Department of Conservation
Fonterra

Living Water: Collation of Baseline Environmental Data for the Lake Rotomanuka Catchment

Kessels Ecology
SURVEY, ASSESSMENT AND RESTORATION

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EXECUTIVE SUMMARY

This report provides a collation of baseline environmental information for the Rotomanuka catchment as part of the Living Water Partnership peat lakes project.

A wide variety and considerable quantity of data is available for the catchment which has been collected over at least 30 years. Data relating to the physical characteristics of the catchment, soils, climate, hydrology, water quality, and biodiversity are summarised or discussed. Gaps in the data are also pointed out.

The Rotomanuka catchment has been heavily modified since European settlement in the area. One of the key features of the catchment, its peat soils, have been drained and the lakes have been degraded by eutrophication. Nevertheless, the Rotopiko lakes are considered to be the best quality peat lakes in the Waikato because of their water quality, the dominance of indigenous species in the submerged flora, and for their marginal wetlands. Rotomanuka is the deepest and oldest lake in the Waipa District and despite having poor water quality and completely lacking submerged macrophytes it has good quality marginal wetlands which retain some of the characteristics of the original system.

A significant amount of restoration work has been done in the catchment, both at Rotopiko and at Rotomanuka. This has included pest fish control, weed control, research into macrophyte re-establishment, riparian fencing, planting, and pest control.

The data available for the catchment provides a solid foundation on which managers can base decisions on catchment management and restoration and only minor additions are likely to be required to improve decision making.

1 INTRODUCTION & SCOPE

1.1 The Living Water Partnership

The Living Water Partnership is a collaboration between the Department of Conservation and Fonterra to protect and enhance sensitive water catchments by undertaking restoration and management work beyond normal on-farm commitments. It recognises the importance of healthy waterways for their intrinsic natural value, biodiversity value and for the ecosystem services they provide. The partnership coordinates a $20 million community investment fund and is initially focusing on five key catchments or project areas across New Zealand. One of these project areas comprises the three peat lake catchments of Areare, Rotomanuka, and Ruatuna in the Waikato. This report deals solely with the Rotomanuka catchment which includes five peat lakes: Rotomanuka North, Rotomanuka South (sometimes referred to as Lake Gin), Rotopiko North, Rotopiko South, and Rotopiko East. The Rotopiko lakes are otherwise known as the Serpentine lakes.

The lakes of the Rotomanuka catchment have been the subject of a considerable amount of research and monitoring by the Waikato Regional Council, Waipa District Council, NIWA and their predecessors. Students and researchers from the University of Waikato have undertaken study in the catchment over many years and other organisations such as the Department of Conservation, Landcare Trust, and the National Wetland Trust have all been involved in the management of the catchment and undertaken various studies or produced reports about it. In addition to all of these a number of national datasets provide relevant information about the catchment.

This report outlines the information available for the catchment and summarises key data. Its purpose is to inform future decisions on lake and catchment management by collating existing data which can then be used to undertake modelling and assist in determining the most effective restoration actions for the ecosystem. Water quality, hydrology, biodiversity, climate and resource use are covered. The data most relevant to the purpose of the report are summarised while less relevant or older data are merely mentioned or are only included in the bibliography. Gaps or deficiencies in the data are identified within each section and summarised at the end of the report.

2 DATA AVAILABILITY

A large quantity of data is available for the Waipa peat lakes in general and the Rotomanuka and Rotopiko lakes are some of the most studied in the district. Detailed ecological and limnological accounts of the lakes date back to the late 1970s and early 1980s when regular inventories were written by the Waikato Valley Authority (Chapman & Boubee 1977; Boubee 1978; Town 1980, 1982; Davenport 1981). This information provides a valuable picture of the status of the lakes at that time and successive reports covering many aspects of the ecosystem help to build a picture of how the lake ecosystems have changed over time.

Waikato Regional Council holds a large quantity of data for the lakes including monthly water quality data for four of the five lakes, depth profiles of dissolved oxygen and temperature for four of the five lakes, daily lake level data from six separate stations and invertebrate data. The temporal coverage of the data varies considerably with new stations being brought online and other stations being closed over the last few decades. The available WRC datasets are summarised in Appendix 1 along with their location, frequency, and temporal coverage.

Other databases relevant to this project include the New Zealand Freshwater Fish Database (NZFFD) and the Freshwater Biodata Information System, both of which are maintained by NIWA and publicly available through the Environmental Information Browser (http://ei.niwa.co.nz/). The locations of available records from these databases and the WRC datasets are displayed in Figure 1.

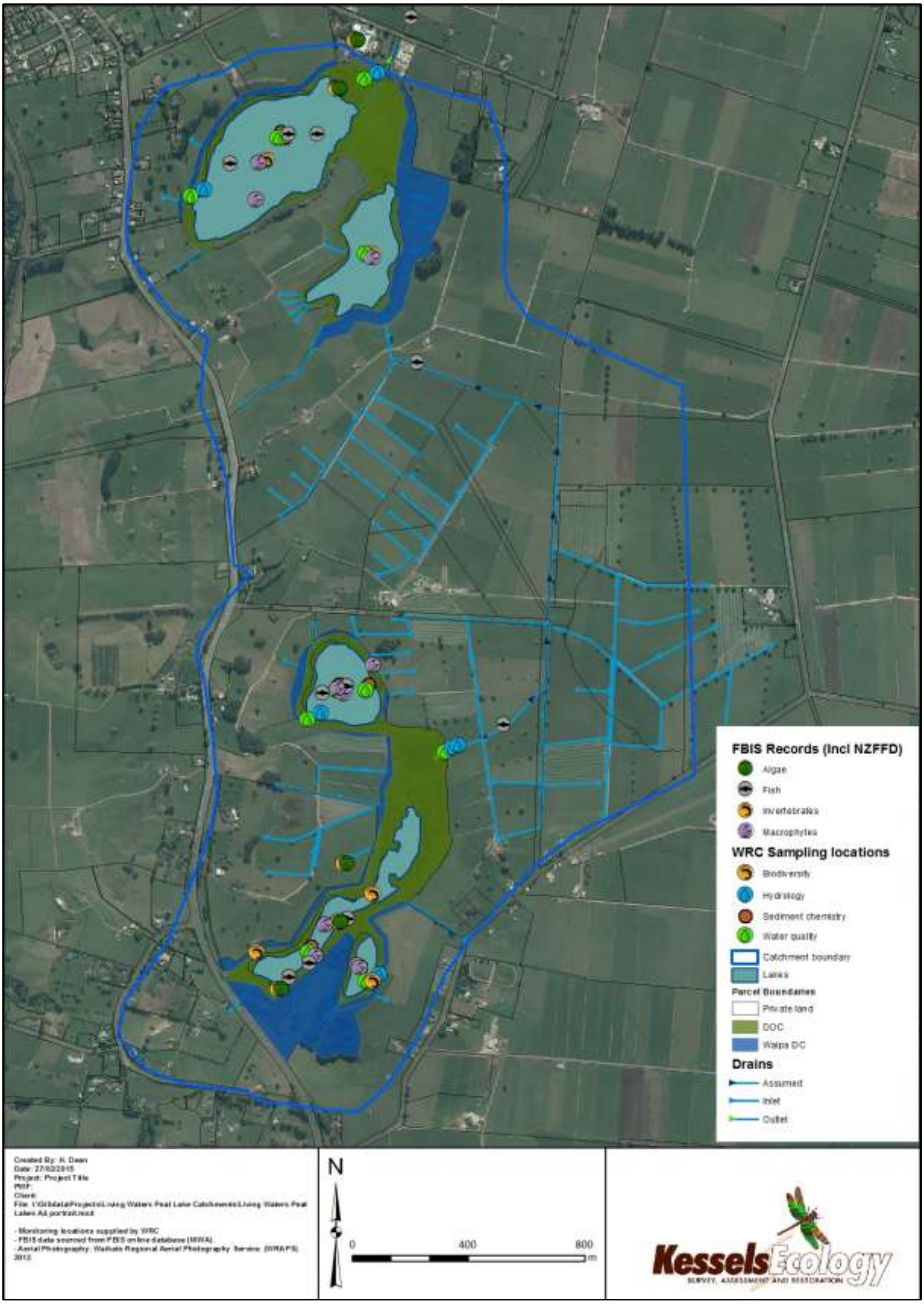

Figure 1: Locations of records and monitoring stations for WRC and FBIS data.

3 CATCHMENT DESCRIPTION

The Rotomanuka catchment is located at Ohaupo in the Waipa District approximately 15 km south of Hamilton city (Figure 2). It occupies an area of 479 ha in two basins; the northern one contains Lakes Rotomanuka and Rotomanuka South and naturally drains to the northeast. The southern basin contains the Rotopiko (Serpentine) complex which historically would have drained to the east but has been artificially linked to the Rotomanuka complex via a drain which goes through a low ridge separating the two basins (Figure 4). Historically the two Rotomanuka lakes were joined as one lake, as were the three Rotopiko lakes, but lowering of the water levels for agricultural purposes has exposed the shallower areas of the historic lakes. A third lake known as Round Lake was situated to the east of Rotopiko within the modern catchment boundary but this was drained sometime prior to 1939 (Grange *et. al.* 1939).

The lowest point of the catchment is at the Rotomanuka outlet which is set at 50.1 m relative to the Moturiki datum. This level is specified in the Waikato Regional Plan (section 3.2.4.7). The highest point in the catchment is to the south of Rotopiko where the land reaches 87.5 m elevation.

The lakes occupy an area of approximately 36 ha (7.5% of the catchment area). The largest of the lakes is Rotomanuka North (17.1 ha), followed by Rotomanuka South (6.8 ha). Rotopiko north covers an area of approximately 5.2 ha, Rotopiko South 5.5 ha, and Rotopiko East the smallest at just 1.4 ha.

The lakes are fed by drains and groundwater flow and no natural inlet streams exist. Multiple minor drains from the surrounding pasture feed into each lake and several drains also join the main drain flowing between Rotopiko and Rotomanuka. The majority of drains are not planted but many are fenced. The exact status of fencing on each drain is not known and would need to be determined by survey or by talking with landowners.

The catchment contains approximately 41 ha of wetlands exhibiting at least the remnants of natural vegetation communities. In addition to these there are other areas which could be defined as wetlands where the soil and vegetation characteristics are determined by permanent or periodic saturation. These areas are often dominated by exotic and native *Juncus* rushes and water-loving exotic grasses and herbs such as Yorkshire fog (*Holcus lanatus*) and buttercup (*Ranunculus repens* and *R. sceleratus*) but are managed as pasture. The wetlands within the catchment comprise palustrine and lacustrine swamps although small areas may be able to be more accurately defined as fens.

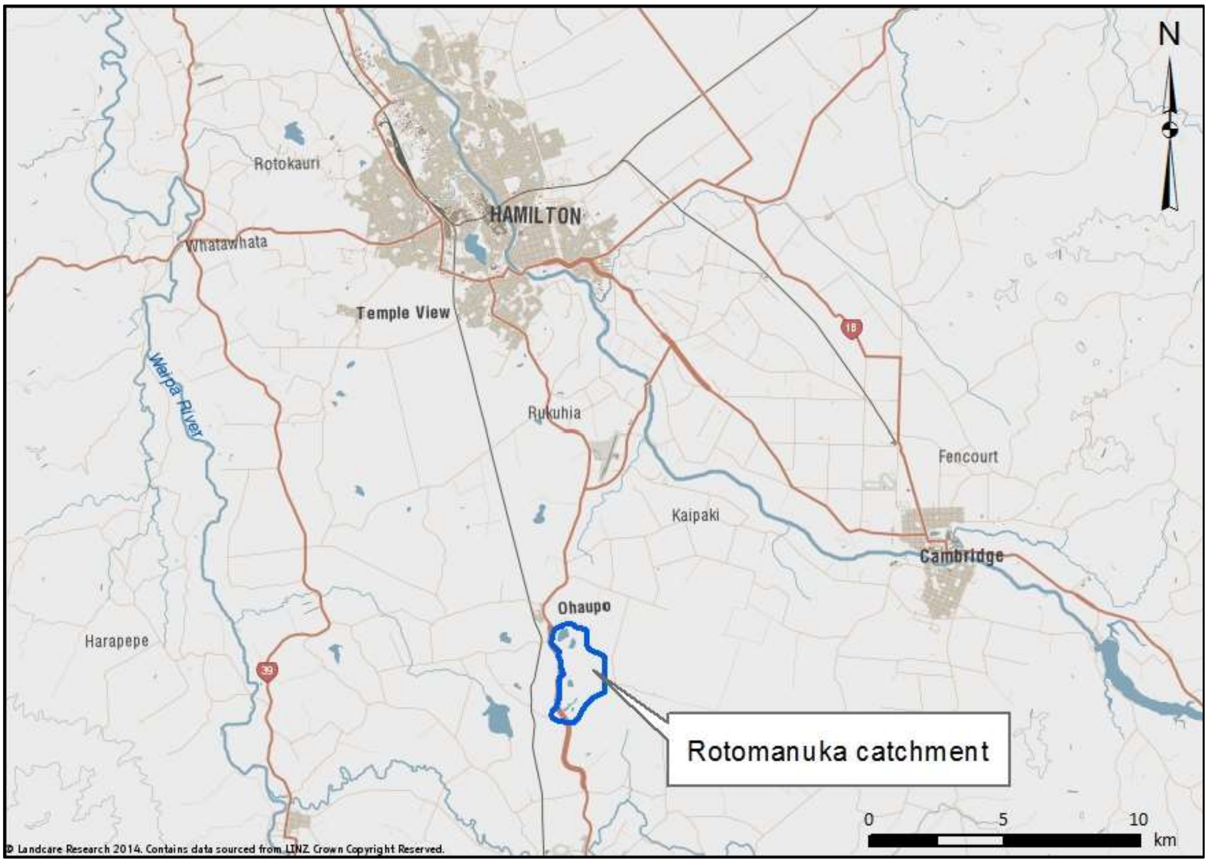

Figure 2: Location of the Rotomanuka catchment.

Rotomanuka and Rotopiko, like the other Waipa lakes, were likely formed at least 18,000 years ago when the changing course of the Waikato River through the Hamilton basin caused the deposition of large amounts of sand and silt and formed many small lakes (Environment Waikato 2002; Waipa District Council 2007). As the climate warmed and became wetter (around 10,000 years ago) peat-forming vegetation established on alluvial plains and on the margins of the lakes (Waipa District Council 2007). Large domed peat bogs were formed, including Moanatuatua, on the edge of which the Rotomanuka and Rotopiko lakes sit. Many of the Waipa lakes were significantly affected by peat formation and became dystrophic (i.e. brown stained, with low oxygen levels in the water), but Rotomanuka was much less influenced by peat (Waipa District Council 2007).

3.1 Catchment Land Cover and Use

The Rotomanuka catchment is primarily a dairy farming catchment with almost 80% of the land in high producing pasture (Table 1, Figure 3). At least five dairy farms are situated either wholly or partially in the catchment. A number of smaller lifestyle properties around the margins of the catchment have been subdivided relatively recently and there is one orchard property within the catchment on the western side of State Highway 3. The remaining area is taken up with the lakes themselves, the wetlands surrounding them, and several small areas of native and exotic forest.

Table 1: Landcover Classes in the Rotomanuka catchment. Based on LCDB4 (Landcare Research) but with alterations based on 2012 WRAPS aerial photography.

Landcover Class	Area (ha)	% of catchment
Broadleaved Indigenous Hardwoods	2.8	0.59%
Built-up Area (settlement)	2.2	0.45%
Deciduous Hardwoods	4.7	0.99%
Exotic Forest	2.6	0.55%
Herbaceous Freshwater Vegetation	36.4	7.59%
High Producing Exotic Grassland	382.7	79.85%
Indigenous Forest	3.1	0.65%
Lake or Pond	36.1	7.53%
Manuka and/or Kanuka	0.4	0.09%
Orchard Vineyard and Other Perennial Crops	4.5	0.94%
Transport Infrastructure	3.7	0.77%
Grand Total	479.3	100.00%

3.1.1 Land ownership

Approximately 79% of the catchment (377 ha) is privately owned. Crown-owned reserve land, including the beds of the five lakes, DOC-administered Wildlife Management Reserves, and Waipa District Council land accounts for 19% (91.6 ha) of the catchment and the remaining 2% is road reserve (Figure 1).

3.1.2 Land Use Capability

The Land Use Capability (LUC) classification is a long-established system for assessing the suitability of land for various uses. The system uses data from the Land Resources Inventory to classify land into eight major classes: Class 1 land is highly versatile, with no limitations and suitable for arable cropping or intensive grazing while Class 8 land is unsuitable for any farming or forestry and is highly limited (Lynn *et. al.* 2009). The system also incorporates a land use subclass which provides information about the limitations of the land.

The flat peat land within the Rotomanuka catchment is classed as 2w land under the LUC classification (Figure 4) indicating that it is highly suitable for arable cropping and intensive grazing with a high water table being the limiting factor (Lynn *et. al.* 2009). The hillslopes are classified as 4e land which is moderately suitable for grazing and erosion is the limiting factor (Lynn *et. al.* 2009).

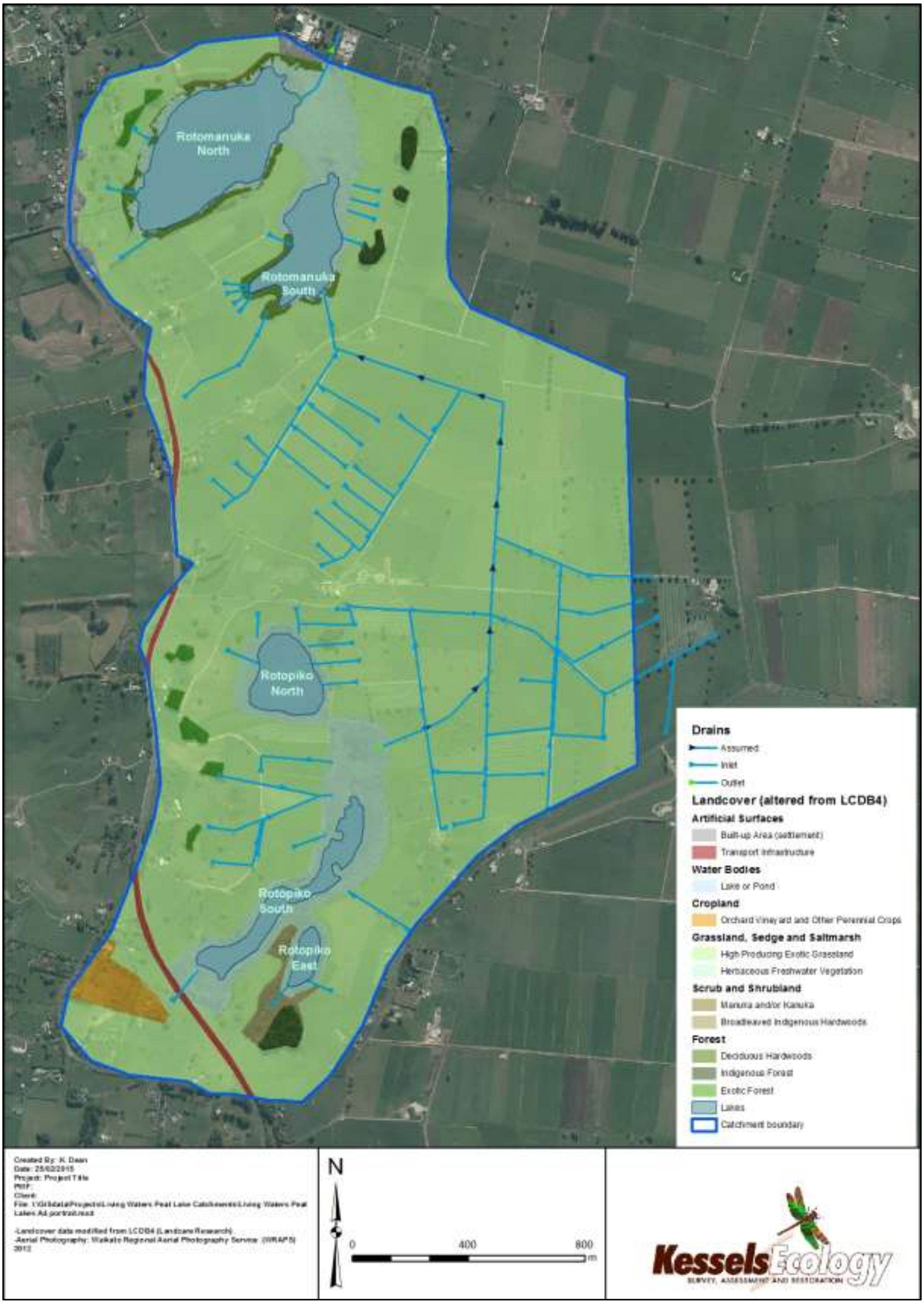

Figure 3: Landcover and drainage network of the Rotomanuka catchment.

4 SOILS

Two soil classes are mapped for the Rotomanuka catchment (Figure 4). The soils of Lakes Rotomanuka, Rotomanuka South, the Rotopiko complex, and the eastern part of the catchment, an area of approximately 325 ha, comprise Mesic Organic peaty loam soils of moderately decomposed peat (NZFSL Soil Geospatial Layer 2014). At least three types of peat are present around Rotomanuka; lake peat, sedge and reed-derived peat, and kahikatea-derived peat (Thompson 2014). Low-density bog peat derived from restiad rushes may also be present to the north east of Rotomanuka and is the dominant peat of the Rotopiko Complex (Stockdale 1995). Both lake complexes lie on the historic western edge of the Moanatuatua Bog (Lowe 2010). Peat soils which are now grazed have been modified from restiad bog peat to “well consolidated crumby peat” by cultivation and partial mineralisation (Stockdale 1995). Peat deposits at Rotomanuka are 2-3 m deep in places but the bog peat around the Rotopiko lakes is generally at least 4 m deep and is over 5 m deep in places (Thompson & Greenwood 1997)

To the west of the catchment the low ridge on which State Highway 3 is situated comprises mineral soil classified as Typic Orthic Granular clay loam (NZFSL Soil Geospatial Layer 2014). This soil also extends around the southern margin of the Rotopiko complex and along the low ridge between the Rotomanuka and Rotopiko sub-catchments, covering an area of approximately 154 ha (Figure 4).

Peat soils can be highly productive but are fragile and careful management is required if peat soils are to be sustained. Undeveloped peat contains a very high proportion of water, has low bulk density (i.e. small amount of dry matter for the volume), and a very low mineral content (Environment Waikato 2006). When peat is drained it shrinks and over time drains have to be deepened as the shrinkage catches up with the water table. Thompson & Greenwood (1997) reported peat shrinkage at Rotomanuka of more than 80 cm in less than 20 years and 4.5 cm per year adjacent to Rotopiko. Farming peat usually requires the addition of fertilisers and over time the peat becomes compacted and oxidised and the bulk density increases (Environment Waikato 2006). Sensibly managed peat soils can be sustained and effectively managing the peat resource will be one of the key restoration issues in the Rotomanuka catchment.

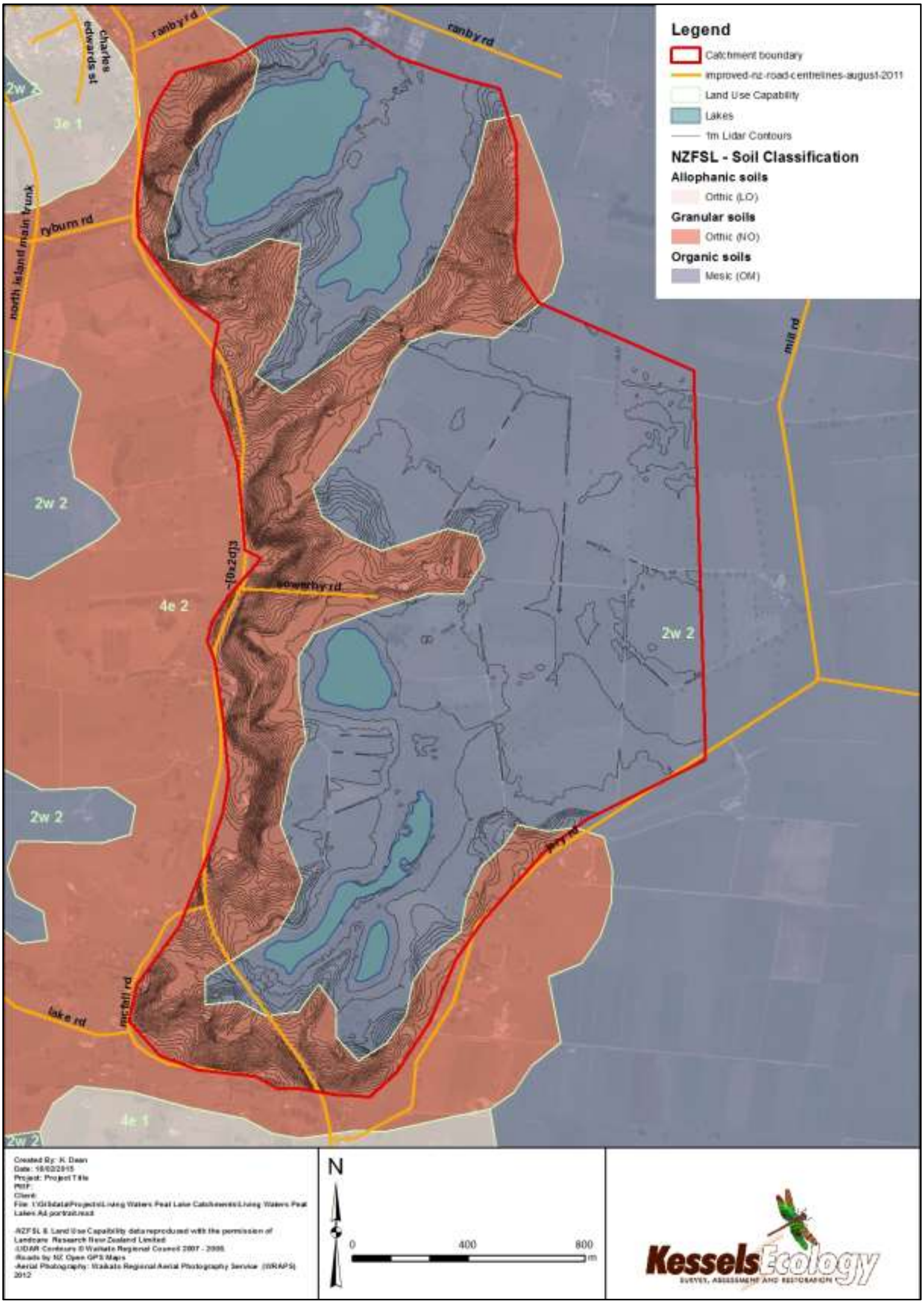

Figure 4: Soils, Land Use Capability and contour of the Rotomanuka Catchment.

5 CLIMATE

There are several sources of climate data for the Rotomanuka catchment but there does not appear to be any derived from direct measures within the catchment. NIWA provides climate information (CliFlo) from a network of stations, the nearest in this case being Hamilton Airport approximately 6.5 km to the north of Rotomanuka. NIWA also supply modelled climate data through their Virtual Climate Station network which is a 5km grid covering the entire country. This data needs to be purchased but may be the best option for catchment modelling at Rotomanuka.

Land Environments of New Zealand (LENZ; Leathwick *et. al.* 2003) is an environmental classification system which used a suite of climate, soil, and landform data to classify the whole of New Zealand into land environments. Environments with the same classification have similar environmental conditions. The data underpinning the LENZ system provides a general picture of the climate in the catchment but is unlikely to be suitable for detailed catchment modelling. Climate data from the two land environments in the Rotomanuka catchment show a mean annual temperature of approximately 14°C and mean coldest month temperatures around 4°C. Rainfall data is not directly incorporated into the LENZ data but annual water deficit is an indication of the difference between rainfall and evaporation and gives an indication of soil dryness. Data in Table 2 indicate a relatively low water deficit.

Table 2: Climate variables from the LENZ environmental classification. Refer to Figure 3 for locations of each Land Environment within the catchment.

	LENZ Lvl 4 Environment	
LENZ Climate Variables	**A5.3a**	**A7.2b**
Mean annual temperature (°C)	13.9	14
Mean minimum temperature of coldest month (°C)	4	4.8
Mean annual solar radiation (MJm^{-2}day^{-1})	14.8	14.8
Winter solar radiation (MJm^{-2}day^{-1})	5.7	5.7
October vapour pressure deficit (kPa)	0.37	0.35
Monthly water balance ratio	2.4	2.6
Annual water deficit (mm)	55.3	41.41

NIWA's CliFlo data for Hamilton Airport for 2009 - 2014 shows annual rainfall between 1086 mm and 1539 mm and a mean annual temperature between 13.3 °C and 14.2 °C (Table 3). Maximum high temperatures typically reach around 30 °C while minimum low temperatures are between -3.2 °C and -4.5 °C. The number of frost days experienced at the airport varies considerably from year to year with just 11 in 2014 and 31 in 2009. Sunshine hours were not available for the Hamilton airport climate station.

Table 3: Climate data for Hamilton Airport between 2009 and 2014. Data from NIWAs CliFlo service.

	Mean Air Temp (°C)	Lowest Daily Mean Temp (°C)	Highest Daily Mean Temp (°C)	Extreme Maximum Air Temp (°C)	Extreme Minimum Air Temp (°C)	Number of frost days	Mean Of 9am Relative Humidity (%)	Total Rainfall (mm)
2009	13.3	2.3	25	29.8	-4.5	31	88	1088
2010	14.2	4.2	23.7	30.3	-3.3	13	87.2	1236
2011	14.1	3.1	23.7	30.3	-3.9	17	89	1539
2012	13.4	3	23	27	-3.6	24	88.2	1290
2013	14.2	4.2	22.5	30.7	-3.2	11	87.9	1086
2014	13.7	-	-	-	-	-	89.2	-

A privately owned weather station at Blueberry Country on Jary Road collects detailed information about temperature, humidity, rainfall, and wind speed. This data is freely available on the harvest.com website but cannot be downloaded. Data was not manually copied for this project except for the two months of daily rainfall data used in Figure 7. The data available only goes back to 2012 but as this site is less than 2 km from the catchment boundary it is likely to be the most accurate data available for the catchment. A request to the website owner to access the data in bulk did not receive a response but further enquiries could be made if this data is required.

6 HYDROLOGY

6.1 Drainage

The five lakes in the catchment are fed by a network of drains as well as groundwater. At least 14.5 km of drains take water from the flatter parts of the catchment either direct to the lakes or into the Rotopiko-Rotomanuka drain. Almost every paddock on the peat soils is flanked by at least one drain but many of these only flow during rainfall. Drains were mapped (Figure 3) using existing WRC drain data, manually using WRAPS 2012 aerial photography and with ground truthing where possible. The data is not accurate but gives a good picture of the extent to which the catchments hydrology has been altered by drainage. Mapping of the drains has also revealed that the exact boundary of the Rotomanuka catchment is not completely accurate, especially along its eastern edge. This could be improved by ground survey or by talking to landowners.

6.2 Streams

No natural streams are present within the catchment although ephemeral overland flow paths would have existed on the hilly land. The lakes themselves did not originally have outlet streams but rather the water flowed through the adjacent peat swamps when levels were high (Thompson & Greenwood 1997).

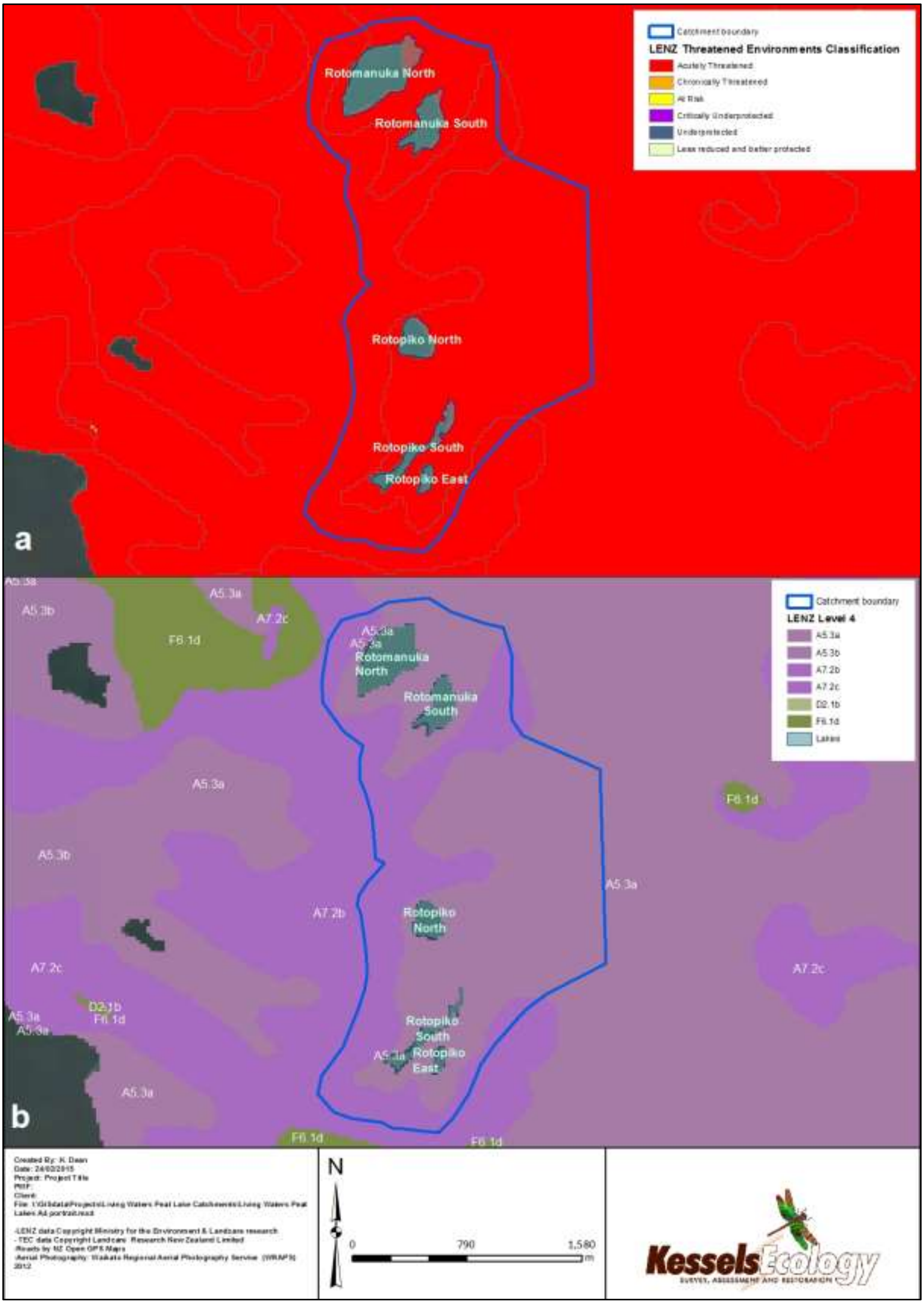

Figure 5: Rotomanuka catchment showing (a) Threatened Environments classification and (b) LENZ Level 4 classification.

6.3 Lakes

The outlet level of Lake Rotomanuka is set at 50.1 m above sea level (Moturiki datum). This level is specified in the Waikato Regional Plan (section 3.2.4.7) and cannot be changed without a plan change process. The level of the Rotopiko outlet is set at 54.92m asl and will be included in a variation to the Regional Plan (Dean-Spiers *et. al.* 2014). Daily lake level data is available for Rotomanuka from October 1999 through to 2014 while data for the Rotopiko lakes begins in 2003 and continues through until the present. Rotopiko outlet and downstream weir level data begin in 2008 and 2009 respectively. All level data sets have gaps in them, possibly as the result of equipment malfunction. Water level data shows a general pattern of winter-spring high levels and summer lows. The Rotopiko lake levels fluctuate much less than the outlet levels and perhaps slightly more than the Rotomanuka water level (Figure 6).

Rainfall data was obtained from nearby Blueberry Country on Jary Road for a two month period in winter 2014. Plotted against water level data (Figure 7) it shows how the lakes fluctuate in response to rainfall. Lake and drain levels rise relatively quickly after rainfall but it takes two or three days after the beginning of a significant rainfall event for water levels to reach their maximum and a further three or four days for levels to come down again after rain ceases.

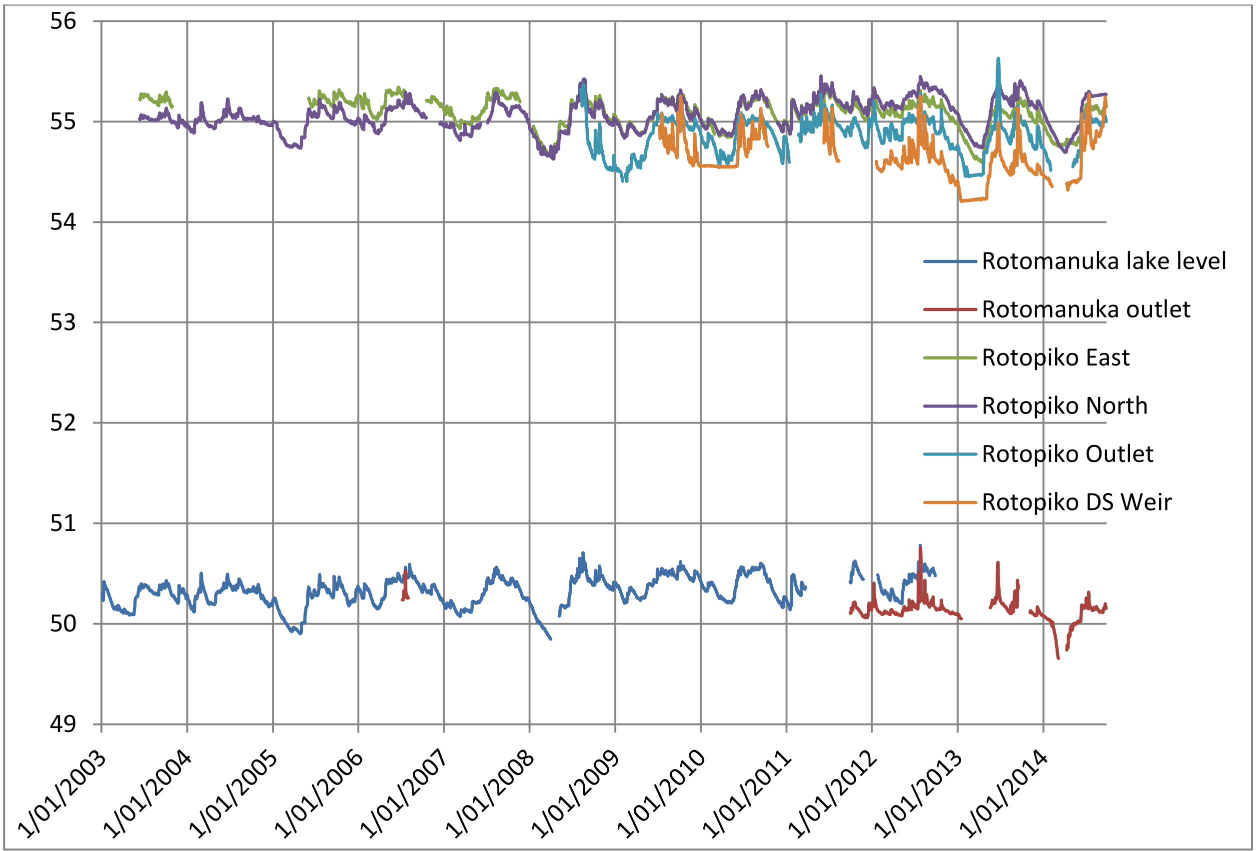

Figure 6: Lake water levels between January 2003 and September 2014. Level data courtesy of WRC.

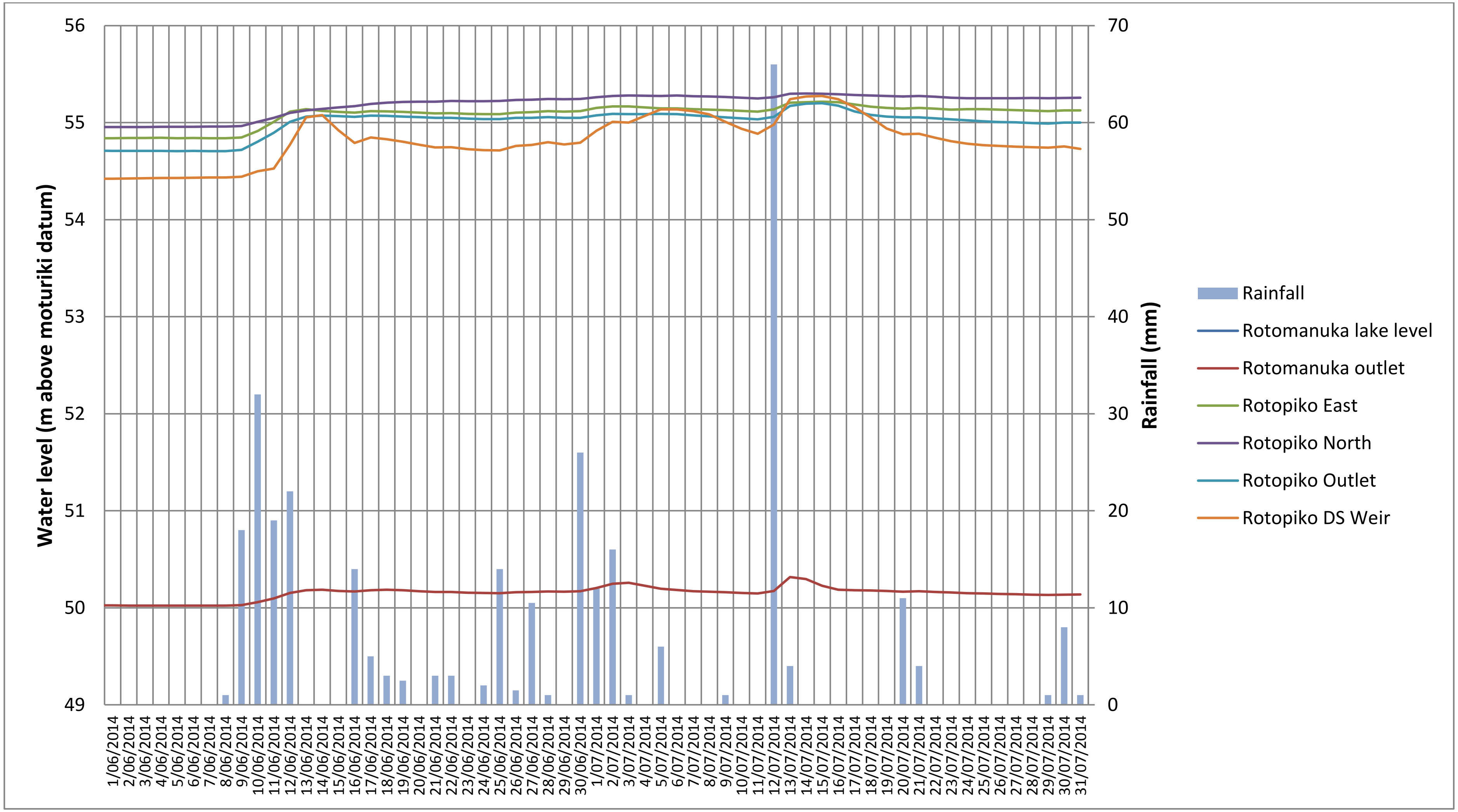

Figure 7: Lake levels and rainfall for a two month period in winter 2014. Lake level data courtesy of WRC. Rainfall data courtesy of Blueberry Country and Harvest Electronics.

6.4 Groundwater

Waikato Regional Council does not have any groundwater monitoring sites within the Rotomanuka catchment; however Dianne Stockdale (1995) monitored lake and groundwater levels on the eastern sides of the Rotomanuka and Rotopiko lakes using dip wells between November 1993 and December 1994 as part of her MSc research and this remains the most detailed study of hydrology in the catchment. Stockdale identified an annual groundwater level fluctuation of greater than 2 m in some areas, with higher fluctuations further from the lake edges. Her study found that drainage had caused a significant reduction in the storage capacity of the lakes and the peat resulting in accelerated peat decomposition through consolidation and de-watering. Water tables generally flowed towards the lakes but were reversed during summer which was attributed to accelerated water loss (Stockdale 1995).

Rotomanuka North receives a significant quantity of groundwater but with draining for agriculture the input of water diverted from the Rotopiko system is now important for maintaining the lake’s Hydrology (Thompson & Greenwood 1997).

Further hydrological investigations and modelling may prove necessary in order to undertake accurate catchment modelling.

7 BATHYMETRY

The bathymetry of Lakes Rotomanuka North and Rotomanuka South was surveyed in 1979 by the New Zealand Oceanographic Institute (Irwin 1982). A scanned image of the chart was kindly supplied by NIWA and 1m isobaths were digitised from the chart image (Figure 8). A survey in February 2014 by NIWA scientists (de Winton *et. al.* 2014) and comparison between the two surveys showed that the northwest end of the lake may have become shallower (de Winton *et. al.* 2014).

Rotomanuka North had a maximum depth of 8.7 m in 1979 and a maximum depth of 8.31 m in 2014, although the difference between the two measurements can be explained by the normal fluctuations in lake water level. Rotomanuka South has a maximum depth of around 5.0 m.

Bathymetry charts have also recently been completed for the Serpentine lakes (NIWA n.d.) (Figure 10 - Figure 13). Rotopiko North has a maximum depth of 4 m, Rotopiko South 3.6 m, while Rotopiko East is 4.4 m (Dean-Spiers *et. al.* 2014).

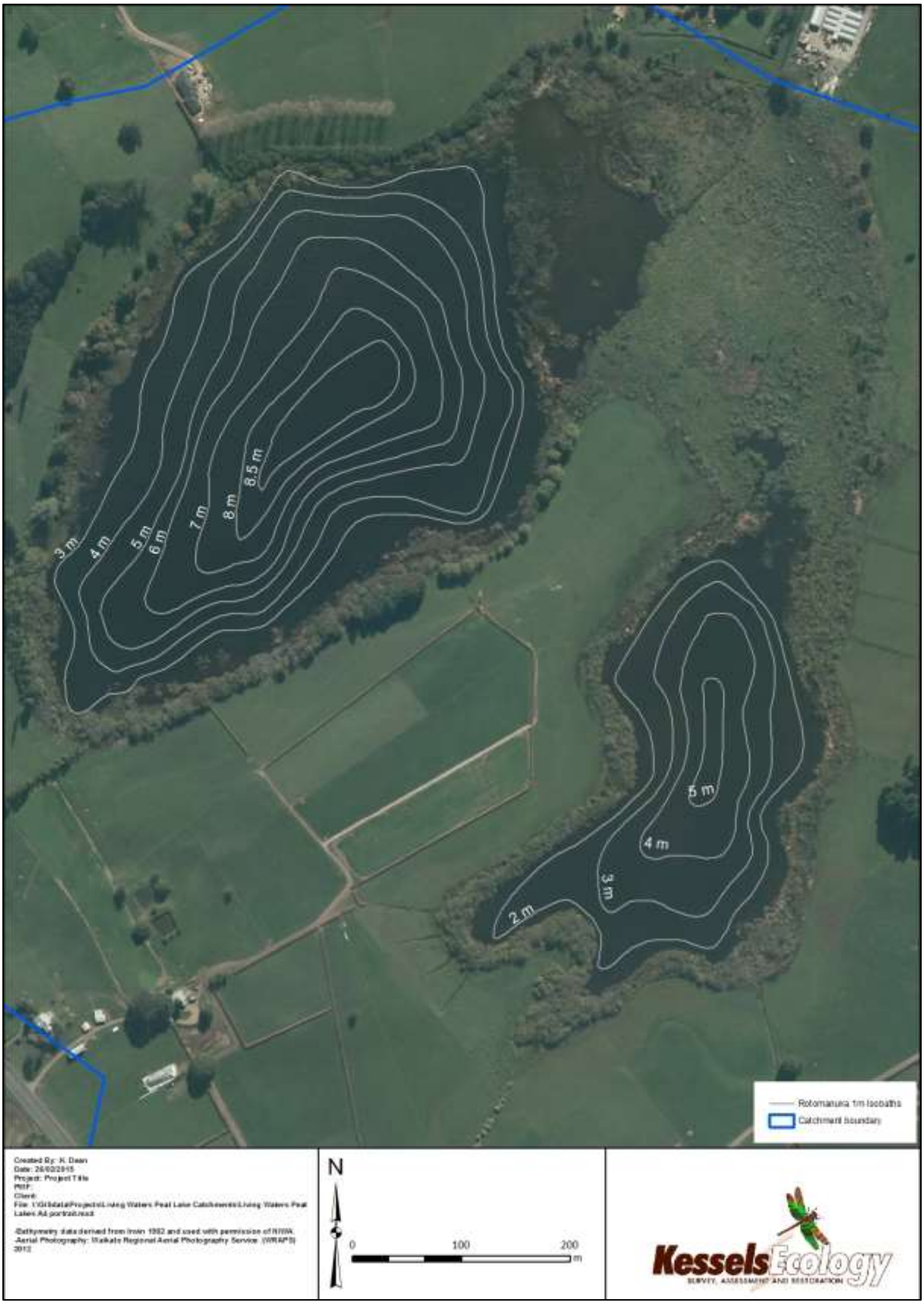

Figure 8: Bathymetry of the Rotomanuka lakes. Data from Irwin 1982, supplied by NIWA.

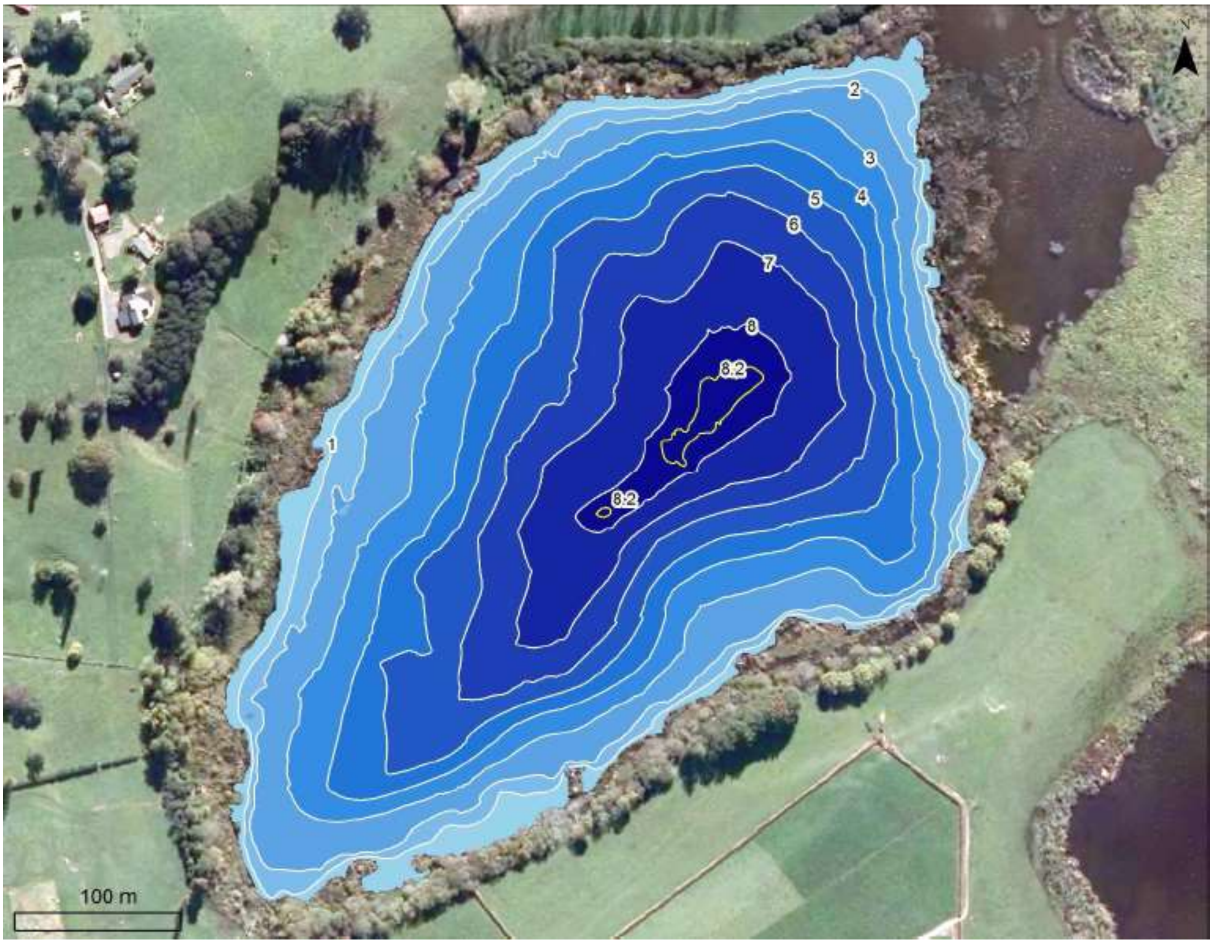

Figure 9: Bathymetry of Rotomanuka North in February 2014. Map created by de Winton *et. al.* 2014 (NIWA) and supplied by DOC.

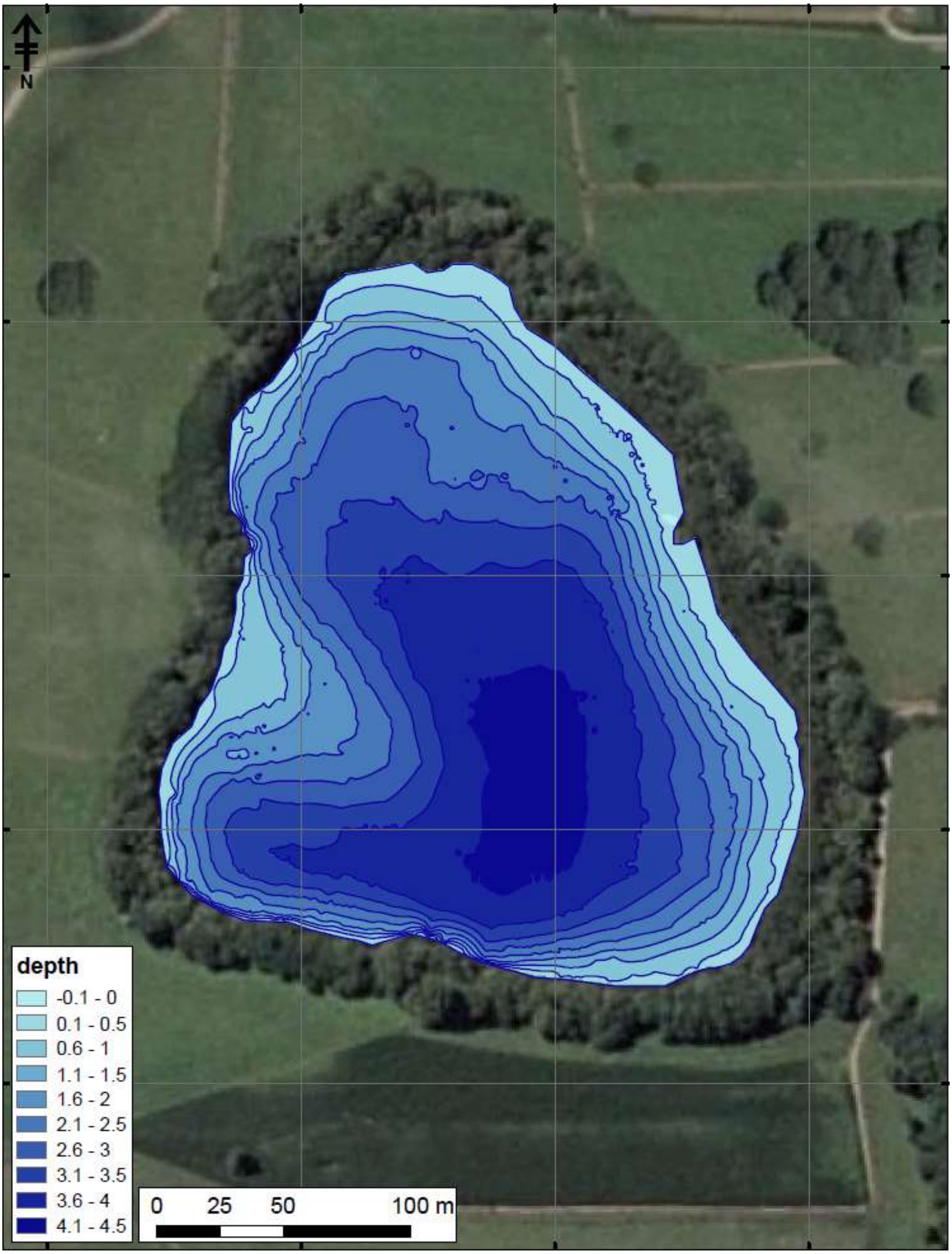

Figure 10: Bathymetry of Rotopiko North. Map created by NIWA and supplied by DOC.

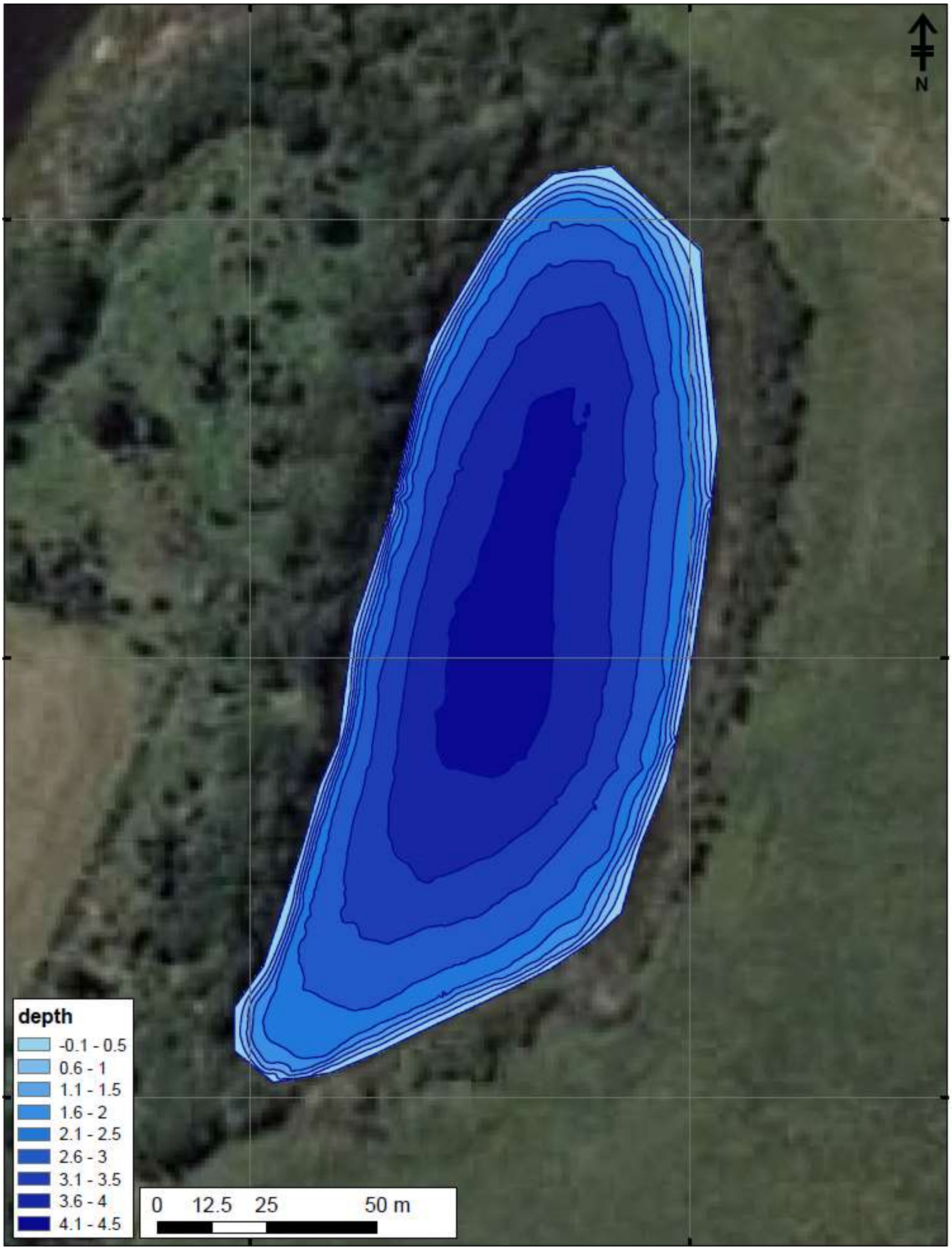

Figure 11: Bathymetry of Rotopiko East. Map created by NIWA and supplied by DOC.

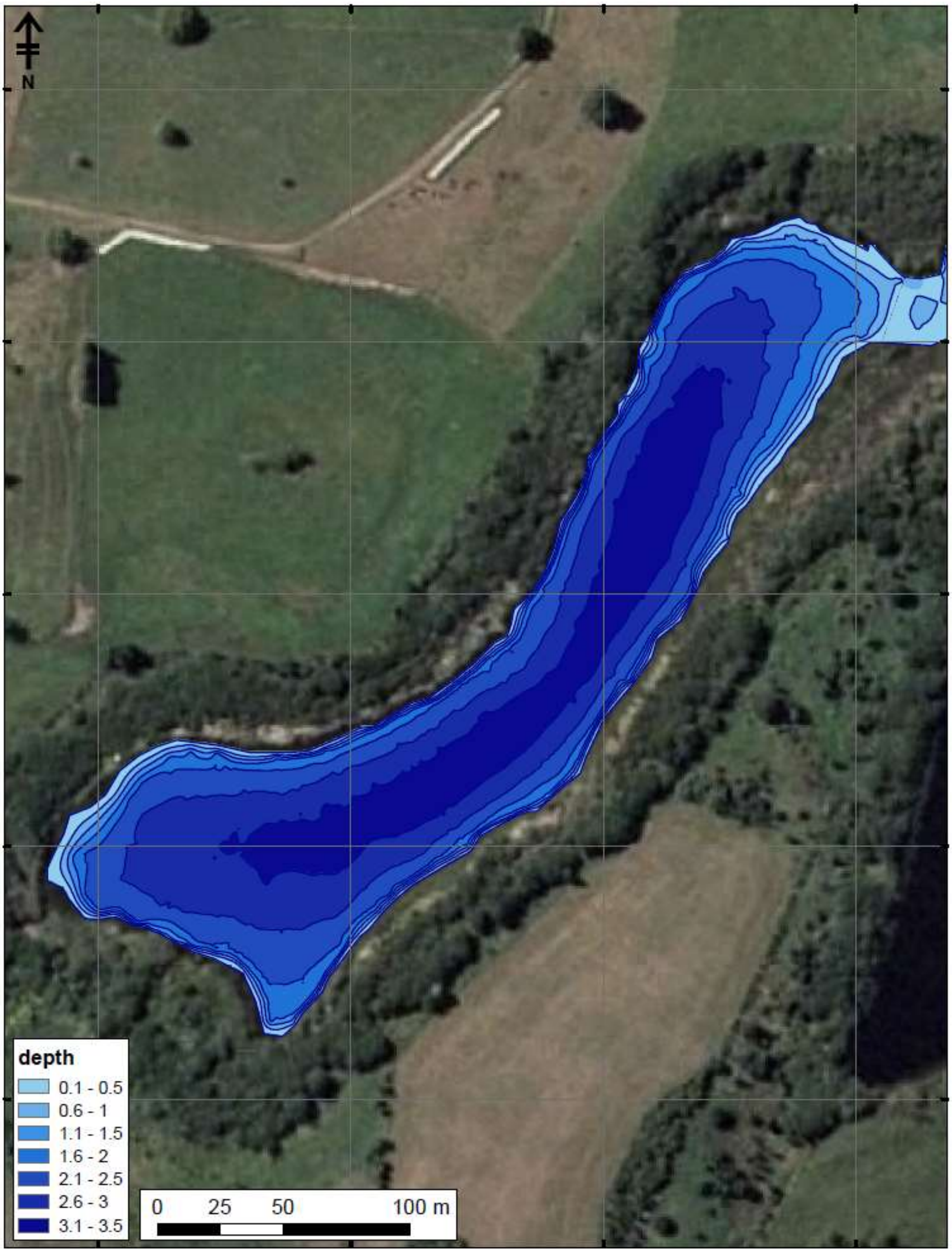

Figure 12: Bathymetry of Rotopiko South. Map created by NIWA and supplied by DOC.

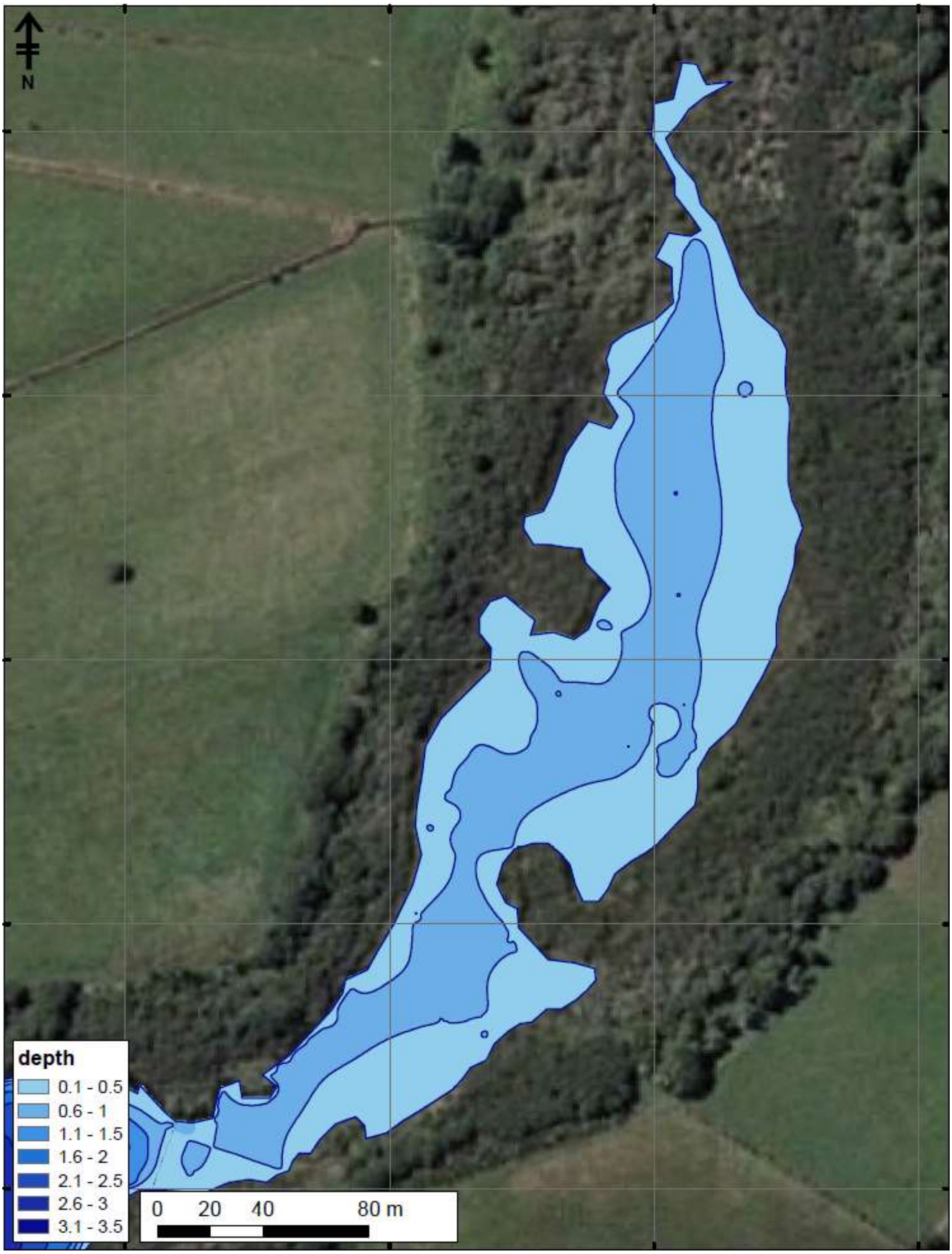

Figure 13: Bathymetry of Rotopiko winter lake. Map created by NIWA and supplied by DOC.

8 WATER QUALITY

As no water quality information is available for the streams and drains flowing into or out of the lakes in the Rotomanuka catchment this section focuses on the key attributes of the lake water quality. It covers water chemistry, clarity, and temperature, along with Trophic Level Index (TLI) and rotifer-derived TLI. Lake SPI, an indicator of the ecological health of a lake is covered in Section 10.1.4 below.

The water quality in Rotomanuka and the Rotopiko Lakes has been investigated for a number of studies and is regularly monitored by WRC. Datasets available include daily automated temperature readings at several stations, monthly temperature and dissolved oxygen depth profiles at four stations, monthly secchi depth readings at four stations, and monthly comprehensive water quality testing at eight stations (see Appendix 1 for details). The temporal range of each dataset varies somewhat as sampling locations have been added or discontinued. For example depth profiles of temperature and dissolved oxygen have been recorded monthly in Lake Rotomanuka since 1995 whereas the sampling at Rotopiko South was only begun in 2007 and is done only two or three times per year. Not all datasets are complete; most have gaps in the data and some are irregularly sampled or were sampled as part of a particular investigation. Nevertheless these datasets provide a comprehensive picture of water quality change in the lakes over the last 10-15 years.

In general the Rotopiko Lakes are considered the best quality peat lakes remaining in the region with reasonably intact assemblages of submerged vegetation and good water quality. The Rotomanuka lakes are not as high quality but are nevertheless much better than many other peat lakes in the region.

Dean-Spiers *et. al.* (2014) provided a summary of water quality data sourced from a range of studies and monitoring programmes. This report provides an excellent outline of the issues affecting both the Rotopiko and Rotomanuka complexes.

Davenport (1981) conducted a study of nine lakes which involved weekly measurements of a range of water quality parameters between January and March 1981 and comparative samples in August 1981. During this period the water in Rotomanuka North was described as “quite clear with only a light peat stain” and secchi depths of up to 3.5 m were recorded in both summer and winter (Davenport 1981).

Barnes (2002a) reported on water quality in Rotomanuka North for the period between 1995 and 2001. This report was based on data collected by Waikato Regional Council as part of its routine monitoring of lake water quality. It revealed a significant decline in secchi depth of 0.27 m per year, and significant increases in total nitrogen (TN; 2.28 mg y^{-1}, and total phosphorus (TP; 19.65 mg y^{-1}) during the study period (Barnes 2002a). Although the lake remained eutrophic during the study period, except in 1998 and 2000 when it was at the lower end of the supertrophic range, there was a significant increase in trophic status.

The study also found that chlorophyll α concentrations had remained relatively constant during the study period and that the decreasing water clarity over the period was influenced more by non-algal suspended sediments than by algal biomass (Barnes 2002a). The question was also raised as to whether the increase in trophic state is due to eutrophication through external nutrient inputs or because of the collapse of the macrophyte beds and subsequent input of organic nitrogen and phosphorus (Barnes 2002a).

8.1 Water Chemistry

High levels of TN have been recorded in both Rotomanuka lakes since the early 1980s although Rotomanuka South has been consistently above 2000 mg m^{-3} (Table 6) whereas Rotomanuka North has undergone a steady increase from around 700 mg m^{-3} in the early 1980s to concentrations around 1000 mg m^{-3} in recent years (Table 5). Nitrogen levels in the Rotopiko lakes have fluctuated considerably over the period for which data is available with a definite peak in 2010 when all three lakes recorded TN concentrations > 1400mg m^{-3}.

Total phosphorus concentrations in Rotomanuka North have fluctuated within the mesotrophic and eutrophic ranges for the entire period for which data is available (Table 5, Figure 14) while TP concentrations in Rotomanuka South have remained very high throughout the period. This is likely as a result of the direct input of water from the entire southern part of the catchment via the Rotopiko-Rotomanuka drain which will be carrying nutrients and sediments into the lake. TP concentrations in the Rotopiko lakes remained relatively consistent with only minor fluctuations.

Water chemistry results for both lake complexes show lower concentrations of phosphorus than nitrogen indicating that the lakes are phosphorus limited (Barnes 2002a; Sukias *et. al.* 2009); i.e. lower levels of phosphorus are limiting the productivity of the lake despite high nitrogen concentrations. As phosphorus is generally transported in sediments by surface flows it is very important to ensure that the lake systems are protected as far as possible from direct unfiltered flows entering them (Sukias *et. al.* 2009). Existing and proposed infiltration wetlands at both Rotopiko and Rotomanuka will help to attenuate phosphorus inputs.

A considerable quantity of water chemistry data is available from the Waikato Regional council which has not been summarised here. Detailed analyses of water quality data have been published by Barnes (2002a, 200b), and earlier by Town (1980, 1982) and Davenport (1981) but more regular analysis (5-yearly) would be beneficial for the management of the lakes, especially now that additional resources will be put into restoration and catchment management.

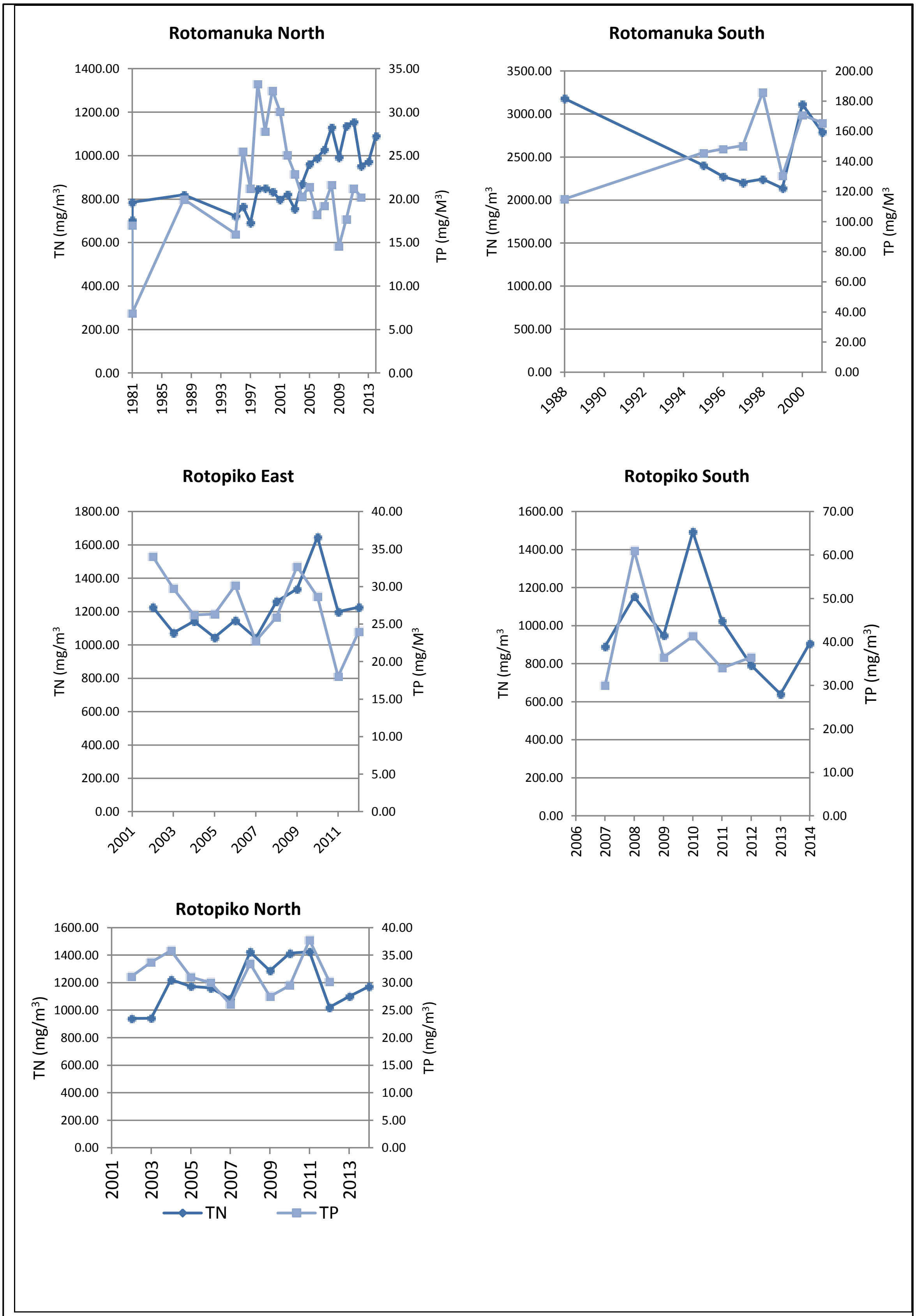

Figure 14: Total Nitrogen (TN) and Total Phosphorus (TP) concentrations in all five lakes. Note that temporal scale varies. Data from WRC.

8.2 Trophic Level Index

The Trophic Level index (TLI) is a standard method for measuring the trophic status of lakes in New Zealand (Burns *et. al.* 2000). It provides a single indicator value based on information on the nutrient status of the lake and is an important indicator of water quality. TLI is calculated using measurements of Total Phosphorus (TP), Total Nitrogen (TN), chlorophyll α (chl a), and secchi depth (SD) and ranges in value from 0 (ultra microtrophic) to 7 (hypertrophic; Table 4) (Burns *et. al.* 2000).

Table 4: Values of TLI, TP, TN, SD, and Chl a in relation to trophic states (from Burns *et. al.* 2000).

Trophic State	TLI	Chlorophyll α (mg/m^3)	Secchi depth (m)	Total Phosphorus (mg/m^3)	Total Nitrogen (mg/m^3)
Ultra microtrophic	0 - 1	0.13 - 0.33	33 - 25	0.84 - 1.8	16 - 34
Microtrophic	1 - 2	0.33 - 0.82	25 - 15	1.8 - 4.1	34 - 73
Oligotrophic	2 - 3	0.82 - 2.0	15 - 7	4.1 - 9.0	73 - 157
Mesotrophic	3 - 4	2.0 - 5.0	7.0 - 2.8	9.0 - 20	157 - 337
Eutrophic	4 - 5	5.0 - 12	2.8 - 1.1	20 - 43	337 - 725
Supertrophic	5 - 6	12 - 31	1.1 - 0.4	43 - 96	725 - 1558
Hypertrophic	6 - 7	> 31	< 0.4	> 96	> 1558

Table 5 to Table 9 outline key water quality information for all five lakes in the Rotomanuka catchment. The majority of the data has been sourced from Waikato Regional Council's regular monitoring programme but some of the earlier data comes from one-off studies or early Waikato Valley Authority reports. Data included in this table have not been properly de-seasonalised and no statistically robust trend analysis has been carried out. Instead, mean values have been calculated from all available data for the year. In some cases this includes samples taken every month but in other cases only a few data points were available. The TLI values calculated for data between 1995 and 2001 for Rotomanuka correspond very closely with those calculated by Barnes (2002a) and it is likely that the remaining values also reasonably accurate. Sample size and the timing of sampling do need to be taken into account when interpreting this data however.

The study of water quality trends between 1995 and 2001 showed a significant increase in TLI at an average of 0.082 units per year and it was predicted that the lake could be consistently hypertrophic by 2004 (Barnes 2002a). Fortunately this does not appear to have eventuated although it has been consistently in the upper end of the eutrophic range since 2002.

Rotomanuka South has had lower water quality than Rotomanuka North for the entire period for which data are available during which it remained supertrophic or hypertrophic. A degradation in water quality in Rotomanuka South was documented for the period between 1995 and 2001 when significant increases in TN, SD, and Chla were detected (Barnes 2002b). All three Rotopiko lakes have remained in the upper end of the eutrophic range or the lower end of the supertrophic range for the last 10-15 years or more.

Table 5: Rotomanuka North: Average annual water quality data and TLI estimates.

Year	Average SchiDisk		Average Cla		TN		TP		pH		Turbidity		TLs	TLc	TLn	TLp	TLI	Trophic State	Data source / comments
	m	n	mg/m^3	n	mg/m^3	n	mg/m^3	n	pH	n	NTU	n							
1981	2.55	10	14.00	5 or 6	703.00	5 or 6	17.00	5 or 6	7.00	10	1.20	5	4.11	5.13	4.96	3.81	4.50	Eutrophic	Davenport 1981; Summer only
1981	3.50	2	2.00	2	785.00	2.00	6.90	2.00	6.10	1	1.00	1	3.77	2.98	5.10	2.67	3.63	Mesotrophic	Davenport 1981; One-off winter sample
1988	2.55	2	12.00	2	820.00	2.00	20.00	2.00	6.80	2		2	4.11	4.96	5.16	4.02	4.56	Eutrophic	Page 1988. Two summer samples only.
1995	3.48	3	14.00	4	721.50	4	16.00	4	7.16	4	2.50	4	3.78	5.13	4.99	3.73	4.41	Eutrophic	WRC monitoring data.
1996	2.73	12	18.75	12	766.33	12	25.50	12	7.21	12	2.73	11	4.04	5.45	5.07	4.33	4.72	Eutrophic	WRC monitoring data.
1997	1.94	12	13.50	10	690.75	12	21.25	12	7.26	12	3.44	12	4.40	5.09	4.94	4.09	4.63	Eutrophic	WRC monitoring data.
1998	1.37	10	24.73	11	847.36	11	33.27	11	7.27	11	4.01	11	4.75	5.76	5.20	4.66	5.09	Supertrophic	WRC monitoring data.
1999	1.50	11	16.45	11	850.82	11	27.82	11	7.23	11	4.16	11	4.67	5.31	5.21	4.44	4.90	Eutrophic	WRC monitoring data.
2000	1.16	12	16.42	12	834.17	12	32.50	12	7.35	12	4.06	12	4.92	5.31	5.18	4.63	5.01	Supertrophic	WRC monitoring data.
2001	1.53	8	16.20	10	798.80	10	30.10	10	7.36	10	3.67	10	4.65	5.29	5.13	4.54	4.90	Eutrophic	WRC monitoring data.
2002	1.62	11	13.55	11	821.45	11	25.09	11	7.30	11	3.22	11	4.59	5.09	5.16	4.30	4.79	Eutrophic	WRC monitoring data.
2003	1.85	11	13.82	11	754.55	11	22.91	11	7.37	11	3.04	11	4.45	5.12	5.05	4.19	4.70	Eutrophic	WRC monitoring data.
2004	1.88	10	14.77	13	870.23	13	20.31	13	7.27	13	3.04	13	4.43	5.19	5.24	4.04	4.72	Eutrophic	WRC monitoring data.
2005	2.37	12	10.50	12	961.25	12	21.42	12	7.15	12	2.86	12	4.19	4.81	5.37	4.10	4.62	Eutrophic	WRC monitoring data.
2006	2.19	12	8.18	11	988.00	12	18.25	12	7.19	12	3.45	12	4.27	4.54	5.40	3.90	4.53	Eutrophic	WRC monitoring data.
2007	1.87	12	9.92	12	1028.05	12	19.25	12	7.12	12	3.74	12	4.44	4.75	5.46	3.97	4.65	Eutrophic	WRC monitoring data.
2008	1.49	11	11.93	12	1129.72	12	21.67	12	7.02	12	3.44	12	4.67	4.95	5.58	4.12	4.83	Eutrophic	WRC monitoring data.
2009	1.45	9	9.79	12	992.30	12	14.58	12	7.05	12	3.95	12	4.70	4.74	5.41	3.62	4.62	Eutrophic	WRC monitoring data.
2010	1.28	6	15.41	9	1137.22	9	17.72	9	7.03	9	4.66	9	4.82	5.24	5.59	3.86	4.88	Eutrophic	WRC monitoring data.
2011	1.54	5	7.88	8	1154.38	8	21.25	8	7.07	8	4.43	8	4.63	4.50	5.61	4.09	4.71	Eutrophic	WRC monitoring data.
2012	1.23	7	10.57	7	953.14	7	20.25	4	7.08	7	3.92	7	4.87	4.82	5.36	4.03	4.77	Eutrophic	WRC monitoring data.
2013	1.01	6	12.83	6	972.33	6		0	7.18	6	3.80	6	5.07	5.04	5.38			-	WRC monitoring data.
2014	1.48	5	6.86	7	1090.57	7		0		7		7	4.68	4.34	5.53			-	WRC monitoring data.

Table 6: Rotomanuka South: Average annual water quality data and TLI estimates.

Year	Average SchiDisk		Average Cla		TN		TP		pH		Turbidity		TLs	TLc	TLn	TLp	TLI	Trophic State	Data source / comments
	m	n	mg/m^3	n	mg/m^3	n	mg/m^3	n	pH	n	NTU	n							
1988	0.60	2	86.00	2	3180.00	2	115.00	2	7.30	2			5.59	7.13	6.93	6.24	6.47	Hypertrophic	Page 1988. Two summer samples only.
1995	1.00	3	17.00	4	2405.50	4	145.75	4	6.73	4	15.17	4	5.08	5.35	6.57	6.54	5.88	Supertrophic	WRC monitoring data.
1996	0.74	11	48.25	12	2274.33	12	148.33	12	6.85	12	13.78	11	5.38	6.50	6.49	6.56	6.23	Hypertrophic	WRC monitoring data.
1997	0.64	11	153.10	10	2205.58	12	150.42	12	6.97	12	12.38	12	5.52	7.77	6.45	6.58	6.58	Hypertrophic	WRC monitoring data.
1998	0.61	10	101.64	11	2243.18	11	185.91	11	6.99	11	12.42	11	5.58	7.32	6.48	6.84	6.55	Hypertrophic	WRC monitoring data.
1999	0.71	11	135.73	11	2138.00	11	130.45	11	7.00	11	15.58	11	5.42	7.64	6.41	6.40	6.47	Hypertrophic	WRC monitoring data.
2000	0.48	12	270.92	12	3112.75	12	170.83	12	7.10	12	16.99	12	5.82	8.40	6.90	6.74	6.97	Hypertrophic	WRC monitoring data.
2001	0.56	8	309.20	10	2791.60	10	165.60	10		10		10	5.65	8.55	6.76	6.70	6.91	Hypertrophic	WRC monitoring data.

Table 7: Rotopiko East: Average annual water quality data and TLI estimates.

Year	Average SchiDisk		Average Cla		TN		TP		pH		Turbidity		TLs	TLc	TLn	TLp	TLI	Trophic State	Data source / comments
	m	n	mg/m^3	n	mg/m^3	n	mg/m^3	n	pH	n	NTU	n							
1977	1.80		8.00										4.48	4.51				-	Chapman & Boubee 1977
1988	1.35	2	42.00	2	1220.00	2	35.00	2	6.75				4.77	6.34	5.68	4.73	5.38	Supertrophic	Page 1988. Two summer samples only.
2001		0		0		0		0	6.60	0	2.31	0						-	WRC monitoring data.
2002	1.12	3	14.00	3	1226.33	3	34.00	3	6.74	3	1.79	3	4.96	5.13	5.69	4.69	5.12	Supertrophic	WRC monitoring data.
2003	1.94	10	17.00	11	1072.64	11	29.73	11	6.80	11	1.83	11	4.40	5.35	5.51	4.52	4.94	Eutrophic	WRC monitoring data.
2004	1.51	10	22.69	13	1141.92	13	26.23	13	6.76	13	1.81	13	4.66	5.66	5.59	4.36	5.07	Supertrophic	WRC monitoring data.
2005	2.17	12	15.50	12	1044.92	12	26.33	12	6.68	12	1.99	12	4.28	5.24	5.48	4.37	4.84	Eutrophic	WRC monitoring data.
2006	1.85	12	14.82	11	1147.00	12	30.17	12	6.81	12	2.06	12	4.44	5.19	5.60	4.54	4.94	Eutrophic	WRC monitoring data.
2007	2.07	12	13.92	12	1041.08	12	22.75	12	6.74	12	1.86	12	4.33	5.12	5.47	4.18	4.78	Eutrophic	WRC monitoring data.
2008	1.37	12	15.16	13	1260.07	13	25.92	13	6.67	13	1.93	13	4.75	5.22	5.72	4.35	5.01	Supertrophic	WRC monitoring data.

2009	1.28	6	12.73	9	1335.62	9	32.67	9	6.86	9	2.20	9	4.82	5.03	5.80	4.64	5.07	Supertrophic	WRC monitoring data.
2010		0	13.40	3	1646.83	3	28.67	3	6.75	3	2.65	3		5.08	6.07	4.47		-	WRC monitoring data.
2011		0	9.33	3	1199.50	3	18.00	3	6.64	3	2.19	3		4.68	5.66	3.88		-	WRC monitoring data.
2012		0	5.00	2	1226.00	2	24.00	2		2		2		4.00	5.69	4.25		-	WRC monitoring data.

Table 8: Rotopiko South: Average annual water quality data and TLI estimates.

Year	Average SchiDisk		Average Cla		TN		TP		pH		Turbidity		TLs	TLc	TLn	TLp	TLI	Trophic State	Data source / comments
	m	n	mg/m³	n	mg/m³	n	mg/m³	n	pH	n	NTU	n							
1977	1.00		11.00										5.08	4.87				-	Chapman & Boubee 1977
1988	1.10	2	29.00	2	1215.00	2	40.00	2	7.00	2			4.98	5.93	5.67	4.90	5.37	Supertrophic	Page 1988. Two summer samples only.
2003 - 2007	1.30		11.00		1000.00		34.00						4.81	4.87	5.42	4.69	4.95	Eutrophic	Hamilton *et. al.* 2009.
2006		0		0		0		0	7.20	0	4.30	0						-	WRC monitoring data.
2007	1.20	1	4.40	1	891.00	1	30.00	1	7.23	1	5.97	1	4.89	3.85	5.27	4.53	4.64	Eutrophic	WRC monitoring data.
2008	1.45	1	33.00	2	1152.55	2	61.00	2	7.18	2	6.85	2	4.70	6.08	5.61	5.43	5.45	Supertrophic	WRC monitoring data.
2009		0	16.50	2	948.50	2	36.50	2	7.10	2	6.26	2		5.31	5.35	4.78		-	WRC monitoring data.
2010		0	18.53	3	1493.53	3	41.33	3	7.10	3	5.58	3		5.44	5.94	4.94		-	WRC monitoring data.
2011		0	11.33	3	1024.67	3	34.00	3	7.07	3	5.47	3		4.90	5.45	4.69		-	WRC monitoring data.
2012	0.80	1	16.33	3	792.00	3	36.50	2	7.08	3	5.48	3	5.30	5.30	5.12	4.78	5.12	Supertrophic	WRC monitoring data.
2013	0.81	1	8.50	2	641.00	2		0	7.17	2	4.53	2	5.29	4.58	4.84			-	WRC monitoring data.
2014	1.17	6	9.71	7	906.00	7		0		7		7	4.92	4.73	5.29			-	WRC monitoring data.

Table 9: Rotopiko North: Average annual water quality data and TLI estimates.

Year	Average SchiDisk		Average Cla		TN		TP		pH		Turbidity		TLs	TLc	TLn	TLp	TLI	Trophic State	Data source / comments
	m	n	mg/m³	n	mg/m³	n	mg/m³	n	pH	n	NTU	n							
1977	1.30		1.00										4.81	2.22				-	Chapman & Boubee 1977
1988	1.50	2	44.00	2	1035.00	2	25.00	2	7.00				4.66	6.39	5.46	4.30	5.21	Supertrophic	Page 1988 reported in Dean-Spiers *et. al.* 2014. Two summer samples only.
2001		0		0		0		0	7.08	0	2.18	0						-	WRC monitoring data.
2002	1.99	10	22.10	10	939.10	10	31.10	10	7.12	10	1.95	10	4.37	5.63	5.34	4.58	4.98	Eutrophic	WRC monitoring data.
2003	2.58	9	16.45	11	941.82	11	33.73	11	7.17	11	2.31	11	4.10	5.31	5.34	4.68	4.86	Eutrophic	WRC monitoring data.
2004	1.90	9	27.00	11	1221.83	12	35.83	12	7.15	12	2.64	12	4.42	5.86	5.68	4.76	5.18	Supertrophic	WRC monitoring data.
2005	2.03	12	19.92	12	1173.17	12	31.00	12	7.10	12	2.42	12	4.35	5.52	5.63	4.57	5.02	Supertrophic	WRC monitoring data.
2006	2.13	11	16.10	10	1161.82	11	30.00	11	7.20	11	2.12	11	4.30	5.29	5.62	4.53	4.93	Eutrophic	WRC monitoring data.
2007	2.50	11	12.83	12	1081.75	12	26.08	12	7.18	12	2.21	12	4.13	5.04	5.52	4.35	4.76	Eutrophic	WRC monitoring data.
2008	1.70	12	18.76	13	1423.42	13	33.46	13	7.11	13	2.53	13	4.53	5.45	5.88	4.67	5.13	Supertrophic	WRC monitoring data.
2009	1.49	8	10.12	12	1287.45	12	27.50	12	7.14	12	2.99	12	4.67	4.77	5.75	4.42	4.90	Eutrophic	WRC monitoring data.

Figure 15 shows the changes in TLI of each of the five lakes over the period between 1981 and 2012, although data is missing for some periods. Note the significant difference between the trophic levels of Rotomanuka North and Rotomanuka south.

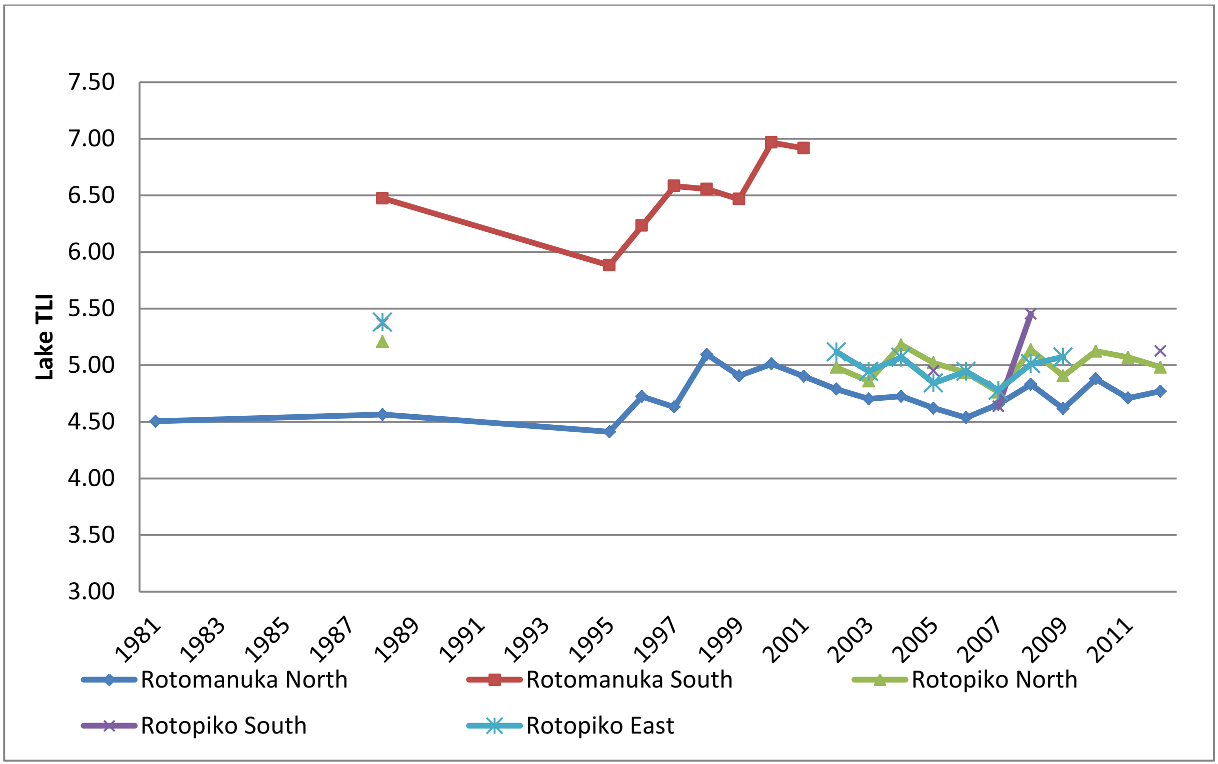

Figure 15: TLI values for all five lakes.

Trend analysis of lake water quality for the period 2005-2009 as part of a nationwide study showed no significant change in trophic status for Rotomanuka North, Rotopiko North, or Rotopiko East (Verburg *et. al.* 2010). Waikato Regional Council's online shallow lakes nutrient enrichment environmental indicator for the period 2008 - 2012 also reports no significant change in trophic status of Rotomanuka North, Rotopiko North or Rotopiko East although small non-significant annual changes in the indicators were apparent (Waikato Regional Council 2015).

8.3 Water Temperature

Waikato Regional Council holds daily water temperature data from nine sites in the catchment (Figure 1; Appendix 1) although three of the sites in the Rotopiko complex were only recording for a period of less than two years in 2007 and 2008. The data displayed in Figure 16 and Figure 17 represents the longest running datasets for each lake complex. Water temperature fluctuates in a seasonal pattern and in both the Rotomanuka and Rotopiko lakes there appears to have been a lowering in average water temperature between 2011 and 2014 although this has not been statistically tested. Air temperature fluctuates in a similar seasonal pattern as well as at a finer scale and lake water temperatures and mean air temperatures appear to be closely related.

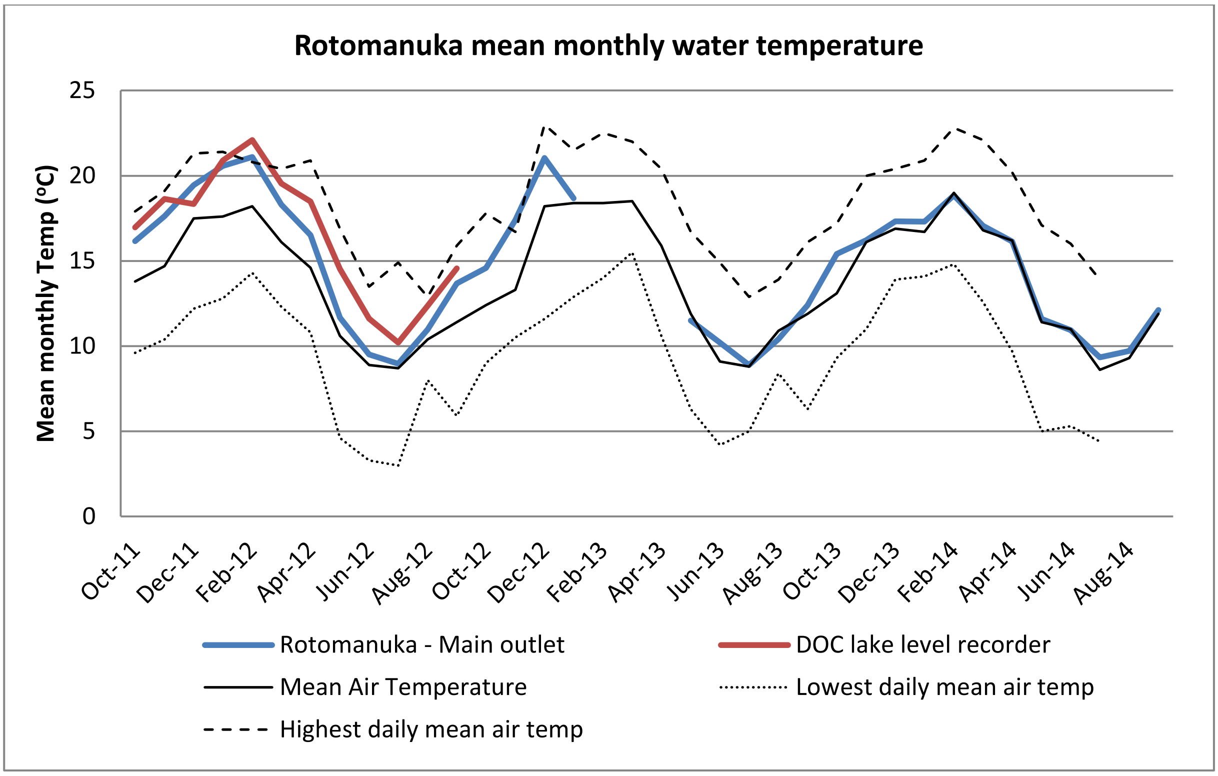

Figure 16: Mean monthly water temperature from two sites at Lake Rotomanuka and air temperatures from the Hamilton Airport climate station. Data from WRC & NIWA.

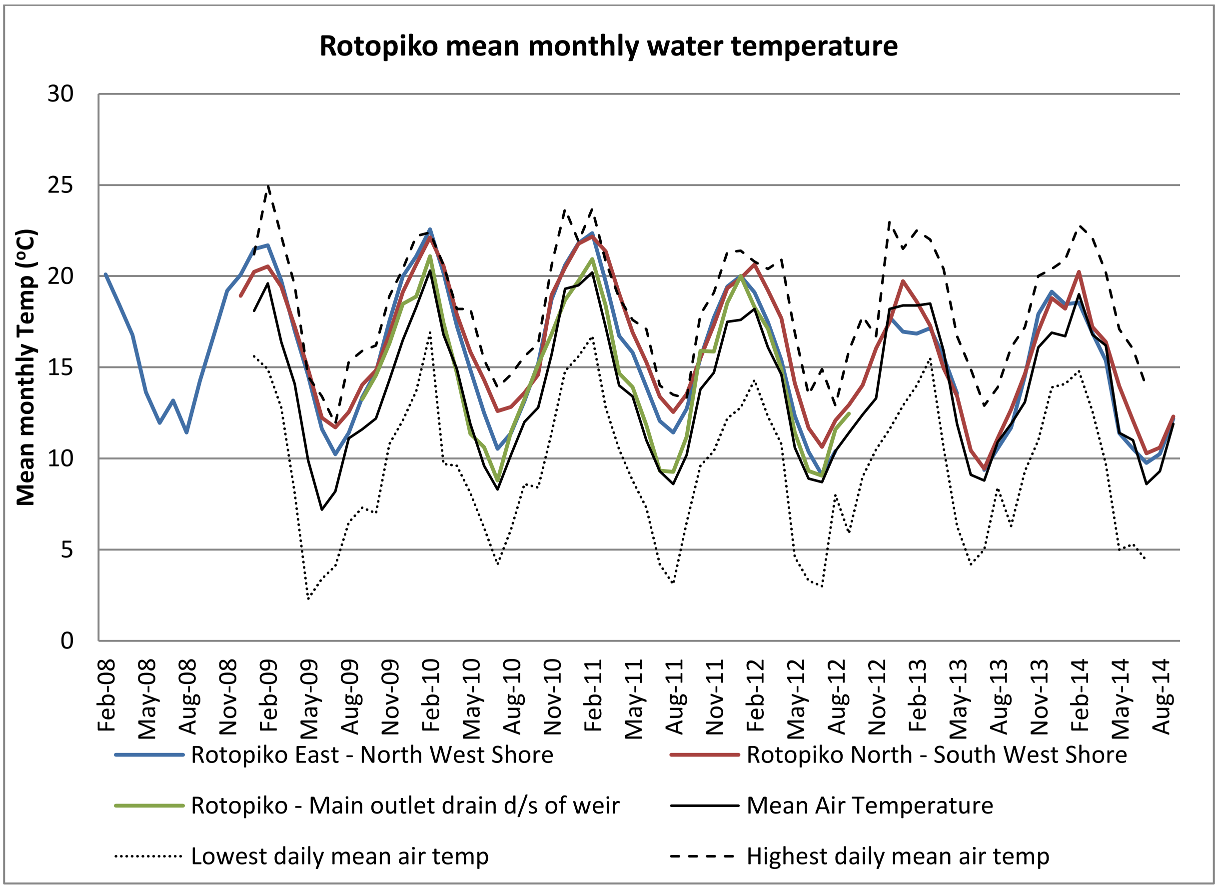

Figure 17: Mean monthly water temperature from three sites at Rotopiko and air temperatures from the Hamilton Airport climate station. Data from WRC & NIWA.

8.4 Dissolved Oxygen

Many lakes naturally stratify for at least part of the year. This is when a layer of warm water sites above a layer of cold dense water and little or no mixing occurs between the two. When there are high levels of algae in the water column because of excessive nutrients stratification can also lead to deoxygenation of the deeper water. This is at least in part because plant material in the bottom layers is broken down by bacteria which use oxygen and this cannot be replaced because of the lack of mixing with the surface. Deoxygenated water is toxic to fish and other aquatic organisms. Rotomanuka North stratifies every year in the warmer months leaving a layer of cold deoxygenised water below a warmer oxygenated one. Figure 18 shows dissolved oxygen (DO) concentrations in Rotomanka North between 1995 and 2014. The bottom waters (8m depth) are regularly deoxygenated and the deoxygenated hypolimnion also regularly extends into the middle depths of the lake. Both Rotopiko East and North also stratify relatively regularly although the hypolimnion appears to be a much narrower band (Figure 19 & Figure 20).

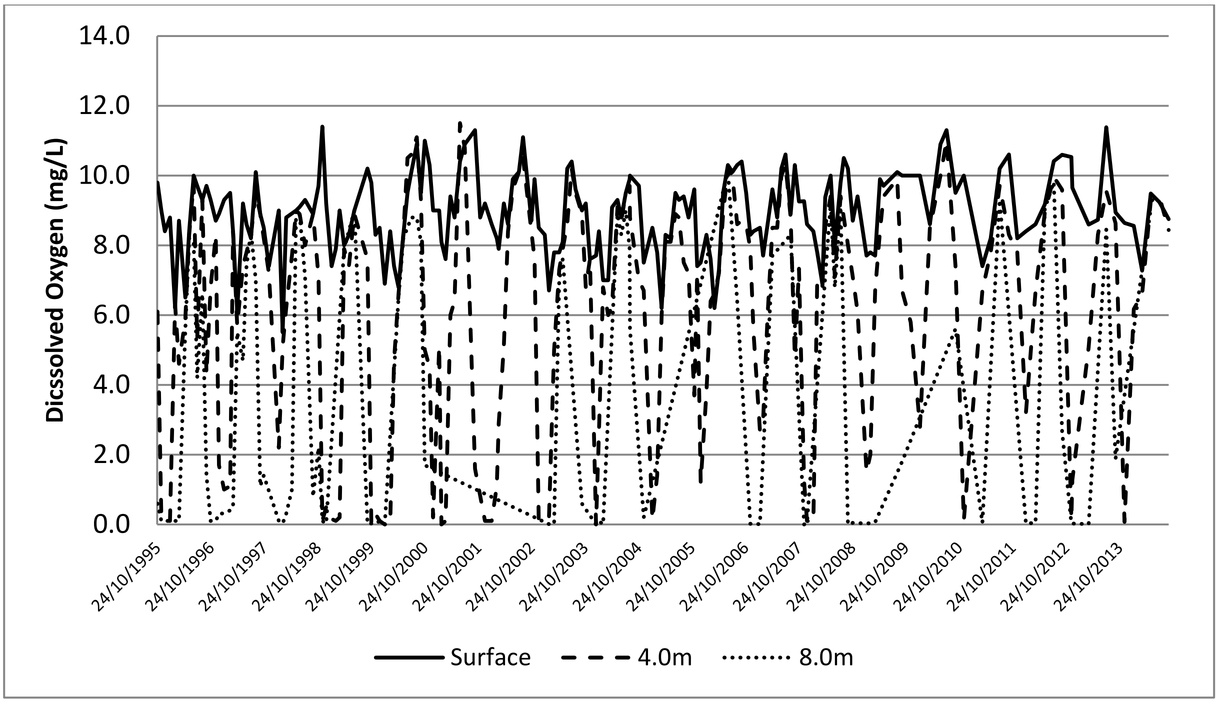

Figure 18: Dissolved oxygen levels at three depths in Lake Rotomanuka between 1995 and 2014.

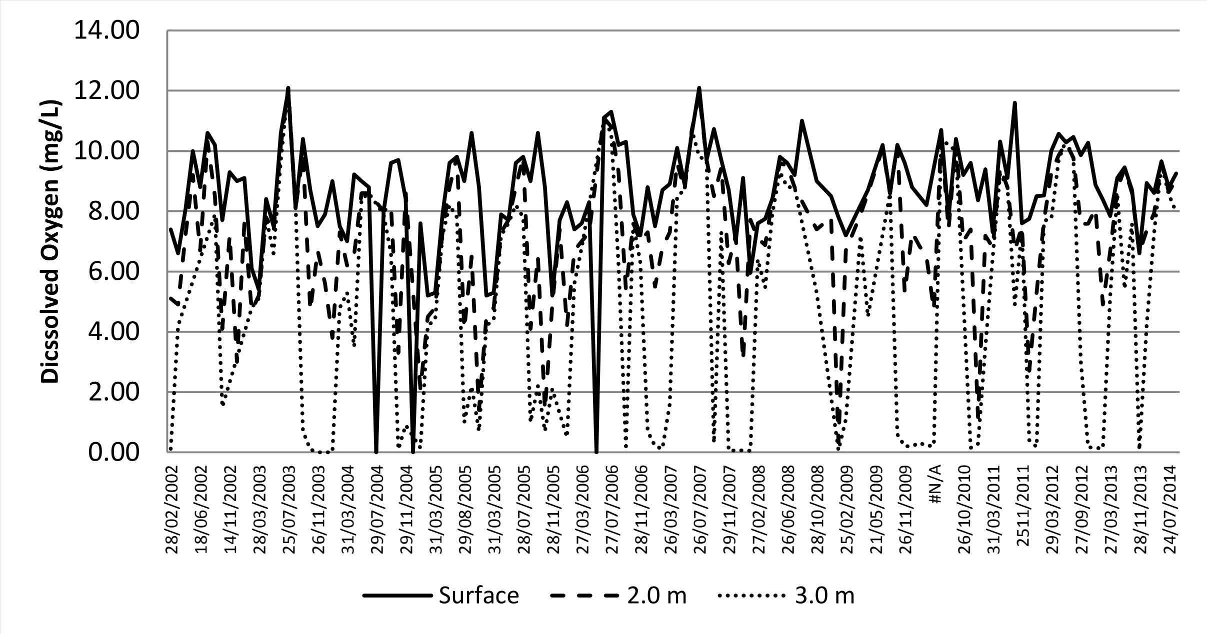

Figure 19: Dissolved oxygen levels for Rotopiko North taken at the surface, approximate mid water, and approximate bottom between 2002 and 2013.

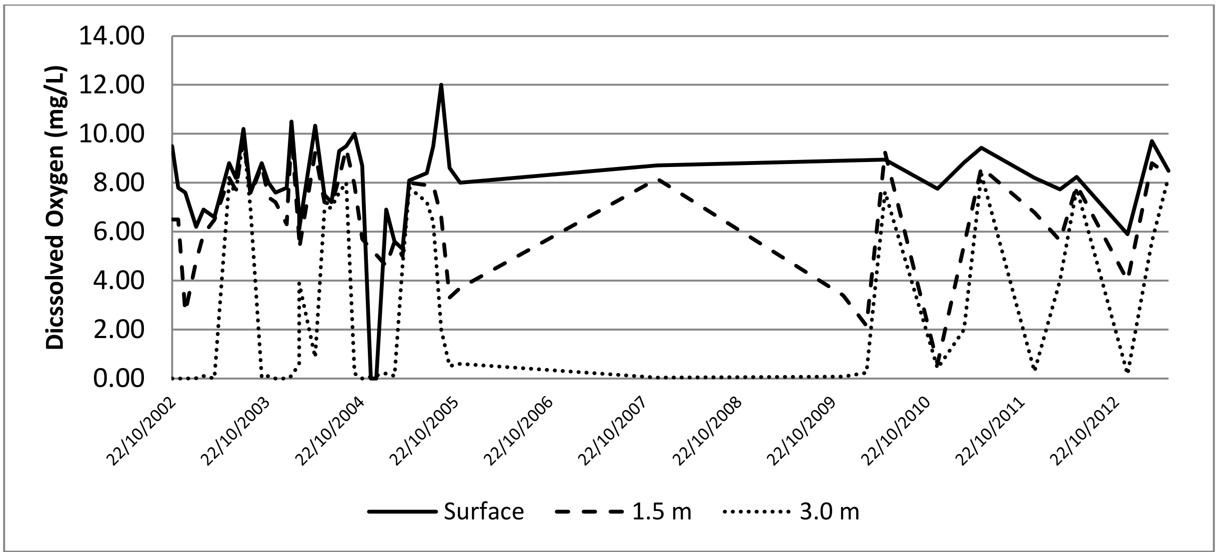

Figure 20: Dissolved oxygen levels for Rotopiko East taken at the surface, approximate mid water, and approximate bottom between 2002 and 2013.

8.5 Chlorophyll a

Chlorophyll a levels are an indication of the productivity of the lake. Trend analysis for chlorophyll a data has not been undertaken but there appears to be a significant decrease in concentrations in Rotomanuka North while the concentrations in Rotomanuka South have increased considerably. The Rotopiko Lakes have all displayed a decline in chlorophyll a concentrations over recent years (Figure 21).

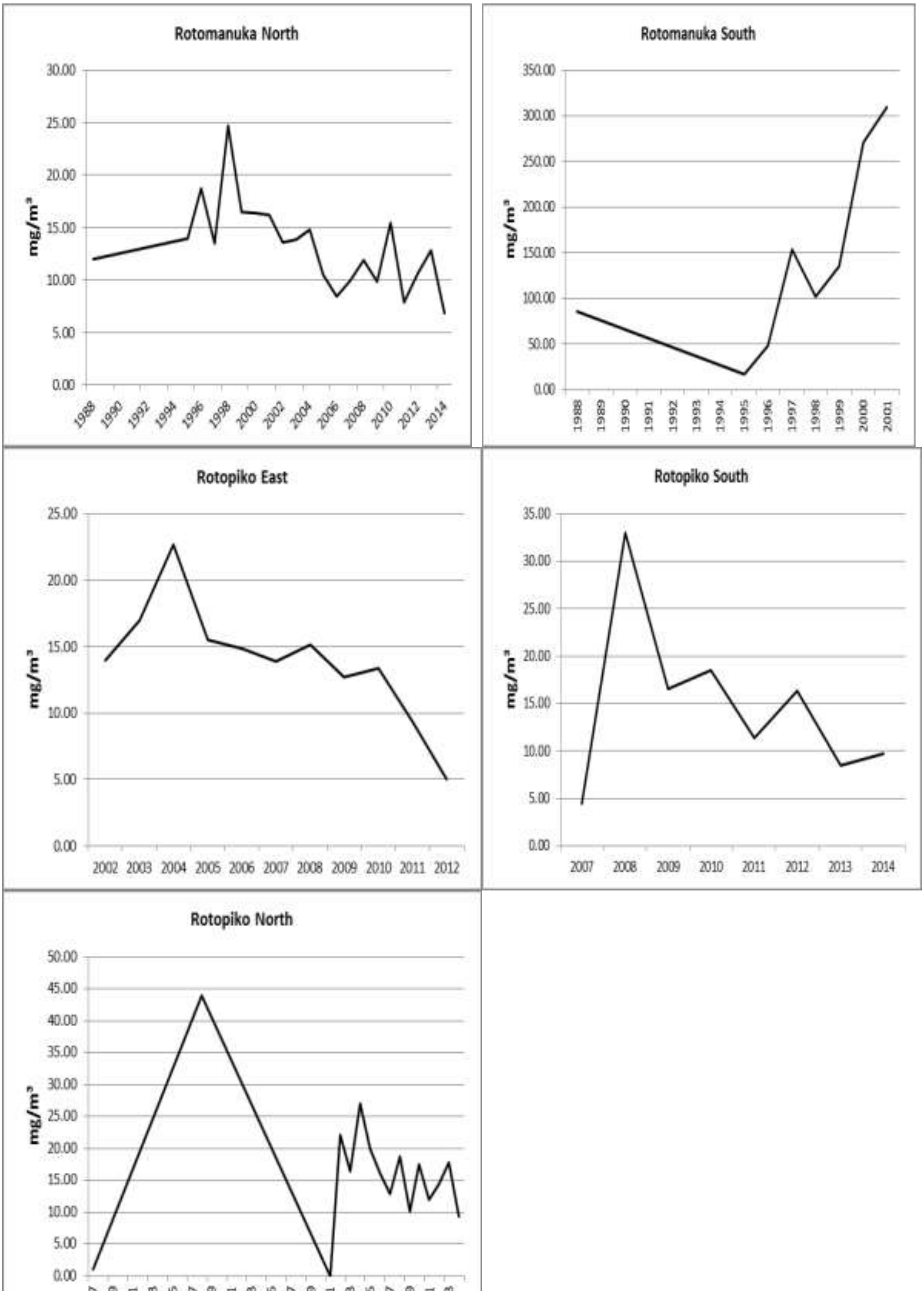

Figure 21: Chlorophyll a concentrations in the Rotomanuka catchment lakes. Note the variation in temporal scale. Data from WRC.

8.5.1 Rotifer Inferred TLI

Rotifer-inferred TLI is a method that has been used to calculate the trophic level of the lake based on the assemblage of rotifers living in it. Rotifer TLI has been calculated for the three Rotopiko lakes and Rotomanuka North since 2007 (Table 10; Duggan 2014). Values are closely related to traditional measurements of TLI although trends do not always match (Duggan 2014).

Table 10: Average rotifer inferred TLI values for four of the Rotomanuka catchment lakes. Data from Duggan 2014.

	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013
Rotomanuka North	--	5.32	4.14	4.64	4.23	4.49
Rotopiko North	5.1	3.84	4.07	3.56	3.34	3.55
Rotopiko South	3.76	3.73	4.18	3.84	3.58	3.12
Rotopiko East	3.38	3.16	3.27	2.97	3.35	2.29

9 RESOURCE USE

Intensively farmed catchments have considerable demand on natural resources and the Rotomanuka catchment is no different. Waikato Regional Council resource consent data shows two ground water takes in the catchment (one active and one application as at October 2014) and four effluent or wash-down water discharge to land consents (Figure 22). Publically available data does not include the volume of groundwater permitted to be taken or the actual volume taken, nor is there information about the volume of effluent being discharged onto land in the catchment. This data is held by Waikato Regional Council but may require permission of landowners to be released.

Other consents in the catchment include those associated with management of lake levels and drainage (dams and diversion consents) and land disturbance consents associated with ecological restoration work at Rotopiko.

As all farm effluent in the catchment is discharged to land there are no defined point-sources of nutrients. However, all of the drains flowing into the lakes will be transporting nutrients and sediment off the surrounding farmland. This has already been identified as a key restoration issue and plans are in place to construct silt traps and infiltration wetlands on most of the major drains flowing into Rotomanuka and Rotomanuka South (Eivers 2014; Dresser & Berry 2014).

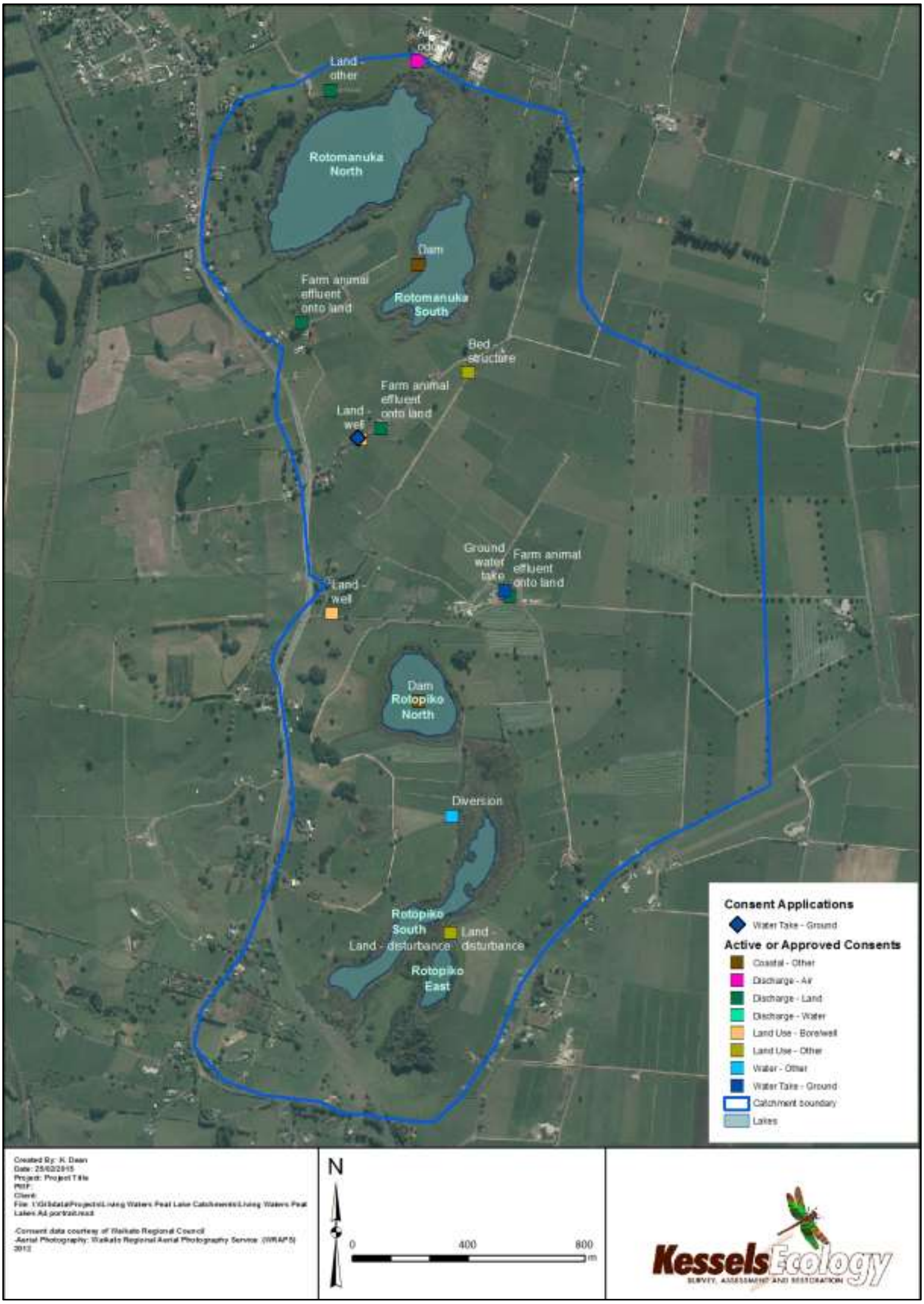

Figure 22: Active and proposed resource consents within the Rotomanuka catchment. Data from Waikato Regional Council.

10 BIODIVERSITY

10.1 Aquatic Fauna

10.1.1 Fish

The New Zealand Freshwater Fish Database (NZFFD) includes 25 unique entries for Lake Rotomanuka dating between 1983 and 2001, while there are 42 records for the Rotopiko lakes dating between 1984 and 2006. Four additional records for the catchment from 2011 appear to be from the drain linking the two lake complexes. A unique record in the NZFFD comprises a single species and a single sample. In other words four species caught in the same net on the same occasion comprise four unique entries in the database. A list of species and where they have been caught is included in Table 11.

The fish recorded comprise common indigenous species as well as four introduced pest fish. No threatened species have been recorded within the catchment and Longfin eel (*Anguilla dieffenbachii*) is the only species that is considered at risk (Goodman *et. al.* 2014). Speirs and Barnes (2002) found that the eel population in Rotomanuka North was skewed towards smaller individuals, probably as a result of periodic commercial harvest of the larger fish, but the population structure of the smaller eels indicated that recruitment into the lake was occurring on a regular basis.

Common smelt were relatively common in Rotomanuka during the three sampling events in 1983, 1991, and 2001. Smelt occurring in Rotomanuka are known to be genetically distinct from those in the Waikato River as they are land-locked and do not have a diadromous lifecycle

Although recorded in 1983 in Rotomanuka North goldfish (*Carassius auratus*) were not found during the 2000 - 2001 survey (Spiers & Barnes 2002) and the authors concluded that they were at very low levels or were no longer present at that time. More significantly the 2000 - 2001 survey was the first time that rudd (*Scardinius erythrophthalmus*) had been recorded in Rotomanuka North although how they got there is not known (Spiers & Barnes 2002). Rudd are known to preferentially browse native macrophytes (Hicks 2003) and have been shown to have a significant impact on submerged macrophytes (see section 10.1.3 below) and to detrimentally affect shallow lake water quality. Although the exact time of their arrival is not known it is likely that their arrival in Rotomanuka contributed to the collapse of the submerged macrophyte beds (Spiers & Barnes 2002).

All of the species found in Rotomanuka have also been recorded in the Rotopiko lakes (NZFFD, Wu *et. al.* 2013). Gambusia were recorded in the Rotopiko lakes for the first time in 2012 having previously been thought to be absent (Wu *et. al.* 2013). Despite the presence of pest fish in the Rotopiko lakes the biomass of indigenous species (31.9 kg ha^{-1}) far outweighs that of introduced species (1.37 kg ha^{-1}) with eels being the most abundant native fish and catfish (*Ameiurus nebulosus*) the most abundant introduced species (Wu *et. al.* 2013). Rudd have been recorded in all three Rotopiko lakes in the past and have been the subject of an intensive control effort by DOC and Waikato Regional Council since 2001 (Lake 2010). Rudd control has been undertaken using fine-mesh nets with the aim of protecting and enhancing the valuable native submerged plant communities (Lake 2010). The programme has been largely successful with catch per unit effort (CPUE) reducing quickly after netting began and staying relatively low ever since (Price 2014). Significantly, rudd were not recorded in the latest survey at Rotopiko indicating that the population is relatively small and that control efforts have been effective (Wu *et. al.* 2013). However no direct relationship has been found between pest fish levels and submerged macrophyte cover and further research may be required to clarify the effects of pest fish removal (Lake 2010; Price 2014). Research in Rotomanuka showed a clear benefit for aquatic plants from the exclusion of pest fish (de Winton & Taumoepeau 2005). The Department of Conservation have recently completed pest fish survey work in the lakes and data was being analysed at the time of writing.

Table 11: Fish records for the Rotomanuka catchment. The majority of records are from the NZFFD but records from Wu *et. al.* 2013 are also included.

	Common name	**Conservation Status**	**Rotomanuka North**	**Rotomanuka Outlet**	**Rotopiko - Rotomanuka Drain**	**Rotopiko North**	**Rotopiko East**	**Rotopiko South**
Ameiurus nebulosus	Brown bullhead catfish	Introduced and naturalised	1985, 2000, 2001			2006, 2012*	2006, 2012*, 2001-2009[#]	1984, 2002, 2003, 2006, 2012*
Anguilla australis	Shortfin eel	Not Threatened	2000, 2001	2011	2011	2001, 2006, 2012*	2006, 2012*	1984, 2001, 2002, 2003, 2006, 2012*
Anguilla dieffenbachii	Longfin eel	At Risk - Declining	1991, 2001			2012*	2012*	1984, 2006, 2012*
Carassius auratus	Goldfish	Introduced and naturalised	1983			2001	2012*, 2001-2009[#]	2001, 2002, 2003, 2012*
Gambusia affinis	Gambusia	Introduced and naturalised		2011	2011			2012*
Gobiomorphus cotidianus	Common bully	Not Threatened	1983, 1991, 2000	2011	2011	2001, 2006, 2012*	2006, 2012*	1984, 2001, 2002, 2003, 2006, 2012*
Retropinna retropinna	Common smelt	Not Threatened	1983, 1991, 2000, 2001			2001, 2006, 2012*	2006	2002, 2003, 2012*
Scardinius erythrophthalmus	Rudd	Introduced and naturalised	2000, 2001			2001	2001 - 2009[#]	2001, 2002, 2003

* Data from Wu *et al* 2013. [#]Data from Lake 2010.

10.1.2 Invertebrates

The invertebrate fauna of Lake Rotomanuka has been studied extensively over at least the last 30 years predominantly by University of Waikato scientists and students.

A study was undertaken in Rotomanuka by Duggan *et. al.* (2001) to examine the influence of macrophytes on littoral rotifer distribution. This showed a significant variation in the abundance of some rotifer species across different macrophyte species and various explanations about the likely causes were presented.

Invertebrate records from NIWA's FBIS database are included in Appendix 2.

Studies of the zooplankton fauna have been undertaken in Rotomanuka as part of analysis of rotifer inferred TLI (Duggan 2008, 2014). Lists of species are available in these reports and are not repeated here.

10.1.3 Flora

Aquatic macrophytes are an important component of lake ecology, providing valuable services including habitat for fauna and algae, wave attenuation, nutrient sequestration, and sediment capture (Barnes 2001). As such the aquatic macrophyte community is now used as an important indicator of lake health (see section 10.1.4 below). The aquatic macrophyte flora of Rotomanuka has changed dramatically over the last several decades. In the late 1970's Rotomanuka North had a band of the introduced *Elodia canadensis* approximately 20 m wide around the margin of the lake (Chapman & Boubee 1977, Boubee 1978) although this is likely to have been a mis-identification of *Egeria densa* (Champion *et. al.* 1993). The survey undertaken by Davenport (1981) found that *Egeria densa* was the dominant submerged macrophyte and in 1983 beds of this species were found to extend down to 5.5 m depth and growing up to 2.5 m tall (Campion *et. al.* 1993). Several other aquatic macrophytes were present during this period including a population of the now threatened *Utricularia australis* in Rotomanuka North, *Potamogeton cheesemanii* and *P. ochreatus,* (Chapman & Boubee 1977; Davenport 1981, Champion *et. al.* 1993).

In 1991 the submerged flora was surveyed by Champion *et. al.* (1993) and was found to be largely similar to the early 1980's; *Egeria densa* was the dominant species forming a band of vegetation down to 5.5 m depth and reaching to around 1m below the surface. Browsing of apical shoots by swans was evident (Champion *et. al.* 1993). *Nitella hookeri* and *Potamogeton cheesemanii* were recorded where *Egeria* was less dominant but *Utricularia australis* was not observed (Champion *et. al.* 1993). The submerged macrophytes in Rotomanuka North are thought to have completely disappeared in about 1996 and the lake remains non-vegetated (Burton *et. al.* 2014).

Early records of submerged vegetation in Rotomanuka South are absent but in 1993 Champion *et. al.* described a relatively sparse submerged flora of *Nitella hookeri, Potamogeton ochreatus,* and *Egeria densa*.

The Rotopiko Lakes have until relatively recently supported a solely indigenous submerged flora but in 2009 the invasive bladderwort *Utricularia gibba* was found in Rotopiko South for the first time (de Winton 2009). This species then spread to Rotopiko East in 2010, and Rotopiko North in 2011 (NIWA 2015).

A survey of the submerged flora of the Rotopiko lakes in 1991 showed occasional *Nitella hookeri, Potamogeton ochreatus,* and *P. cheesmannii* in Rotopiko East between 1.5 m and 2.5 m depth (Champion *et. al.* 1993). Rotopiko South had a similar sparse flora with *P. ochreatus* and *P cheesemanii* reported to depths of 2 m; the vegetation growth likely restricted by poor light penetration through the peat-stained water (Champion *et. al.* 1993). Rotopiko North was more densely vegetated, being dominated by *P. ochreatus* with *P. cheesemanii* and occasional *Chara corallina (*Champion *et. al.* 1993). Over the last 10 - 15 years the submerged flora of Rotopiko North has remained in good health with high cover of indigenous species. Rotopiko South was reported as non-vegetated between 2002 and

2004 but vegetation recovered and it has generally been in a healthy state since then (NIWA 2015). Rotopiko East has remained relatively healthy although the invasion by *Utricularia gibba* has had some impact on the submerged indigenous flora (NIWA 2015).

Lists of phytoplankton have been presented in a number of reports (e.g. Chapman & Boubee 1977; Town 1980; Barnes 2002a) and are not repeated here.

10.1.4 Lake Submerged Plant Indicators (SPI)

Lake SPI uses the extent and diversity of submerged native and exotic plants to provide an indicator of lake health (Clayton & Edwards 2006). Lake SPI data is available for all three Rotopiko Lakes and Rotomanuka North although temporal coverage varies somewhat. Historical SPI data for the 1800s has been reported (Burton *et. al.* 2014), presumably derived from early descriptions of the submerged flora and one-off data points from the late 1970s and early 1908s are also available. More consistent SPI monitoring began in the 2000s after which regular measurements have been taken in the Rotopiko lakes. The data shows high SPI values for Rotopiko North and East until the invasion of *Utricularia gibba* in around 2009 after which SPI declines. Rotopiko South has undergone at least two fluctuations from vegetated to non-vegetated between 1991 and 2012. These fluctuations are more extreme than would be expected of such a system and are an indication that the lake is on the point of becoming de-vegetated (Burton *et. al.* 2014).

Figure 23: Trends in Lake SPI in four of the Rotomanuka catchment lakes between 2001 and 2014. Data from Burton et. al. 2014 and NIWA 2015.

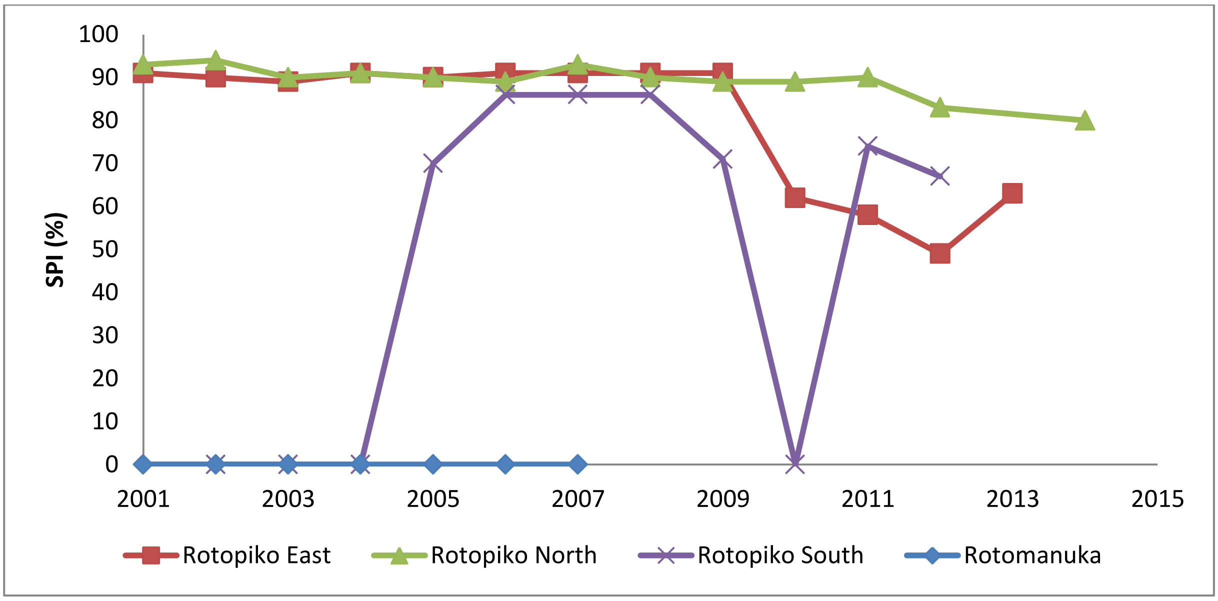

Table 12: Lake SPI data for four of the lakes in the Rotomanuka catchment. Data from Burton et. al. 2014 and NIWA 2015.

	Rotomanuka			Rotopiko East			Rotopiko North			Rotopiko South		
Year	SPI (%)	Native Index (%)	Invasive Index (%)	SPI (%)	Native Index (%)	Invasive Index (%)	SPI (%)	Native Index (%)	Invasive Index (%)	SPI (%)	Native Index (%)	Invasive Index (%)
1800s	95	90	0	97	93	0	97	93	0	97	93	0
1977	41	52	78	89	73	0	91	80	0			
1983	11	0	91									
1991	18	7	87	0	0	0	85	69	0	0	0	0
1992										0	0	0
2001	0	0	0	91	80	0	93	84	0			
2002				90	77	0	94	87	0	0	0	0
2003				89	75	0	90	76	0	0	0	0
2004				91	80	0	91	80	0	0	0	0
2005				90	76	0	90	77	0	70	56	0
2006				91	79	0	89	73	0	86	67	0
2007	0	0	0	91	80	0	93	83	0	86	68	0
2008				91	79	0	90	76	0	86	68	0
2009				91	79	0	89	75	0	71	60	0
2010				62	71	0	89	75	0	0	0	0
2011				58	60	0	90	81	0	74	60	0
2012				49	57	0	83	76	0	67	60	0
2013				63	72	0						
2014							80	69	0			

10.2 Terrestrial biodiversity

10.2.1 Vegetation

Significant vegetation change in the Waikato lowlands has been well documented by Newnham et al. (1989). They described a succession from sub-alpine shrublands and beech forest prior to 14,500 years ago, through matai and rimu forest, podocarp-broadleaved forest, predominance of kauri between 1000 and 3000 years ago, and subsequent anthropogenic clearance. It is thought that peat formation began around 10,000 years ago (Waipa District Council 2007) and the vegetation in the catchment may have included areas dominated by the restiad rushes *Sporadanthus ferrugineus* and *Empodisma minus* which are the key peat-forming species of the Waikato. The Rotomanuka and Rotopiko lakes are situated on the edge of the historic extent of the Moanatuatua Bog which was a 7,500 ha oligotrophic peat bog prior to drainage and clearance of all but 137 ha of it to make way for farming (Clarkson et al. 2004). Because of their location at the edge of the historic bog the lakes and wetlands would have been influenced by adjacent mineral soils and much of the area is likely to have been subject to swamp or fen conditions, with a higher nutrient status than the nearby bog. These areas would likely have supported *Carex*, *Machaerina arthrophylla*, *M. rubiginosa*, *Leptospermum scoparium,* and *Cordyline australis* as the wetland does now. Lower nutrient areas would have included manuka and tangle fern communities (Campbell 1975; Clarkson et al. 2004) and kahikatea forest would likely have dominated in drier areas where flooding was less frequent. Neither of the two key restiad rushes remains at Rotomanuka and any peat formation will be restricted to that which is sometimes formed by *Machaerina* species (Campbell 1975).

Since European settlement the lakes have been lowered, exposing land where the water was shallow so that Rotopiko is now three lakes and Rotomanuka two. The surrounding landscape has been cleared of indigenous forest cover and is now intensively farmed. The wetlands have a higher nutrient status than they would have historically which is reflected by the dominance of nutrient-loving species such as raupo (*Typha orientalis*), grey willow (*Salix cinerea*), and *Carex secta*. One or two small areas of vegetation more indicative of mesotrophic conditions remain.

Marked changes in the vegetation cover have also occurred in the last 25 years. The vegetation map produced by Champion et al. (1993) shows a large area of manuka (*Leptospermum scoparium*)-dominated scrub in the wetlands between the two Rotomanuka lakes. Manuka scrub appears to have been replaced by a dense canopy of grey willow, as evidenced in a photo included in the Waipa District Peat Lakes and Wetlands booklet (pg. 11), although the photo is not dated. Control work by DOC at Rotomanuka over recent years has reduced the cover of willow in the central wetlands significantly to leave the current cover which is dominated by *Carex* species. Vegetation change around the margins of the lakes, away from the central wetlands, appears to have been less marked. The current cover in these areas does not differ greatly from the vegetation described and mapped by Champion et al. (1993), apart from some willow clearance and subsequent planting of manuka on the northern edge of Rotomanuka.

At Rotopiko a considerable effort has been put into restoration of the marginal vegetation since the Champion *et. al.* (1993) survey although even at that time it appears the vegetation was in a relatively natural state. Since 1993 willow and other weed control has resulted in marginal vegetation dominated by natural vegetation associations. Planted natives including kahikatea (*Dacrycarpus dacrydioides*), harakeke (*Phormium tenax*), *Carex* sedges, and cabbage tree (*Cordyline australis*) are common around the lakes and there are areas of manuka-*Macharina* associations, kuta (*Eleocharis sphacelata*) reedland, and sedgeland. The giant cane rush *Sporadanthus ferrugineus* has been planted and is well established on the southern shore of Rotopiko East.

Several small remnants of kahikatea forest remain within the catchment, the largest of which is just south of Rotopiko East and within the predator-proof enclosure. This stand has been subject to weed control and enhancement planting in an effort to restore it to a more natural state. Another small kahikatea stand is located just to the east of Rotopiko North and there are three small stands east of the Rotomanuka lakes. At least one of these has been recently fenced and planted.

The remaining vegetation in the catchment is dominated by high-production pasture grassland with scattered small stands of Tasmanian blackwood (*Acacia melanoxylon*) and other exotic trees.

A vegetation management plan completed for Rotomanuka in 2014 details the vegetation types within the wetlands surrounding the lakes (Dean 2014) and the botanical species list from that report is included as Appendix 3. Barnes (2001) surveyed the aquatic and marginal vegetation of Rotopiko North and described the composition and structure of the plant communities and the ecological drivers affecting them.

10.2.2 Fauna

Bird species recorded from the catchment in include the Nationally Endangered Australasian bitters (Cheyne 2013), Nationally Vulnerable Caspian tern (Dean 2014) and New Zealand dabchick (Reeves et al 2011), Naturally Uncommon black shag, and North Island Fernbird which is ranked as Declining (Table 13).

Table 13: Bird species recorded from the catchment. Data from Dean 2014, Reeves et al 2011, and Cheyne 2013.

Common Name	**Specific Name**	**Threat status** (Robertson et. al. 2013)
Australasian bittern	*Botaurus poiciloptilus*	Threatened: Nationally Endangered
Black shag	*Phalacrocorax carbo novaehollandiae*	At Risk: Naturally Uncommon
Black swan	*Cygnus atratus*	
Canada goose	*Branta canadensis*	
Caspian tern	*Hydroprogne caspia*	Threatened: Nationally Vulnerable
Dabchick - NZ	*Poliocephalus rufopectus*	Threatened: Nationally Vulnerable
fantail	*Rhipidura fuliginosa placabilis*	
Fernbird - North Island	*Bowdleria punctata vealeae*	At Risk: Declining
Grey warbler	*Gerygone igata*	
Kahu, Harrier	*Circus approximans*	
Mallard	*Anas platyrhynchos*	
Pukeko	*Porphyrio melanotus melanotus*	
Ring-necked pheasant	*Phasianus colchicus torquatus*	
Sacred kingfisher	*Todiramphus sanctus vagans*	
Silvereye	*Zosterops lateralis lateralis*	
Song thrush	*Turdus philomelos clarkei*	
Tui	*Prosthemadera novaeseelandiae novaeseelandiae*	
Welcome swallow	*Hirundo neoxena neoxena*	

Long-tailed bats (*Chalinolobus tuberculatus*) have been recorded at Lake Rotopiko in the past although a recent survey (2015) did not record any bats (G. Kessels *pers. comm*). Although the status of the population there is not known it is likely that long-tailed bats utilise the wider catchment area for foraging and may roost in other appropriate habitat such as the kahikatea remnants east of Rotomanuka. Long-tailed bats are a Nationally Vulnerable species (O'Donnell *et. al.* 2013).

A number of pest mammals are also likely to be present in the catchment including Norway rats (*Rattus norvegicus*) ship rats (*Rattus rattus*), mice (*Mus musculus*), stoats (*Mustela erminea*), ferrets (*M. furo*), weasels (*M. nivalis*), cats (*Felis domesticus*), possums (*Trichosurus vulpecula*), and hedgehogs (*Erinaceus europaeus*). Control of several of these species is undertaken at Rotopiko and further control may be started at Rotomanuka (Paula Reeves *pers. comm.* 9/12/2014). Rats, possums, and hedgehogs are likely to be widespread throughout the catchment.

10.3 Biodiversity Information Gaps

The work carried out by NIWA scientists on the effects of pest fish on the re-establishment and survival of aquatic macrophytes highlights the need for pest fish removal and particularly rudd control. However, given that complete eradication of pest fish is very difficult it would be very useful to know how low the rudd population needs to be in order for submerged macrophytes to be able to re-establish from founder colonies. It seems likely that if the expectation was that submerged macrophytes re-colonise naturally the rudd population would need to be almost zero but if an aquatic re-vegetation programme was undertaken in a similar way to the trial work carried out by de Winton & Taumoepeau (2005) the planted macrophytes may be able to tolerate at least some grazing pressure. If the rudd population level at which planted macrophytes can effectively re-establish was known a fish removal and re-vegetation programme could be established, utilising the experience gained in the Rotopiko lakes.

Additional bat survey at Rotomanuka would be beneficial. Suitable roost habitat exists both in exotic trees around the lake and in the kahikatea remnants to the east of the lakes and additional survey would confirm the presence of bats and give an indication of how bats move around the local landscape. Additional wetland and wader bird survey could also be carried out, along with establishing a regular monitoring programme.

No terrestrial invertebrate information is available for the catchment and this could be rectified by undertaking a dedicated survey.

11 ECOLOGICAL SIGNIFICANCE

Lake Rotopiko has been ranked as 15th in the list of significant lakes of the Waikato while Rotomanuka has been ranked as 18th (Reeves et al 2011). The wetlands around both lake complexes have been assessed as being Nationally Significant (Deichmann & Kessels 2012).

The entire Rotomanuka catchment is classified as Acutely Threatened under the LENZ Threatened Environments Classification (Figure 5) which is a reflection of the scarcity of indigenous ecosystems in lowland areas and on peat soils in particular.

12 MANAGEMENT

Several agencies and a number of landowners are involved in the management of the catchment and the lakes. This section briefly outlines recent management work in the catchment relevant to the project.

12.1 Nutrient Management

Management of nutrients both on-farm and within the lake and drain network is the single most important aspect for maintaining and improving the quality of aquatic habitat and water quality in the catchment. Dairy farm effluent systems have been changed over the last two or three decades so that effluent is now irrigated onto land where excess nutrients can be filtered or assimilated by soil and plants. All farms in the catchment now irrigate to land, the last having converted from a two-pond system in 2001 (Barnes 2002a). Nevertheless nutrient runoff is still an issue and considerable nutrient stores exist within lake sediments (Faithfull *et. al.* 2005). Measures for reducing nutrients transport into lakes include reduction or more target fertiliser application on pasture, riparian fencing and planting, silt traps and infiltration wetlands. An infiltration wetland was constructed in March 2008 on the western edge of Rotopiko North as a trial (Sukias *et. al.* 2009) and more are planned for the Rotomanuka lakes (Dresser & Berry 2014; Eivers 2014). While an initial assessment of the Rotopiko infiltration wetland showed no significant nutrient removal it is expected to improve as the wetland plants establish and deposition of organic matter improves denitrification (Sukias *et. al.* 2009).

12.2 Department of Conservation

The Department of Conservation administers the Wildlife Management Reserves around both lake complexes and is actively involved in the management of the lakes. DOC has undertaken pest plant control work in the Rotomanuka and Rotopiko Wetlands and a significant amount of pest fish control and survey in the Rotopiko Lakes since 2001. They have invested a considerable amount of resources into studying the effects of pest fish removal (Lake 2010; Price 2014), pest fish control methods (Ling 2013), the efficacy of the pilot infiltration wetland (Sukias *et. al.* 2009), and developing restoration plans (e.g. de Winton *et. al.* 2007; Dean 2014).

12.3 National Wetland Trust of New Zealand

The National Wetland Trust has had a significant involvement in the restoration of the Rotopiko Lakes. The Trust has, with the assistance of a number of other agencies, built a pest-proof enclosure around Rotopiko East and the Waipa DC reserve land situated between Rotopiko East and South. Plans to build a National Wetland Centre within the enclosure are well underway. The trust has also developed a revegetation plan for Rotopiko East (National Wetland Trust 2011) which outlines target vegetation types, planting lists, constraints, and a weed management plan for the entire site.

12.4 Waipa District Council

Waipa DC owns land around the margins of both lake complexes and is heavily involved in the lake management and protection through the Waipa Peat Lakes Accord. The council has recently purchased additional land to the east of Rotomanuka to allow a wider riparian buffer to be fenced and planted. The Waipa Peat Lakes Accord group have recently been discussing establishing predator control at several lakes in the Ohaupo area which would complement existing control at Rotopiko (Paula Reeves *pers. comm.* 9/12/2014).

12.5 New Zealand Landcare Trust

The New Zealand Landcare Trust are undertaking a restoration project in the Rotomanuka catchment, focussed on the Rotomanuka lakes. The Trust has been working with landowners to develop whole farm plans which deal with nutrient management and reducing the impact of the farm on the lake ecosystem. The Trust has also managed community planting days at Rotomanuka and commissioned a scoping study of likely nutrient inputs to the lakes and potential mitigation measures (Dresser & Berry 2014; Eivers 2014). This study identified a number of mitigation measures and a total of 12 infiltration wetlands or silt traps were recommended (Eivers 2014).

12.6 Waikato Regional Council

As previously discussed Waikato Regional Council have several active monitoring programmes in the catchment and have commissioned a considerable amount of research.

13 KNOWLEDGE GAPS

This section provides an outline of gaps in the data which may need to be filled in order to efficiently manage the catchment and restoration work within it. Other data gaps may be revealed as restoration work progresses. Of course all of the data could be improved on; monitoring could be more often and at more sites and studies could be done over longer periods but the quantity, quality, and extent (both temporal and spatial) of the environmental data available for the Rotomanuka catchment is very good, and much better than is available for most other catchments. As it is it provides a solid foundation on which managers can base decisions on catchment management and restoration actions. The following are generally small gaps in the data that could be filled.

13.1 Catchment Extent

Catchment boundary data held by WRC was used which was originally derived from WRAPS aerial photography and NZMS260 maps. This data provides an indicative boundary only but could be significantly improved by a simple ground survey after rain to check which way drains are flowing. This is only required on the eastern boundary where the land is relatively flat and the watershed highly modified by drainage. This is a relatively simple fix and should be done before further restoration planning work is undertaken.

13.2 Soils

The available soil survey data is relatively course-scaled and the extent of the peat soils does not appear to be accurate based on the land contour. Some soil sampling work has already been undertaken as part of whole farm plans (Thompson 2014) but improving the soil map for the catchment would require additional survey work. One of the most important aspects of peat lake management is the sustainable management of the peat itself and knowing exactly where that peat is, its physical properties, and its depth would be valuable for future management of the catchment.

13.3 Climate Data

The climate data available for the area is relatively good, especially if the data from Blueberry Country can be obtained. However, establishing a climate station within the catchment would provide valuable data for the assessment of hydrology and the effects of eutrophication in the catchment. It would enable finer-scale monitoring of the effects of restoration and land management work and assessment of relationships between rainfall and water quality for example.

13.4 Hydrology

Stockdale’s 1995 thesis appears to be the current extent of groundwater investigation in the catchment. It provides a valuable source of information but did only cover the areas immediately adjacent to the two lake systems. Additional and updated information on the behaviour of the ground water, storage capacity of lakes and wetlands, and hydrological cycling in the lakes may be useful for catchment modelling. This kind of research could be carried out by a post-graduate student.

13.5 Bathymetry

Bathymetry data for the Rotopiko lakes could not be found during this project and may not exist. However, NIWA have undertaken sonar surveys of the Rotopiko lakes as part of the Lake SPI work (de Winton 2009) and bathymetry data may be available from this.

13.6 Water Quality

Water quality data collected by Waikato Regional Council is reasonably comprehensive but monthly monitoring of Rotomanuka South was stopped in 2001, apparently on the recommendation of Barnes (2002b) and based on the premise that water quality had reached such a poor state and was unlikely to improve without management. Now that considerable resources are to be put in to the management and restoration of the catchment, including a proposed silt trap and infiltration wetland in the main Rotopiko-Rotomanuka drain it seems prudent to re-establish water quality monitoring in Rotomanuka South so that improvements can be detected.

13.7 Biodiversity

Biodiversity information is generally very good although more regular invertebrate and fish sampling could be done.

Pest fish removal in the Rotopiko lakes has been successful but the relationship between catch per unit effort (CPUE) and actual population density for pest fish in the Rotopiko Lakes is not known and was identified by Lake (2010) as a significant knowledge gap. The relationship between fish density macrophyte decline could also be better understood. Research by de Winton and Toumoepeau (2005) and Dugdale *et. al.* (2006) has shown that indigenous macrophytes can establish in turbid water conditions such as those found in Rotomanuka so long as they are protected from herbivorous pest fish but could not establish even when pest fish numbers are low. However, it may be useful to know how low rudd population density needs to be before the proposed macrophyte founder colonies can spread into un-fenced parts of the lake.

14 SUMMARY

A summary of the state of key environmental data is included in Table 14 along with a statement about the trend in each attribute and potential restoration actions that may be required to improve the state of that attribute. In many cases the data available was not sufficient to show a clear trend but an assessment of the likely trend has been made based on information from other lakes and our own experience.

Table 14: Summary of the current state, trend and potential restoration actions for key environmental attributes.

Attribute	Current State	Trend	Potential Restoration Actions
Soils	Peat soils occupy around 68% of the catchment.	Probably deteriorating. Significant peat shrinkage has been reported in the past.	Maintenance of water level is important for maintaining peat and reducing shrinkage. If drains need to be cleaned they should be widened rather than deepened. Consideration should be given to fencing and retiring permanently wet areas which are prone to pugging including wider buffers around all of the lakes.
Land use/cover	Approximately 80% of the catchment is in pasture and 7.5% is occupied by the five lakes. Indigenous vegetation and wetlands with a significant indigenous component occupy less than 10% of the catchment.	Over the last 10 or 15 years exotic weedy vegetation has been replaced in many areas with indigenous wetland species.	Increasing the indigenous cover would benefit wildlife native plants and may provide ecosystem services such as buffering and filtering. However, the economic viability of the land is of prime importance and vegetation restoration may be restricted to riparian planting and the wetlands around the lakes.
Climate	Average annual rainfall in the district is around 1.2 m. Average annual temperatures range between 13 and 14.2°C and number of frost days varies considerably.	N/A	N/A

Attribute	Current State	Trend	Potential Restoration Actions
Hydrology	The catchment hydrology has been altered significantly since European settlement prior to which no natural waterways or lake outlets existed. Lake levels are controlled by outlet structures at Rotomanuka North and Rotopiko South. Groundwater flows have been considerably altered due to drainage, lowering of lake levels, and peat shrinkage.	Lake hydrology is probably stable. Groundwater flows will continue to be altered if peat shrinkage is allowed to continue.	Maintenance of a high water table in peat areas is important to slow peat shrinkage. Lake levels have been set based on solid monitoring data and only need to be maintained. Drains should only be cleaned where necessary and herbicide should be used to clean drains clogged with vegetation rather than a machine. If more drain capacity is required they should be widened rather than deepened.
Trophic Level (water quality)	Water quality in all five lakes is poor although Rotomanuka South has consistently had the worst water quality since at least 1988 and is considered hypertrophic. The other four lakes were eutrophic or on the border between eutrophic and supertrophic at the times they were last sampled.	**Rotomanuka North:** Currently stable but significant decline since 1981. **Rotomanuka South:** Current trend unknown. **Rotopiko North:** Current trend unknown but TN levels increased between 2002 and 2009. **Rotopiko South:** TN & TP levels have fluctuated considerably since 2003. **Rotopiko East:** Current trend unclear but appears to have been relatively stable since 2002.	Restoration of water quality in shallow lakes is very difficult and requires a range of remediation measures. Dealing with the sources of the problem will require fencing and planting of drains and permanently wet areas and better management of effluent disposal (timing, location). Infiltration wetlands which filter water-soluble and sediment-bound nutrients from the drains before they reach the lake have been shown to be effective and are already planned for the catchment. Nutrients stored in lake sediments can also be a significant problem and methods such as dredging or application of flocculants which bind nutrients and prevent their release from the sediment may be required.

Attribute	Current State	Trend	Potential Restoration Actions
Rotifer-inferred TLI	Rotifer-Inferred Trophic Level Index uses the composition and abundance of zooplankton as an indicator of trophic level. Rotifer-inferred TLI for Rotomanuka North was eutrophic in 2013, Rotopiko North and South were Mesotrophic, and Rotopiko East was Oligotrophic.	All lakes appear to have improved slightly since 2007.	As this is another indicator of water quality the methods listed above should be employed to improve rotifer-derived TLI.
Dissolved Oxygen	Dissolved oxygen levels in the surface waters of Rotomanuka North, Rotopiko North, and Rotopiko East fluctuate but remain relatively good during the year but the deeper water in all three lakes becomes completely anoxic on a regular basis. Conditions in deoxygenated bottom waters are toxic to many aquatic organisms at these times.	No obvious trends.	The same restoration actions required for improvement of water quality will also help to reduce deoxygenation of lake waters.
Fish	Four species of native fish including the At Risk longfin eel have been recorded from at least four of the catchment lakes. Four pest fish species are also present in the catchment (rudd, goldfish, catfish, and gambusia).	Improving in Rotopiko. Likely stable or declining in Rotomanuka lakes	Pest fish control in the Rotopiko lakes has been relatively successful and rudd and umbers have been kept low. Control will need to be continued on a regular basis to maintain low pest fish levels. No control is done in the Rotomanuka lakes although they would benefit considerably. Ongoing netting associated with fish barriers is likely the only viable option for pest fish control in the Rotomanuka catchment.

Attribute	Current State	Trend	Potential Restoration Actions
Aquatic flora & Lake SPI	The Rotomanuka lakes are either completely de-vegetated or have only sparse submerged plants. Rotomanuka North had an Submerged Plant Indicator (SPI) score of 0 when last surveyed in 2007, indicating low ecological health. The Rotopiko Lakes have the best submerged flora of any peat lake in the Hamilton Basin with a high cover of indigenous species. Recent invasion by an exotic bladderwort has had some impact. Rotopiko North had an SPI score of 80% in 2014.	No obvious trends in SPI data but these may begin to deteriorate with the invasion of *Utricularia gibba*.	Restoration of aquatic plants in Rotomanuka will require an improvement in water clarity but more importantly the control of rudd and other pest fish. Maintenance of the existing plant populations in the Rotopiko lakes will require maintenance of water quality and clarity, along with continued pest fish control.
Terrestrial Biodiversity	Although the majority of the catchment is in pasture there are still relatively large areas of wetland habitat and scattered small kahikatea forest fragments. Fifty-nine indigenous plant species were recorded during a recent survey of the Rotomanuka wetlands. Fourteen native bird species have been recorded in the catchment of which five are threatened or at risk.	Biodiversity is likely to be improving at the local scale due to considerable restoration efforts at both lake complexes.	Restoration efforts already in place include a predator-free enclosure around Rotopiko East and a considerable amount of pest plant control and restoration planting at both lake complexes. This work should be continued. Fencing and planting of major drains and increasing buffer zones around the lakes will also benefit biodiversity as will protection and enhancement of kahikatea stands. Establishing predator control at Rotomanuka would also benefit native birds and other fauna. Additional bat and bird survey in the catchment would improve the ability to manage indigenous fauna.

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APPENDIX 1:
SUMMARY OF WRC DATA SETS

Site	Station ID	Station name	Category	Data type	Data type2	Frequency	Lake/Stream	Easting	Northing	Start date	End date	Owner	Collector	Notes
Lake Serpentine	1456_10	North	Biodiversity	Invertebrates	Discrete	N/A	Lake	1803883	5797371	1/07/1977	1/07/1977		Chapman & Boubee 1977	
Lake Serpentine	1456_11	South	Biodiversity	Invertebrates	Discrete	N/A	Lake	1803484	5797171	1/07/1977	1/07/1977		Chapman & Boubee 1977	
Lake Serpentine	1456_13	South	Water quality	DO, PCDO, Temperature	Depth profiles	Random. At least 2x per year	Lake	1803684	5797171	12/12/2007	6/11/2014	WRC	WRC	
Lake Serpentine	1456_13	South	Water quality	Secchi depth	Discrete	Random. At least 2x per year	Lake	1803684	5797171	12/12/2007	6/11/2014	WRC	WRC	
Lake Serpentine	1456_13	South (Bottom)	Water quality	Water quality	Discrete	1-3/year	Lake	1803684	5797171	12/12/2007	15/03/2011	WRC	NIWA & UOW	Irregular frequency
Lake Serpentine	1456_13	South (Bottom)	Sediment chemistry	Sediment chemistry	Discrete	N/A	Lake	1803684	5797171	15/03/2011	15/03/2011	WRC	UOW	3 samples
Lake Serpentine	1456_14	South (Surface)	Water quality	Water quality	Discrete	1-3/year	Lake	1803684	5797171	12/12/2007	6/11/2014	WRC	NIWA/UOW/WRC	Irregular frequency
Lake Serpentine	1456_2	Eastern Outlet of Lake	Hydrology	Water level gauging & flow	Discrete	N/A	Lake/Stream			19/10/2000	19/10/2000	WRC	WRC	manual readings?
Lake Serpentine	1456_3	North	Water quality	DO, PCDO, Temperature	Depth profiles	Monthly	Lake	1803782	5798071	28/02/2002	25/09/2014	WRC	WRC	Gaps
Lake Serpentine	1456_3	North	Water quality	Secchi depth	Discrete	Monthly	Lake	1803782	5798071	27/07/2006	25/09/2014	WRC	WRC	Gaps
Lake Serpentine	1456_3	North (Surface)	Water quality	Water quality	Discrete	2 months or better	Lake	1803782	5798071	28/02/2002	25/09/2014	WRC	WRC & UOW	Monthly to begin with then every two months
Lake Serpentine	1456_4	North (Bottom)	Water quality	Water quality	Discrete	Monthly	Lake	1803782	5798071	28/02/2002	12/12/2011	WRC	WRC, few NIWA	Gaps
Lake Serpentine	1456_4	North (Bottom)	Sediment chemistry	Sediment chemistry	Discrete	N/A	Lake	1803782	5798071	25/02/2004	15/03/2011	WRC	WRC & UOW	4 samples total
Lake Serpentine	1456_5	East	Water quality	DO, PCDO, Temperature	Depth profiles	Monthly	Lake	1803882	5798071	22/10/2002	14/05/2013	WRC	WRC	Gaps
Lake Serpentine	1456_5	East	Water quality	Secchi depth	Discrete	Monthly	Lake	1803882	5798071	29/08/2006	14/05/2013	WRC	WRC	Gaps
Lake Serpentine	1456_5	East (Surface)	Water quality	Water quality	Discrete	Monthly	Lake	1803882	5798071	22/10/2002	25/05/2012	WRC	WRC & UOW	Some gaps
Lake Serpentine	1456_6	East (Bottom)	Water quality	Water quality	Discrete	Monthly	Lake	1803882	5798071	22/10/2002	14/05/2013	WRC	WRC & UOW	Some gaps
Lake	1456_6	East (Bottom)	Sediment	Sediment	Discrete	N/A	Lake	1803882	5798071	25/02/2004	15/03/2011	WRC	UOW	6 samples in 2011, 1 in

Serpentine			chemistry	chemistry										2004
Lake Serpentine	1456_8	East (North West Shore)	Biodiversity	Invertebrates	Discrete	N/A	Lake	1803884	5797071	1/07/1977	1/07/1977		Chapman & Boubee 1977	
Lake Rotomanuka	317_1		Water quality	DO, PCDO, Temperature	Depth profiles	Monthly	Lake	1803580	5799971	24/10/1995	25/09/2014	WRC	WRC	
Lake Rotomanuka	317_1		Water quality	Secchi depth	Discrete	Monthly	Lake	1803580	5799971	27/07/2006	25/09/2014	WRC	WRC	
Lake Rotomanuka	317_1	Lake Gin Centre (Bottom)	Water quality	Water quality	Discrete	Monthly	Lake	1803880	5799572	24/10/1995	10/12/2001	WRC	WRC	Gaps
Lake Rotomanuka	317_2	Lake Gin Centre (Surface)	Biodiversity	Invertebrates	Discrete	N/A	Lake	1803880	5799572	1/07/1977	1/07/1977		Chapman & Boubee 1977	
Lake Rotomanuka	317_2	Lake Gin Centre (Surface)	Water quality	Water quality	Discrete	Monthly	Lake	1803880	5799572	27/09/1995	10/12/2001	WRC	WRC	Gaps
Lake Rotomanuka	317_3	Lake Centre (Bottom)	Water quality	Water quality	Discrete	Monthly	Lake	1803580	5799971	27/09/1995	29/03/2011	WRC	WRC & UOW	Some gaps
Lake Rotomanuka	317_3	Lake Centre (Bottom)	Sediment chemistry	Sediment chemistry	Discrete	N/A	Lake	1803580	5799971	25/02/2004	29/03/2011	WRC	WRC & UOW	1 sample in 2004, 4 in 2011
Lake Rotomanuka	317_4	Lake Centre (Surface)	Biodiversity	Invertebrates	Discrete	N/A	Lake	1803580	5799971	1/07/1977	1/07/1977		Chapman & Boubee 1977	
Lake Rotomanuka	317_4	Lake Centre (Surface)	Water quality	Water quality	Discrete	Monthly	Lake	1803580	5799971	27/09/1995	8/10/2014	WRC	WRC & UOW	
Lake Rotomanuka	317_9	Main outlet of lake	Hydrology	Water level gauging & flow	Discrete	Random?	Lake/Stream	1803879	5800172	19/10/2000	30/11/2000	WRC	WRC	Are these manual readings?
Lake Rotomanuka		DOC Lake Level Recorder	Water quality	Temperature	Daily mean	Daily	Lake	1803280	5799771	29/09/2011	1/10/2012	WRC	WRC/DOC	
Lake Rotomanuka		Main outlet of lake	Water quality	Temperature	Daily mean	Daily	Lake	1803879	5800172	29/09/2011	26/09/2014	WRC	WRC	Some gaps
Lake Rotomanuka		Lake centre (bottom)	Water quality	Temperature	Daily mean	Daily	Lake	1803580	5799971	21/12/2007	26/03/2008	WRC	WRC	
Lake Serpentine		East - North West Shore	Water quality	Temperature	Daily mean	Daily	Lake	1803884	5797071	17/01/2008	26/09/2014	WRC	WRC	Some gaps
Lake Serpentine		North - South West Shore	Water quality	Temperature	Daily mean	Daily	Lake	1803683	5797971	27/11/2008	26/09/2014	WRC	WRC	One gap 2010
Lake Serpentine		East - Bouy at deepest basin	Water quality	Temperature	Daily mean	Daily	Lake	1803882	5798071	13/12/2007	26/03/2008	WRC	WRC	
Lake Serpentine		North - Buoy at deepest basin	Water quality	Temperature	Daily mean	Daily	Lake	1803782	5798071	13/12/2007	3/04/2008	WRC	WRC	
Lake Serpentine		South - Buoy at deepest basin	Water quality	Temperature	Daily mean	Daily	Lake	1803684	5797171	13/12/2007	26/03/2008	WRC	WRC	
Lake Serpentine		Main outlet drain DS Weir	Water quality	Temperature	Daily mean	Daily	Stream	1804155	5797858	8/07/2009	26/09/2014	WRC	WRC	Some gaps
Lake Rotomanuka		DOC Lake Level Recorder	Hydrology	Water level	Daily mean	Daily	Lake	1803280	5799771	13/10/1999	27/09/2012	WRC	WRC/DOC	Some gaps
Lake		Main outlet of	Hydrology	Water level	Daily mean	Daily	Lake	1803879	5800172	7/07/2006	26/09/2014	WRC	WRC	Some gaps

Rotomanuka		lake												
Lake Serpentine		East - North West Shore	Hydrology	Water level	Daily mean	Daily	Lake	1803884	5797071	12/06/2003	26/09/2014	WRC	WRC	Some gaps
Lake Serpentine		North - South West Shore	Hydrology	Water level	Daily mean	Daily	Lake	1803683	5797971	12/06/2003	26/09/2014	WRC	WRC	Some gaps
Lake Serpentine		Main outlet of lake	Hydrology	Water level	Daily mean	Daily	Lake	1804135	5797850	6/08/2008	26/09/2014	WRC	WRC	Some gaps
Lake Serpentine		Main outlet drain DS Weir	Hydrology	Water level	Daily mean	Daily	Stream	1804155	5797858	8/07/2009	26/09/2014	WRC	WRC	Some gaps
Lake Rotomanuka			Biodiversity	Invertebrates	Discrete		Lake	1803516	5799897	6/12/2012	30/05/2013			

APPENDIX 2:
INVERTEBRATE SPECIES IN THE ROTOMANUKA CATCHMENT

Rotomanuka			
Species	**2006**	**Sample ID**	**Data source**
Acarina	*	96646, 96715, 96764, 96767	Wetland Invertebrates 2010
Anisoptera	*	96690, 96713, 96757, 96776	Wetland Invertebrates 2010
Austrolestes colensonis	*	96751, 96781	Wetland Invertebrates 2010
Ceratopogonidae	*	96697, 96745	Wetland Invertebrates 2010
Chironomus zealandicus	*	96759, 96770	Wetland Invertebrates 2010
Collembola	*	96645, 96684, 96709	Wetland Invertebrates 2010
Corynocera	*	96654, 96677, 96702, 96718, 96750, 96771	Wetland Invertebrates 2010
Corynoneura	*	96733	Wetland Invertebrates 2010
Enochrus tritus	*	96691, 96731	Wetland Invertebrates 2010
Forcipomyiinae	*	96735	Wetland Invertebrates 2010
Glyptophysa variabilis	*	96663, 96694, 96736, 96652	Wetland Invertebrates 2010
Hirudinea	*	96657, 96680, 96689, 96712, 96741, 96779	Wetland Invertebrates 2010
Hydra	*	96648, 96670, 96723, 96740	Wetland Invertebrates 2010
Hydraenidae	*	96695	Wetland Invertebrates 2010
Hydrophilidae	*	96687, 96726, 96747, 96769	Wetland Invertebrates 2010
Ilyocryptidae	*	96650, 96674, 96704, 96725, 96760, 96766	Wetland Invertebrates 2010
Laccobius arrowi	*	96706, 96722, 96778	Wetland Invertebrates 2010
Lymnaea	*	96641, 96707, 96738, 96761, 96768	Wetland Invertebrates 2010
Microvelia	*	96647, 96666, 96683, 96724	Wetland Invertebrates 2010
Nematoda	*	96660, 96665, 96696, 96714, 96752, 96775	Wetland Invertebrates 2010
Oligochaeta	*	96653, 96675, 96688, 96730, 96746, 96780	Wetland Invertebrates 2010
Orthocladiinae	*	96642, 96668, 96701, 96721, 96762	Wetland Invertebrates 2010
Platyhelminthes	*	96644, 96669, 96685, 96732, 96749	Wetland Invertebrates 2010
Potamopyrgus antipodarum	*	96703, 96717	Wetland Invertebrates 2010
Procordulia smithii	*	96672, 96748	Wetland Invertebrates 2010
Rhantus suturalis	*	96698, 96710	Wetland Invertebrates 2010
Scirtidae	*	96649, 96693, 96728	Wetland Invertebrates 2010
Sigara	*	96744, 96782	Wetland Invertebrates 2010
Tanytarsus	*	96661, 96673, 96699, 96754, 96777	Wetland Invertebrates 2010
Xanthocnemis	*	96742, 96656, 96678, 96708, 96737, 96753, 96783, 97020	Wetland Invertebrates 2010
Acarina	*	96646, 96715, 96764, 96767	Wetland Invertebrates 2010

Rotopiko			
Species	**Year 2006**	**Sample ID**	**Data source**
Acarina	*	97028, 97035, 97072, 97090, 97125, 97141	Wetland Invertebrates 2010
Aeshna brevistyla	*	97013, 97033, 97091, 97110, 97130	Wetland Invertebrates 2010
Anisops assimilis	*	97067, 97093, 97124, 97134	Wetland Invertebrates 2010
Anisoptera	*	97018, 97044, 97073, 97098, 97120, 97142	Wetland Invertebrates 2010
Austrolestes colensonis	*	97051, 97063	Wetland Invertebrates 2010
Chironomus zealandicus	*	97011, 97046, 97115	Wetland Invertebrates 2010
Collembola	*	97009, 97037, 97080, 97092, 97122, 97140	Wetland Invertebrates 2010
Corynocera	*	97078	Wetland Invertebrates 2010
Corynoneura	*	97095	Wetland Invertebrates 2010
Forcipomyiinae	*	97057, 97064	Wetland Invertebrates 2010
Harpacticoida	*		Wetland Invertebrates 2010
Hirudinea	*	97036, 97105	Wetland Invertebrates 2010
Hydra	*	97024, 97065, 97086, 97119, 97144	Wetland Invertebrates 2010
Hydrometra strigosa	*	97017	Wetland Invertebrates 2010
Hydrophilidae	*	97021	Wetland Invertebrates 2010
Ilyocryptidae	*	97012, 97032, 97076, 97111	Wetland Invertebrates 2010
Laccobius arrowi	*	97042, 97100, 97102	Wetland Invertebrates 2010
Lymnaea	*	97015, 97041, 97059, 97089, 97112, 97138	Wetland Invertebrates 2010
Microvelia	*	97019, 97052, 97061, 97101, 97109, 97129	Wetland Invertebrates 2010
Nematoda	*	97016, 97055, 97077, 97084, 97108, 97148	Wetland Invertebrates 2010
Oligochaeta	*	97023, 97038, 97070, 97083, 97107, 97147	Wetland Invertebrates 2010
Orthocladiinae	*	97045, 97066, 97081, 97121, 97127	Wetland Invertebrates 2010
Paroxyethira hendersoni	*	97008	Wetland Invertebrates 2010
Physella acuta	*	97069, 97103, 97143	Wetland Invertebrates 2010
Platyhelminthes	*	97022, 97047, 97071, 97085, 97106, 97133, 97010	Wetland Invertebrates 2010
Polypedilum		97010	Wetland Invertebrates 2008
Potamopyrgus antipodarum		97118, 97128	Wetland Invertebrates 2009
Sigara	*	97146	Wetland Invertebrates 2010
Sphaeriidae	*	97126	Wetland Invertebrates 2010
Stratiomyidae	*	97139	Wetland Invertebrates 2010
Tanytarsus	*	97014, 97048, 97068, 97096, 97104, 97135	Wetland Invertebrates 2010
Xanthocnemis	*	97056, 97079, 97097, 97117, 97136	Wetland Invertebrates 2010

APPENDIX 3:
ROTOMANUKA WETLANDS BOTANICAL SPECIES LIST

This list was compiled for the Rotomanuka Vegetation Management Plan project in 2014 based on visits in June and July 2014. The wetland areas were the focus although species in other parts of the site were also recorded. This list is by no means complete.

* denotes a non-native species

Gymnosperm trees and shrubs

Dacrycarpus dacrydioides	kahikatea
*Pinus radiata	radiata pine

Monocotyledonous trees and shrubs

Cordyline australis	ti, cabbage tree

Dicotyledonous trees and shrubs

Coprosma propinqua	mingimingi
Coprosma tenuicaulis	hukihuki, swamp coprosma
Coprosma robusta	karamu
*Eucalyptus sp.	eucalyptus
*Euonymus japonicas	Japanese spindle tree
Hoheria populnea	lacebark, ribbonwood
Leptospermum scoparium	manuka
*Ligustrum sinense	Chinese privet
*Liquidambar styraciflua	liquidambar
Melicytus ramiflorus	mahoe
Myrsine australis	mapou, red matipo
*Phytolacca octandra	inkweed
Pittosporum crassifolium	karo
Pittosporum eugenioides	tarata, lemonwood
Pittosporum tenuifolium	kohukohu, kohuhu, black matipo
Plagianthus regius	ribbonwood
*Populus deltoids	necklace poplar
*Populus nigra	Lombardy poplar
*Quercus robur	oak, European oak
*Salix cinerea	grey willow
*Salix fragilis	crack willow
Solanum laciniatum	poroporo
*Solanum mauritianum	woolly nightshade
*Solanum pseudocapsicum	Jerusalem cherry
*Ulex europaeus	gorse

Dicotyledonous lianes

*Calystegia sp.	bindweed
Muehlenbeckia australis	pohuehue; large leaved Muehlenbeckia
*Rubus fruticosus agg.	blackberry
*Hedera helix	ivy

Ferns

Asplenium flaccidum	drooping spleenwort, hanging slpleenwort
Asplenium polyodon	sickle spleenwort
Azolla rubra	Pacific Azolla, Azolla, red Azolla
Blechnum minus	swamp kiokio
Cyathea dealbata	silver fern, ponga
Cyathea medullaris	mamaku

Deparia petersenii	
Dicksonia squarrosa	wheki ponga
Histiopteris incisa	water fern
Hypolepis ambigua	
Hypolepis distans	
Microsorum pustulatum subsp. _pustulatum_	kowaowao, hounds tongue
*_Osmunda regalis_	royal fern
Paesia scaberula	ring fern, pig fern
Pyrrosia eleagnifolia	leather-leaf fern

Grasses

*_Agrostis stolonifera_	creeping bent
*_Cortaderia selloana_	pampas grass
*_Cynodon dactylon_	Bermuda grass, Indian doab
*_Dactylis glomerata_	cocksfoot
*_Festuca rubra subsp. rubra_	red fescue
*_Glyceria declinata_	floating sweetgrass
*_Glyceria maxima_	reed sweetgrass
*_Holcus lanatus_	Yorkshire fog
Isachne globosa	swamp millet
*_Lolium perenne_	perennial rye grass
*_Paspalum dilatatum_	paspalum
*_Paspalum distichum_	mercer grass

Sedges

Carex dissita	forest sedge
Carex geminata	rautahi
*_Carex lurida_	
Carex secta	pukio
Carex virgata	pukio
Eleocharis acuta	sharp spike-sedge
Eleocharis sphacelata	kutakuta, spikes of doom, bamboo spike sedge
Isolepis species	
Machaerina arthrophylla	
Machaerina articulata	jointed twig rush
Machaerina rubiginosa	Baumea
Schoenus maschalinus	dwarf bog rush

Rushes and Allied Plants

*_Juncus acuminatus_	sharp-fruited rush
*_Juncus acutiflorus_	sharp-flowered rush
*_Juncus articulatus_	jointed rush
Juncus edgariae	wiwi
*_Juncus effusus_	soft rush
Luzula sp.	

Monocotyledonous herbs

*_Allium triquetrum_	three corner garlic
*_Landoltia punctata_	purple-backed duckweed
Lemna disperma	common duckweed
Phormium tenax	harakeke, flax
Typha orientalis	raupo, bullrush
*_Zantedeschia aethiopica_	arum lily

Dicotyledonous herbs (including composites)

*Achillea millefolium	yarrow
*Bidens frondosa	beggars' ticks
*Bellis perennis	bellis daisy
*Callitriche stagnalis	water starwort
Cardamine debilis	NZ bittern cress
Centella uniflora	centella
*Cirsium arvense	Californian thistle
*Conyza sumatrensis	broad-leaved flea bane
*Epilobium ciliatum	willow herb
*Galium aparine	cleaver
*Galium palustre	marsh breadstraw
Galium trilobum[?]	
*Hypochaeris radicata	catsear
Lobelia angulata	pratia
*Lotus pedunculatus	lotus
*Ludwigia palustris	water purslane
*Lycopus europaeus	gypsywort
Myriophyllum propinquum	common water milfoil
*Nasturtium officinale	watercress
*Nymphaea alba	water lily
Persicaria decipiens	
*Prunella vulgaris	selfheal
*Ranunculus flammula	spearwort
*Ranunculus repens	creeping buttercup
*Ranunculus sceleratus	celery buttercup
*Rumex obtusifolius	broad-leaved dock
*Solanum nigrum	black nightshade
*Sonchus oleraceus	sow thistle
*Stachys sylvatica	hedge woundwort

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