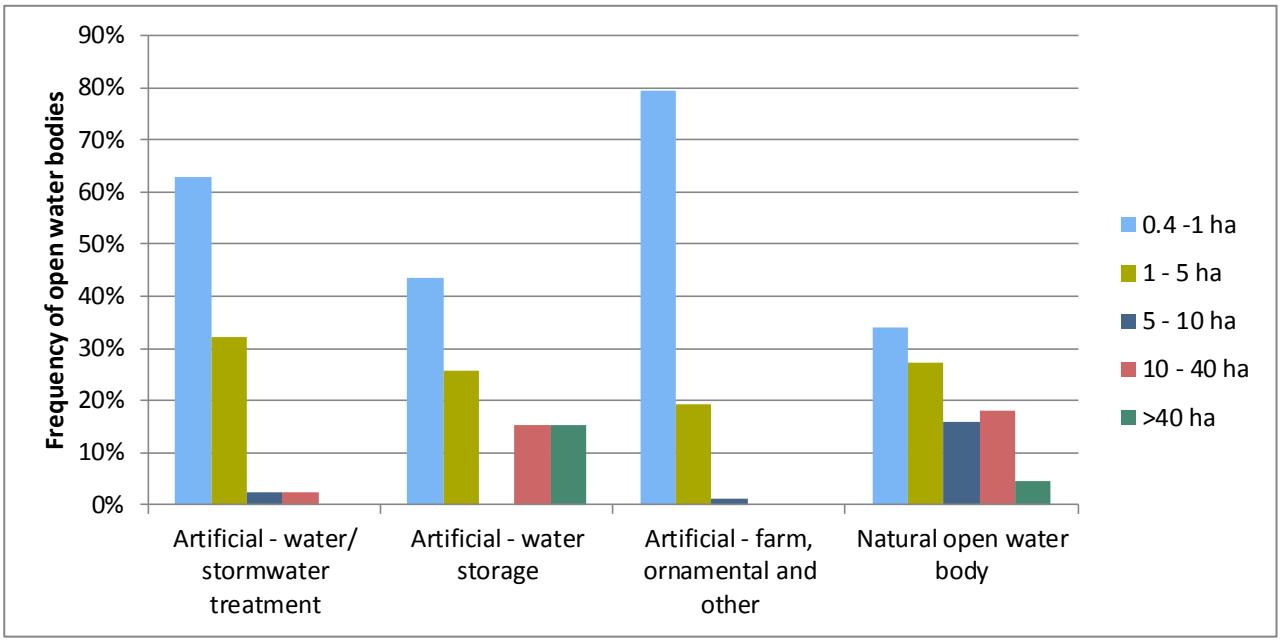
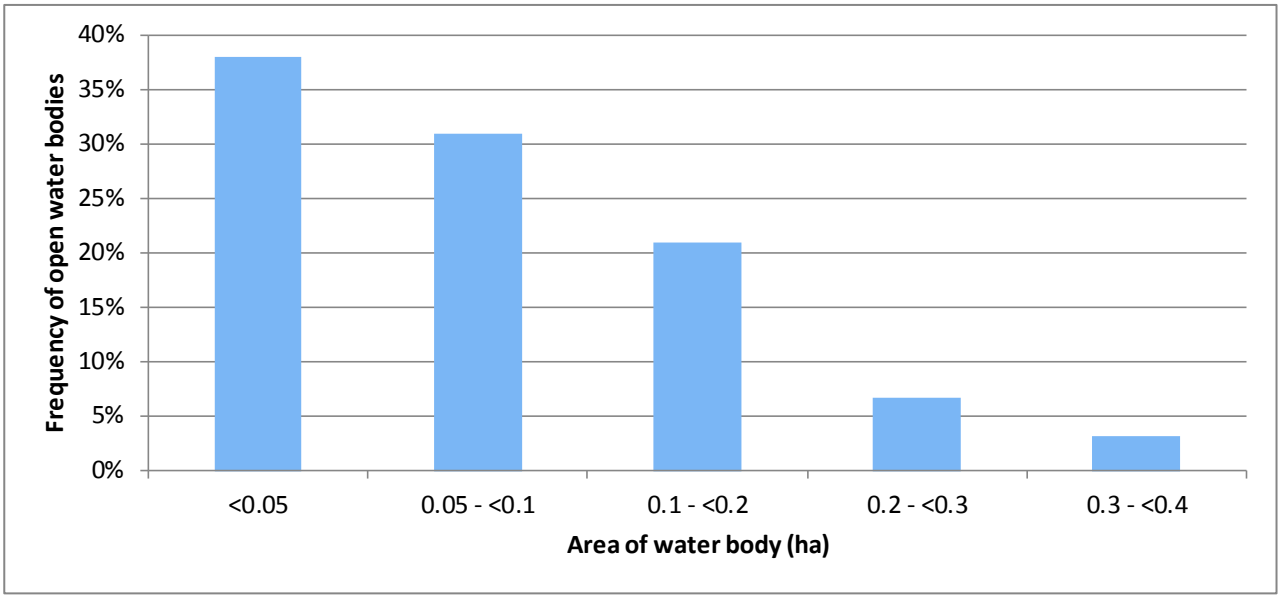


Figure 6: Size frequency distribution of open water bodies < 0.4 ha



Lacustrine

Given the Auckland region's very small area of inland water bodies it is unsurprising that there is only a very small area of lacustrine wetland ecosystems mapped in the Auckland wetland layer. Comprising approximately 40ha of habitat, or <1% of total regional wetland area, lacustrine wetland habitat is mostly concentrated around the margins of the larger dune lakes of the South Kaipara Peninsula and Te Arai, and water supply reservoirs in the Waitākere Ranges. Wetlands at just seven sites – Spectacle Lake, Lake Ototoa, Lake Kerata, Lake Wainamu, Slipper Lake, Lower Nihotapu Reservoir and Waitākere Reservoir – comprised almost 85 per cent of the total area of lacustrine wetland.

Palustrine

Palustrine wetlands are the dominant freshwater wetland type in the Auckland region; comprising 95 per cent of the total area of freshwater wetlands, but only 22 per cent of all wetlands (i.e. with estuarine systems included). The palustrine wetlands include a variety of different wetland sub-classes including those defined in Johnson and Geber (2004) as swamps, fens, marshes and bogs. More fertile, swamp-type, wetland ecosystems are probably the most dominant palustrine sub-class. Data from the regional wetland monitoring programme (Appendix G), which should provide a representative sample of the relative importance of wetland sub-classes, showed that more than three quarters (76%) of palustrine wetlands sampled were swamps, 13 per cent marshes, and the remaining 11 per cent bogs, fens and other types.

Riverine

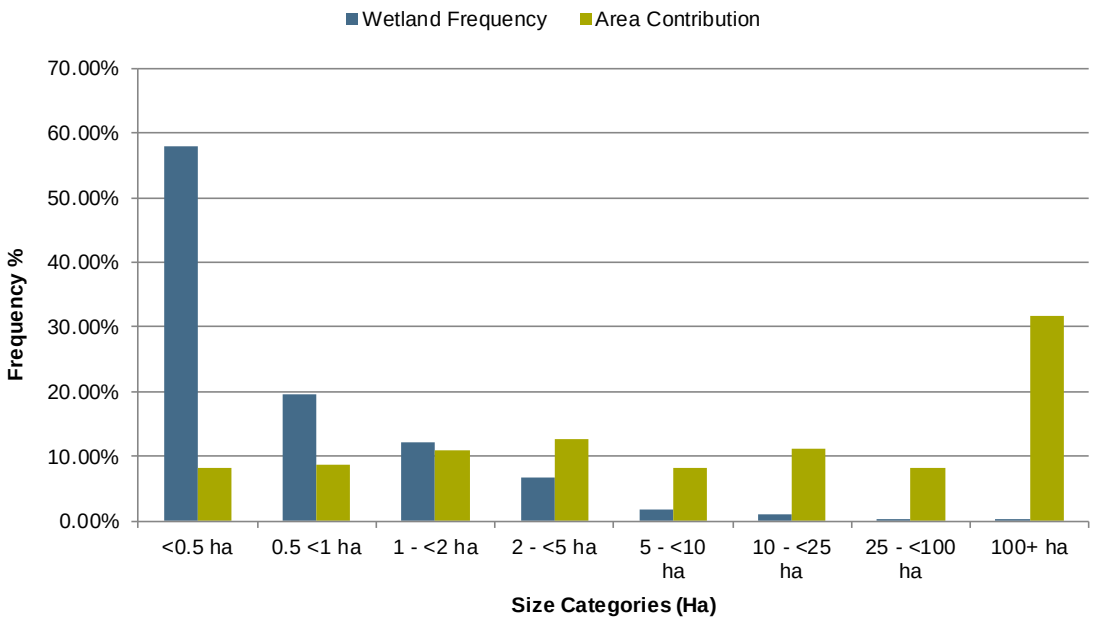
Auckland has no large rivers and very few moderate sized ones, hence the total area of riverine wetlands is a relatively small proportion of total area; approximately 180ha or 4 per cent of freshwater wetlands and <1% of all wetlands.

3.2 Polygons to wetlands

This section summarizes the distribution and characteristics of different wetland types within the Auckland region. It is based on the wetlands, rather than polygons. Wetlands were created by combining individual polygons in close proximity into a single value that was representative of the wetland system as a whole (see section 2.3.5). A total of 3297 palustrine polygons were mapped in the new layer, this was reduced to 2461 wetland sites after aggregating using the proximity measure.

Of the total 2461 palustrine wetland sites mapped in the Auckland region, almost all (98%) are smaller than 10ha, and more than half (58%) are less than 0.5ha, collectively 17 per cent of palustrine wetland area (Figure 7). There are 0.2 per cent palustrine wetlands over 100ha, which in total covers 32 per cent of the total palustrine wetland area. These large wetlands[5] are mainly palustrine, and mostly on the west coast. Auckland's largest wetland (Whatipu: ~400ha) is a complex dune and freshwater wetland system located on the south/western tip of the Waitākere Ranges. Almost half of all Auckland ecological districts contain no palustrine wetlands over 100ha.

Figure 7: Size frequency and proportional contribution to total area of palustrine wetlands across Auckland region (2461 palustrine wetlands)



[5] There are five palustrine wetlands over 100ha in the Auckland region. In order of decreasing size these are: Whatipu wetland complex; Kaitoke Swamp (Aotea/ Great Barrier Island); Papakanui wetland complex (South Kaipara Head); Te-Henga/ Bethell's wetland; and a coastal wetland within the Native Forest Restoration Trust owned Marie Neverman Reserve, Kaipara Harbour

3.3 New wetland polygons vs old

There is a significant difference in the number and extent of wetland polygons between the new Auckland wetland layer and the pre-existing layers. Through the process of compiling the new wetland layer, we have either deleted or re-drawn 98 per cent of the map polygons from the original layers. A large number of wetlands were identified that had not been accounted for in previous inventory layers. Approximately 40 per cent of the freshwater wetland polygons in the new dataset share geometries (intersect) with pre-existing dataset polygons (included in Table 2-1) and the remaining 60 per cent of polygons in the new layer are previously un-inventoried. This means that large portions of pre-existing wetland polygons are not included in the new wetland layer. There are several reasons for this, for example where many of the old wetland polygons were insufficient in size and/or did not accurately represent the features of interest.

As highlighted in the assessment of pre-existing wetlands (Section 2.2) the key difference between the AWL and these historical wetland layers is that the earlier Natural Heritage wetland datasets were created by collating wetland polygons from a variety of sources; which included national, regional and some project level mapping delineations. This resulted in inconsistencies in the scale, classifications and accuracy of the wetland delineations.

4.0 Conclusion and recommendations

Overall, there were a large number of previously unmapped wetlands now delineated in the new Auckland wetland layer. The vast majority of pre-existing wetland delineations have been updated based on the 2010/11 aerial imagery. The near complete re-digitization of pre-existing wetland extents and the mapping of previously un-mapped wetlands has resulted in a single dataset for the Auckland region that has a consistent mapping scale, mapping resolution, delineation and classification methodology, a first for the Auckland region.

The outcomes of this project can inform several aspects of regional wetland, freshwater and terrestrial management for the Auckland Council. This will also be of value for national monitoring and reporting.

- State of the environment monitoring – changes in the regional wetland extent, identification ad prioritisation of wetlands for the condition of monitoring.
- Identification of priority areas for Significant Ecological Areas (SEA's) surveys
- Regional and national planning effectiveness – how effective are our plans and laws at effectively protecting wetlands
- Assess the level of formal protection for wetlands on private land
- Inform biodiversity monitoring programmes

Further work to rank and prioritise the wetland features using other information or surveys and assessments could be undertaken.

The new Auckland wetland layer provides more spatial detail than previously available and is accessible through Auckland Council's, Research and Evaluation Unit (RIMU) or the Geospatial team and publicly available online in Geomaps. The Auckland wetland layer dataset is now strategically placed to be updated using more recent aerial imagery.

5.0 References

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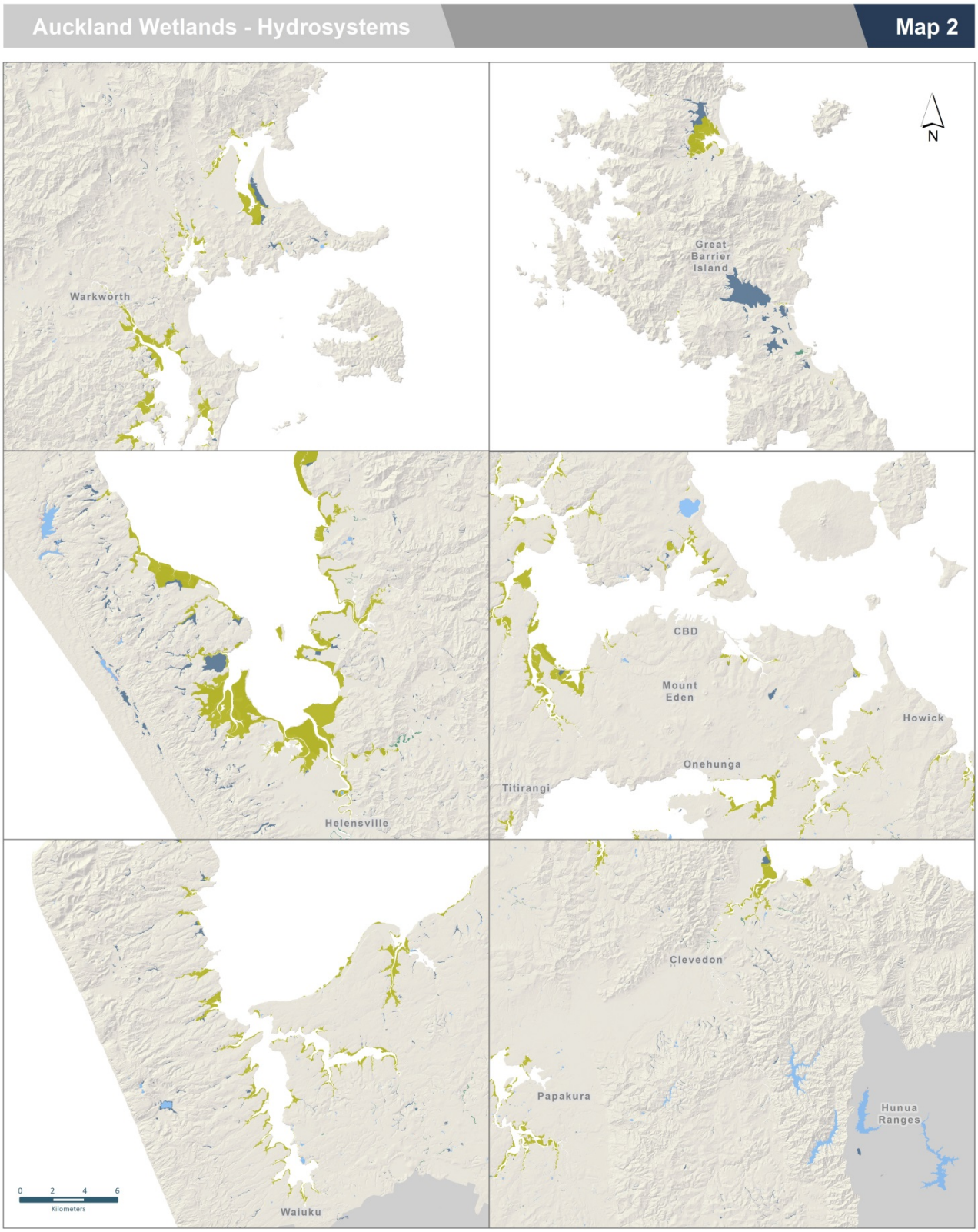
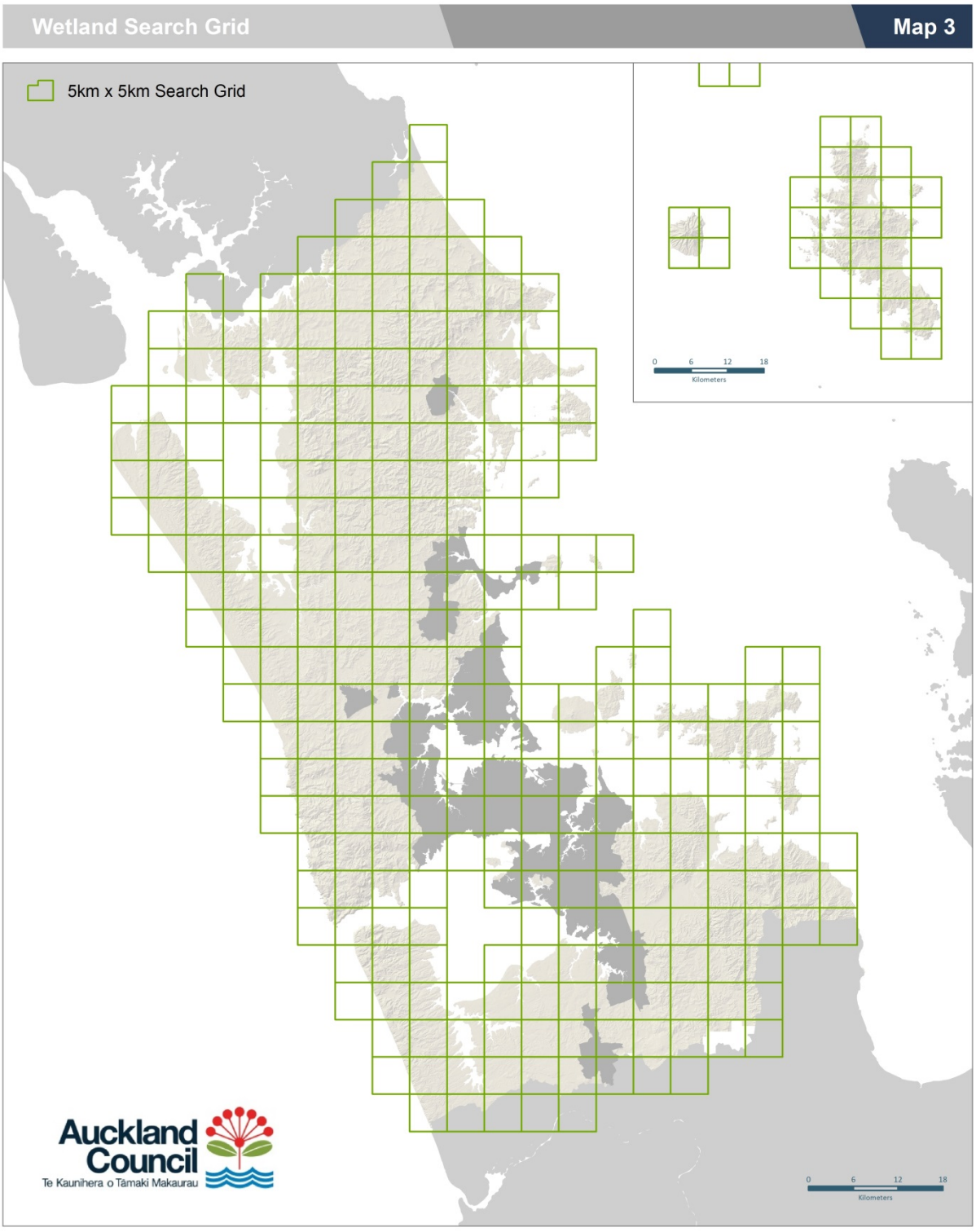
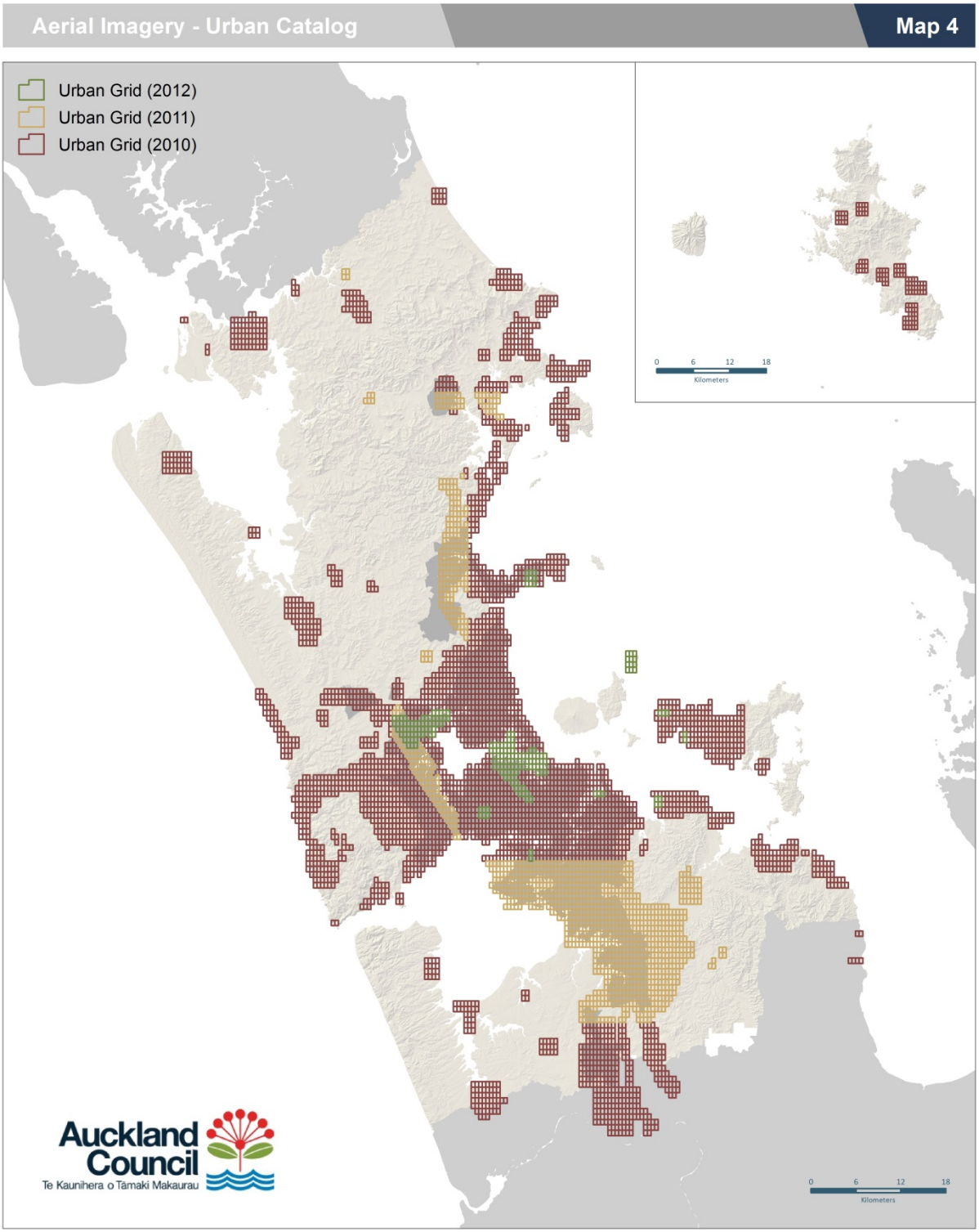
Appendix A: Auckland wetland layer – examples



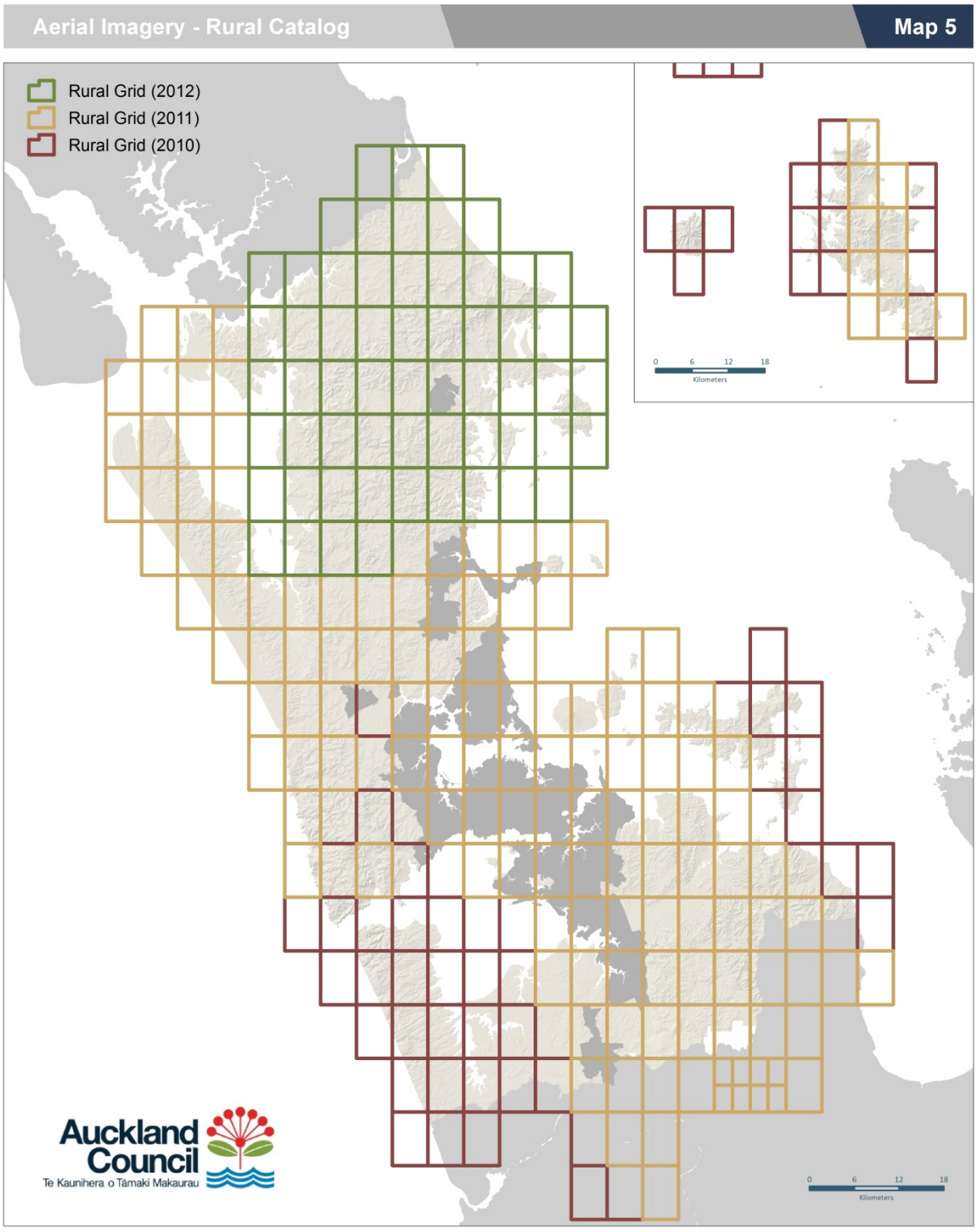
Appendix B: Search grid



Appendix C: Urban aerial image catalogue



Appendix D: Rural aerial image catalogue



Appendix E: Auckland wetland layer notable examples

Appendix F: Wetland classification hierarchy

Semi-Hierarchical Classification system, after Johnson and Gerbeaux (2004)

I_System*	IA_Subsyst	II_Class	IIA_Form	Vege_Type
Palustrine	Permanent	Swamp	Flat	Reedland
Lacustrine	Ephemeral	Marsh	Channel	Grassland
Geothermal		Bog	Basin	Herbfield
Inland Saline		Ephemeral	Other	Cushionfield
			Doomed	
Marine		Fen	Bog	Mixed
Nival		Pakihi	Dune Slack	Rushland
Plutonic		Saltmarsh	Fan	Shrubland
Riverine		Seepage	Mudflat	Openwater
Estuarine		Shallow Water	Plateau	Treeland
Terrestrial			Pool	Scrubland
Openwater			Rand	Tussockland
			Slope	Fernland
			Spring	Floating Herbfield
			String Fen	Cushionfield
			Swale	Turf
			Terrace	Mossfield
				Lichenfield
				Algalfield
				Sedgeland
				Scrub
				Forest
				Flaxland
				Vineland

*Mandatory field: **Bold** are relevant hydrosystems in Auckland

Appendix G: Regional wetland monitoring programme description

Auckland's regional wetland monitoring programme commenced in February 2010, with work carried out under the auspices of the Auckland Regional Council. This work was continued (in expanded form) by the Auckland Council, after the formation of the 'super-city' on the 1 November 2010.

The wetland monitoring programme aggregates data from a network of around 270 wetland sampling points across the Auckland Region. Approximately 150 of these points were chosen from a 4km x 4km grid by selecting the nearest wetland to every 2nd grid point. A further 50 plots located in key interest areas - e.g. inside the Metropolitan Urban Limits, in highly threatened ecological districts etc. – were chosen off the same 4km x 4km grid to increase replication in these landscapes. The remaining 70 plots comprise groups of 12-20 plots established to monitor change in key regional wetland systems such as Te Henga/ Bethell's wetland, Kaitoke Swamp and the Whatipu wetland system.

The regional wetland monitoring programme is based around standard national approaches/ methodologies that have been developed for wetland monitoring in New Zealand (Clarkson et. al. 2004). Using national protocols ensures Auckland Council data collection is a best practice approach, and means Auckland data is comparable with other regional datasets and is easily aggregated for national reporting requirements. Data collection includes intensive, plot based sampling of a single location in the wetland and more general information recorded during a 2 – 3 hour survey of the whole wetland system. Plot data collected includes species presence and abundance data, a vegetation map of the plot and surrounding ecosystems, and establishment of photo-points. Data collected in the general survey includes 10 minute bird counts, playback of taped bird-calls/ listening for key wetland bird species (i.e. fernbird, Australasian bittern and spotless crake), a vegetation map for the whole wetland system, and assessment of wetland condition.

The main objective of the wetland monitoring programmes is to measure landscape scale changes in indigenous biodiversity and the distribution of weeds and pests. When used in conjunction with data from other Auckland Council monitoring programmes, these data can be used to assess whether the various sustainability and natural heritage objectives of council policies and plans are being met. Data from individual plots is aggregated, for example by geographic area or wetland class, and a series of wetland indicator values calculated for each area or wetland class. The exact make-up of the indicators to be used for reporting is still to be determined, and will probably depend on the audience for which the monitoring data is intended.

The plot network includes most of the key wetland ecosystems in the Auckland region. However, there are still some important wetland ecosystems that are missed or poorly represented in the proposed plot network; in particular dune wetlands, saline and brackish wetlands, and lacustrine (lake margin) wetlands are quite ad-hoc in their coverage.

Find out more: phone 09 301 0101, email rimu@aucklandcouncil.govt.nz or visit aucklandcouncil.govt.nz **and knowledgeauckland.org.nz**

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