Lake Waiporohita

MANAGEMENT PLAN

Northland
REGIONAL COUNCIL

CONTENTS

LAKE WAIPOROHITA MANAGEMENT PLAN

1. PURPOSE

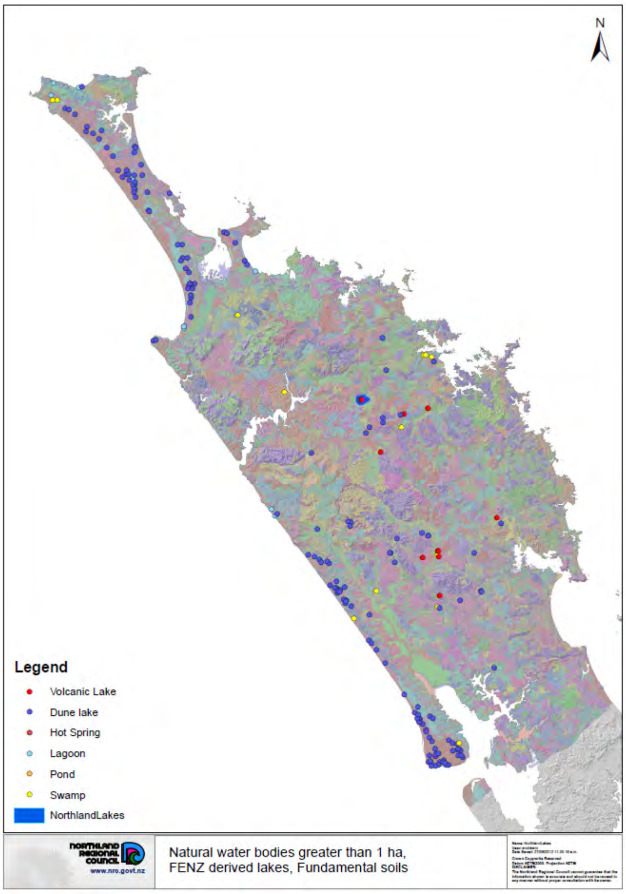
The purpose of the Outstanding Northland Dune Lakes Management Plans is to implement the recommendations of the Northland Lakes Strategy Part II (NIWA 2014) by producing Lakes Management Plans, starting with the 12 'Outstanding' value lakes, and by facilitating actions with mana whenua iwi, landowners and other stakeholders in the lake catchments to deliver priority work which will protect water quality and mitigate current pressures.

2. INTRODUCTION

The following text is taken directly from the Northland Lakes Strategy. Northland dune lakes and their associated wetlands are of national and international significance. These lakes, most of which have been formed between stabilised sand dunes along the west coast, represent a large proportion of warm, lowland lakes in New Zealand which still have relatively good water quality and high ecological values.

The outstanding dune lakes are grouped on the Aupouri, including Sweetwater, Karikari and Pōuto Peninsulas and the Kai Iwi group North of Dargaville.

The lakes vary in size, with the majority being between 5 and 35 hectares in area and generally less than 15 metres deep. Lake Taharoa of the Kai Iwi Group is one of the largest and deepest dune lakes in the country, covering an area of 211.07 hectares and being 38.81 metres deep. Lake Taharoa also has the deepest recorded submerged vegetation of any lake in the North Island, to 24 metres.



The dune lakes generally have little or no continuous surface inflows or outflows, being primarily fed by rainfall directly onto their surfaces and surrounding wetlands. As a result, their levels fluctuate considerably with climatic patterns. As most of the lakes are relatively small and shallow, they have limited capacity to assimilate any contaminants. They are prone to nutrient enrichment from stock and fertiliser, particularly where lakeside vegetation has been grazed or removed, and where there is direct stock access to the lake. Further effects on the lakes result from forestry fertilisation, sediment mobilisation during harvest and water budget dynamics.

These lake and wetland ecosystems are important habitats for a wide variety of plant and animal species, some of which are regionally or nationally significant because of their rarity. These include birds such as the pateke/brown teal, banded rail, New Zealand dabchick, marsh crake, fern bird and Australasian bittern, the aquatic plants *Hydatella inconspicua* and *Myriophyllum robustum* and native freshwater fish including the giant kokopu, banded kokopu, short jawed kokopu, inanga, dwarf inanga and dune lakes galaxias.

The most outstanding characteristic of these lakes is the limited impact of invasive species on their biota, which is unparalleled elsewhere on mainland New Zealand. Despite these values, the status of these lakes is not secure and the overall trend has been gradual deterioration.

Northland Regional Council monitors water quality quarterly in 26 dune lakes and undertakes ecological monitoring, along with NIWA, for ~90 dune lakes on an annual rolling basis. Annual weed surveillance is undertaken at high value lakes with public access. Threats and pressures include biosecurity (aquatic weeds, pest fish and the risk of invasion and spread), eutrophication from surrounding land use for farming and forestry, occurrence of algal blooms and water level fluctuations, especially dropping lake levels. Natural events such as summer droughts and high rainfall events place further pressure on these lakes.

Recreational and commercial activities on or around some of the lakes can affect water quality, lake ecology and increases the risk of introduction of pest weeds and fish.

The Northland Lakes Strategy (NIWA 2012) presents a classification and ranking system for Northland lakes including assessment of ecological values and lake pressures and threats. The 12 highest ranked lakes from north to south are:

Outstanding (12)

- Lakes - Wahakari, Morehurehu, Waihopo, Ngatu, Waiporohita, Waikare, Kai iwi, Taharoa, Humuhumu, Kanono, Rotokawau and Mokeno

Northland Lakes Strategy (NIWA 2012, 2014) recommends that individual lake management plans should be developed for each high value lake. This would include:

- Descriptions of each lake and lake catchment
- Outline of lake values and significance (including ecological and social)
- List of agencies and individuals involved in management
- Communications plan
- Monitoring plan
- Identification of gaps in knowledge/research plan
- Current threats and pressures
- Management actions to mitigate or ameliorate threats and pressures
- Work implementation plan

Key principals of lake management are:

- Balance between protection and utilization
- Managing the environmental quality of the catchment, in particular water quality
- Integrated management of habitat and species (including pests)
- Monitoring as a key environmental management tool

The plan takes the approach of presenting robust information on all aspects of the lakes. This includes social and cultural, physical, chemical and biological summaries of information not generally available to the public in a condensed format. This data is the best available at the time of writing and does not represent peer-reviewed science in the sense that errors may be inherent in the raw data and presence and absence of species changes over time. Yet it offers trends for further discussion among partners involved in protection and restoration activities. The plan goes on to scope required work for the mitigation of threats and offers a communication strategy to implement this work.

2.1. Geographic Lake Groupings

The outstanding dune lakes within these plans all sit within two broad ecological districts; Aupouri and Kaipara. Within these two districts there are further geographical associations of lakes, especially relevant to biosecurity species spread.

Within the Aupouri group, there are three lakes situated near Parengarenga and Houhora Harbours on the narrow Aupouri Peninsula (Lakes Wahakari, Morehurehu and Waihopo).

At the base of the Aupouri peninsula, another cluster of lakes form the west coast Sweetwater group and Lake Ngatu is the only outstanding lake in this area. To the east, on the Karikari Peninsula, Lake Waiporohita is found.

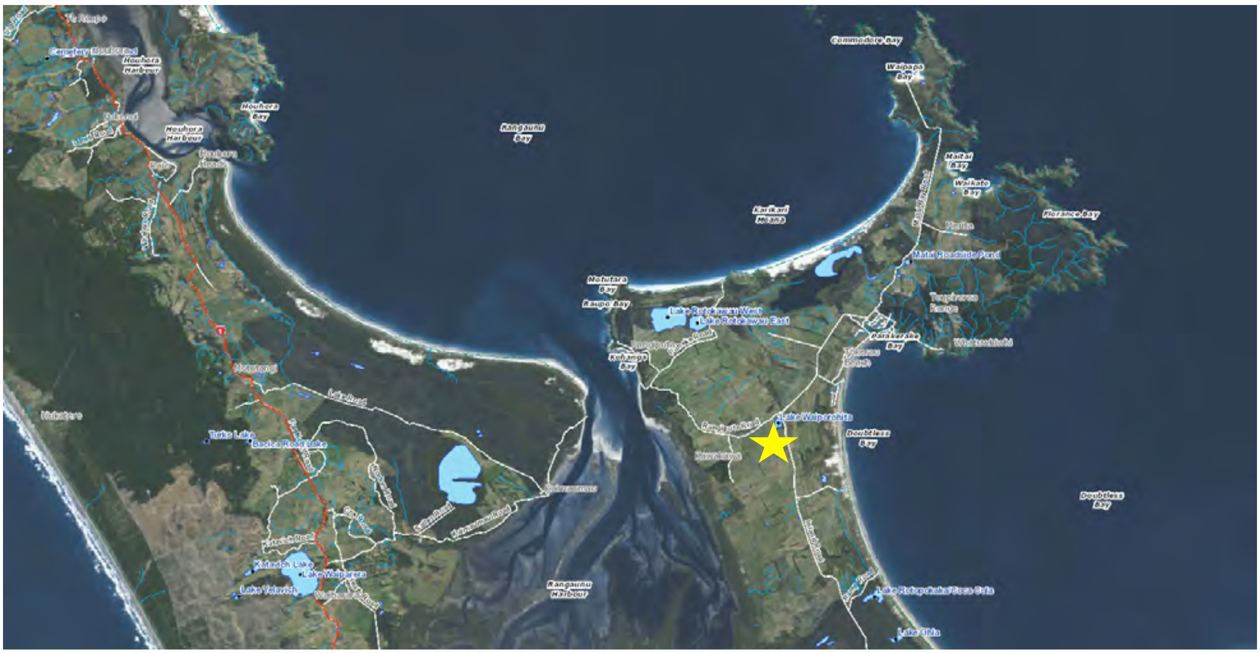
Further south within Northland, on the west coast north of Dargaville, are the three Kai Iwi Lakes (Lake Kai Iwi itself, and Lakes Taharoa and Waikare, sometimes referred to as Waikere).

Finally, four outstanding lakes on the Pōuto Peninsula, on the north head of the Kaipara Harbour, round out the final twelves lakes of covered in the Outstanding dune lake plans. These include the west Pōuto Lake Mokeno and the east Pōuto lakes Humuhumu, Kanono and Rotokawau (Pōuto).

Most lake names come from te reo Māori and, therefore, some names refer to several lakes around Northland. Rotokawau is a name given to several lakes, with one in Pōuto, two in Karikari and one in Sweetwater. Additionally, the word "kawau" means the waterbird shag or cormorant and two additional lakes are also called Shag Lake. To avoid confusion, lakes sharing a name are further referred to with their sub-regional area following in parentheses.

LINZ topographic maps do not legally name every freshwater body. Therefore, for the purposes of the lake plans, additional common lake names are used which are the same as those used in the NIWA ecological surveys. These may not be the same as traditional names used by iwi, which are yet to be known by the NRC. NRC will endeavour to consult with mana whenua iwi on their preferred traditional names for each lake.

3. LAKE LOCATION MAP



4. LAKE OVERVIEW

Lake Waiporohita (NRC Lake Number 99) is a shallow, 6.96 ha (~3.5 m max, 2.13 m mean depth) circular lake with a single basin in the south. The lake is located at the corner of Inland and Rangiputa Roads on the Karikari Peninsula in East-Central Northland and is classified as a Class 1 Perched dune lake (Timms, 1982), meaning it sits above ground water level and relies on rainfall and overland flows for recharge.

The lake is situated in a catchment dominated by high producing exotic grassland with the land used to farm sheep. The NRC-defined catchment, including the lake, is 52.7 ha. The lake surface area is 6.96 ha.

The shallow water is wind-mixed and does not thermally stratify, mixing excess nitrogen and phosphorus, making them available to phytoplankton. Algal blooms have been common over the last 15 years in each season, but most common in November (late spring). Chlorophyll-a levels are in National Policy Statement for Freshwater Management (NPS) State D, which means they threatened to "flip" the lake from a state where the vegetation is dominated by bottom growing plants to being dominated by shading algal blooms.

Both nitrogen and phosphorus are problem nutrients with nitrogen being more abundant in States C and D, whereas phosphorus remains largely in State C. The lake is high level eutrophic (poor water quality). Oxygen is depleted in depths below 2.5 m from November to February. pH has risen (more alkaline) over the last seven years from phytoplankton using up carbon dioxide.

No lake level data exists for this lake. A staff gauge is due to be installed. Water retention time is just under four months.

Nevertheless, the macrophyte native plant community is diverse and thriving. The lake supports 23 native plant species including two rare native plants; *Amphibromas fluitans* and *Centipeda aotearoana.* The Lake Submerged Plant Index is excellent, at 90%.

In addition to the native plants, there are 10 exotic species, three being invasive and including alligator weed, primrose willow and *Paspalum distichum*. Invasive Impact Index is very low at 4%.

The lake has a low level of fish diversity, relative to other lakes on the peninsula. *Gambusia* is the only pest fish species. The only native species present is the common bully.

The lake has a moderate bird diversity and other lakes on the peninsula are popular duck-hunting sites. Of interest are the sole records of dabchick and chestnut-breasted shelduck, which is a vagrant from Australia, in the Karikari Peninsula area.

Canada geese, now removed from the Fish & Game Council game bird schedule, are a common problem in dune lakes, flocking at Waiporohita to such a degree that their droppings litter the entire lake-shelf edges, adding to already high nutrient levels. Large numbers of black swan could also be elevating nutrients. Wide beaches at the lake are favoured roost sites for these species. Canada geese are a particular concern because they feed off-site and bring fresh nutrients into the lakes.

5. SOCIAL AND CULTURAL DIMENSION

5.1. Mana whenua

Te Rūnanga-ā-Iwi o Ngāti Kahu have rohe whenua in the area of Lake Waiporohita. No Deed of Settlement with the Crown has yet been reached. The rūnanga serves as a channel for two hapū; Te Whānau Moana and Te Rorohuri.

The rohe whenua of Ngāti Kahu is displayed in the diagram below and was sourced from Te Puni Kōkiri's Te Kahui Mangai web pages (www.tpk.govt.nz).

5.2. Land Tenure

5.2.1 Catchment landowners and Lake bed owners

Five landowners own six parcels within the lake catchment with the majority of the catchment occupied by the Landcorp Rangiputa Station as a pastoral farm. The lake bed and marginal strip is currently managed by the Department of Conservation.

5.3. Community involvement

The Doubtless Bay catchment group was formed in mid-2013 to help determine how Doubtless Bay catchment's freshwater resources should best be managed into the future. The group includes representatives from tangata whenua, forestry, drystock and dairy industries and recreational, community and environmental interests. It also includes representatives from the Department of Conservation and Far North District Council. The chair is a councillor from the Northland Regional Council.

Restoration planting has been started by Ngāti Kahu.

5.4. Public use

5.4.1. Access

The lake is accessible from Inland Road, however use of the lake by the public is discouraged due to it being regarded by mana whenua as a spiritual entity. Entry into the shallow margins of the lake by four-wheel drive vehicles and boats has been a fairly common activity for the purpose of washing off salt after a visit to the beach. This access is being blocked by a rock barrier due to pest introduction risks and sediment disturbance issues. Cooperation with this restriction will be greatly appreciated.

The landscape views can be enjoyed by the general public through vehicle parking on both Inland and Rangiputa Roads and there are benches for this purpose at the Rangiputa Road end.

5.4.2. Boating

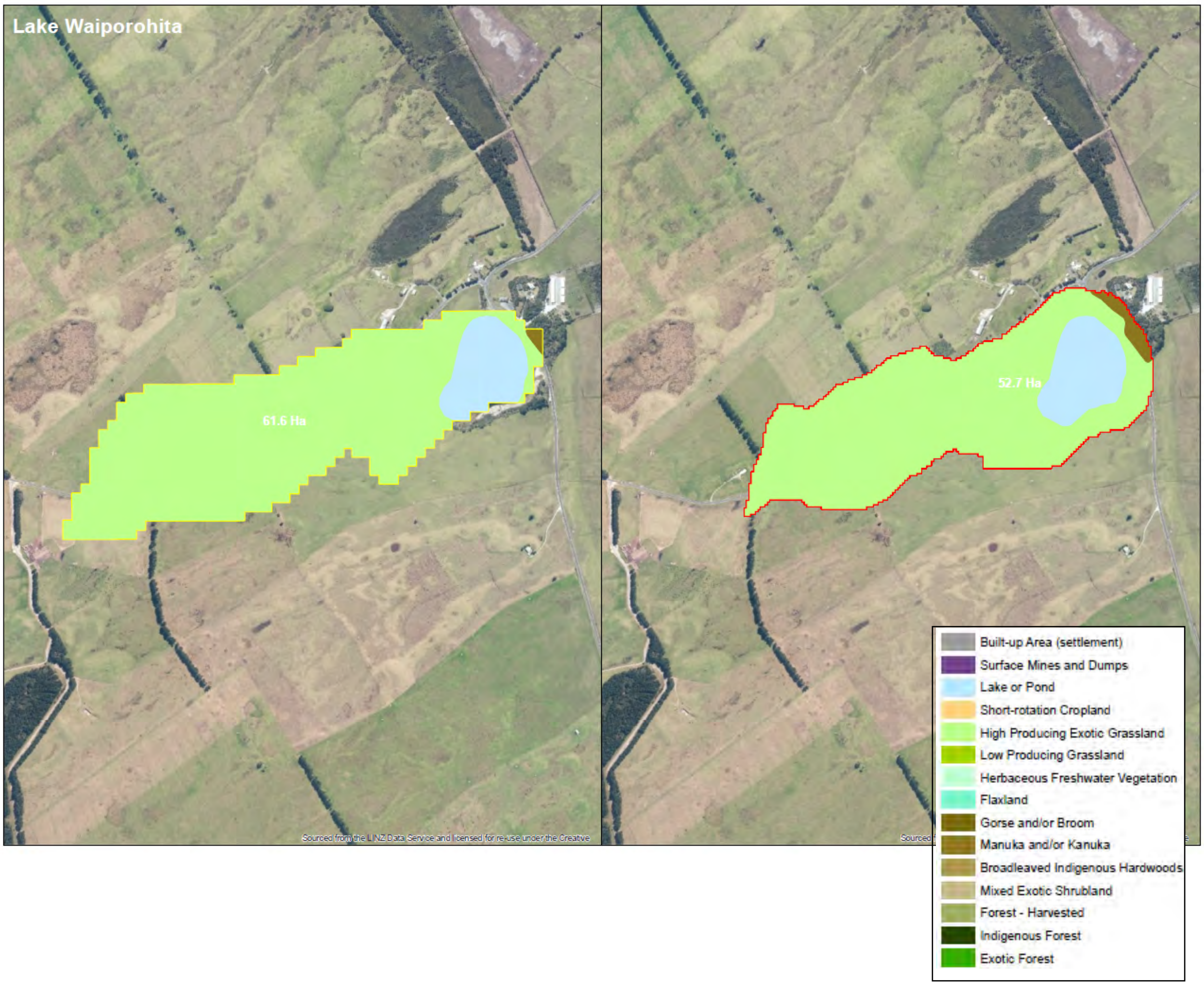
5.4.2.1. Boat access

There is no recreational boating opportunity at the lake.

6. PHYSICAL CHARACTERISTICS

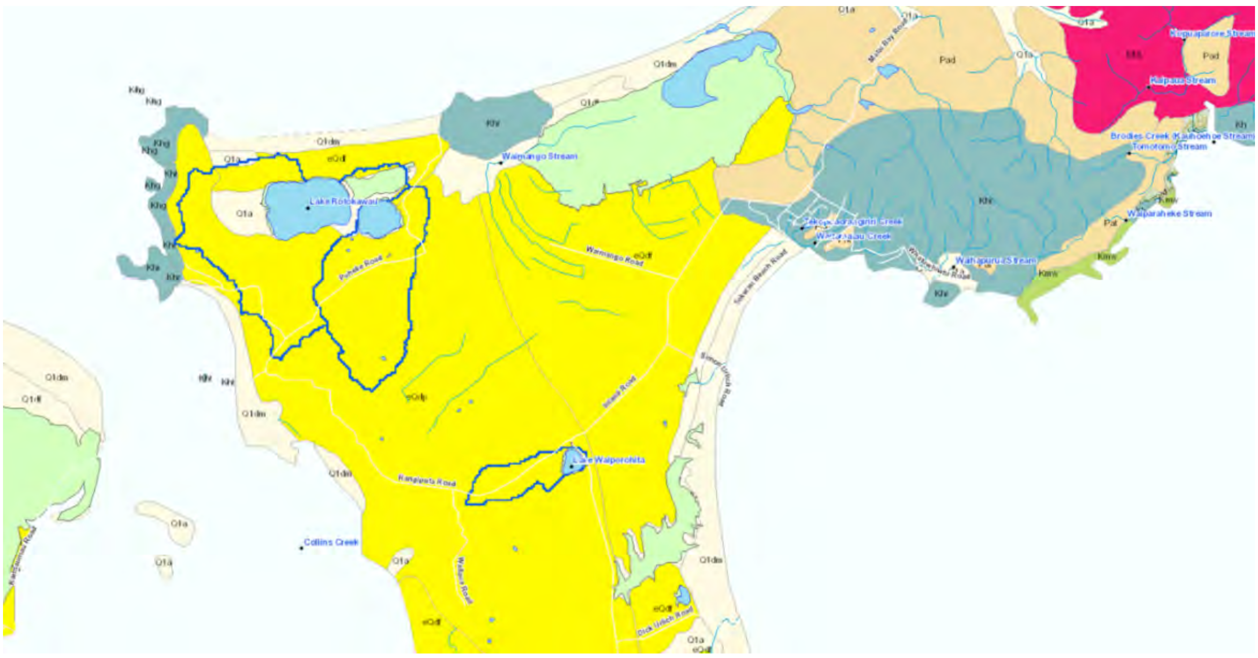
6.1. Catchment Area

The following diagram shows the extent of the lake catchment. On the left is the FENZ boundary and a rationalised boundary prepared by NRC staff is on the right. A more highly accurate boundary based on LiDAR will be available at the end of 2018. The NRC-defined catchment area on the left, including the lake itself, is 52.7 ha. The image on the right is a modified catchment boundary prepared by NRC staff.



6.2. Catchment Geology and soil types

The following map ((C) GNS Science 2016) of the Karikari Peninsula and table below it shows the geological history of the lake catchment. Waiporohita has a uniform geology comprised solely of Early Quaternary dunes (eQd) which formed during higher sea levels 12,000 years ago and earlier. These ancient dunes are now weakly cemented to uncemented.



Plot Symbol	eQd
Name	Early Quaternary dunes
Description	Weakly cemented and uncemented dune sand and associated facies. Clay-rich sandy soil. These dunes arose during higher sea level 12,000 years ago and earler.
Geologic history	Early Quaternary
Simple name	Zealandia Megasequence Terrestrial and Shallow Marine Sedimentary Rocks (Neogene)
Absolute minimum age (millions of years before present)	0.78
Absolute maximum age (millions of years before present)	2.6
Supergroup equivalent stratigraphic name	Pakihi Supergroup
Lithology	Sand

Soil types in the catchment are portrayed in the soil map and table below. The eastern shore of the lake is dominated by yellow-brown sands of the Pinaki series (PN) and the western shore and the majority of the farmed catchment s a combination of Te Kopuru series podzols (TEK), One Tree Point peaty sands organic soils (OT) and Ruakaka peaty sandy loam organic soils (RK). The TEK podzols for a silica and iron pan.

Soil Symbol	Genetic soil group	Geological origin	Suite	Subgroup	Series	Soil name	Description
PN	Yellow-brown sands	Soils of Holocene sands and sand flats	Pinaki	Weakly to moderately leached	Pinaki	Pinaki sand	**Pinaki series** - **Pinaki sand** (**PN** & **PNH**), .the youngest soil in the suite, is found on rolling, stabile former dunes inland of the loose sand along the west coast. Its natural vegetation is sand grasses and scrub. A typical profile would have: 0 to 150 mm of black to very dark grey brown fine to medium sand, on 150 mm dark grey brown to very dark brown fine sand, on light olive brown to light yellowish brown medium sand.
TEK	Podzols	Soils of Lower Quaternary terraces and dunes	Pinaki		Te Kopuru	Te Kopuru sand (podzols)	**Te Kopuru series** – the most mature of the soils on dune sands and old sand terraces, a podzol with a dense, cemented silica sand pan. An iron pan may or may not be obvious below the silica pan.
OT	Organic soils		Ruakaka		One Tree Point	One Tree Point peaty sand	**One Tree Point peaty sand (OT)** is a 'groundwater podzol', its development has been similar in many ways to that of the pakahi soils of Westland. It will have carried kauri forest at some stage in its development but not since human settlement in New Zealand. A typical profile has up to 75 mm of dark reddish brown slightly peaty loamy sand with weakly developed structure and containing bits of kauri gum, on 100 mm of very dark grey peaty sand also with little structure, over 100 mm of very dark grey peaty sand with increasing proportions of white silica sand grains. The boundaries between the layers are indistinct to this point but beneath this last layer is a distinct, iron-cemented layer which acts as a barrier to further root penetration and to the drainage of water on through the profile. Water drains horizontally along this pan. Wind erosion of dust and peat has been a problem during development of this land for urban and industrial use at One Tree Point., causing both onsite problems and difficulty of revegetation, and air quality off-site nuisance problems.
RK	Organic soils		Ruakaka		Ruakaka	Ruakaka peaty sand loam	**Ruakaka peaty sand loam** (**RK**) is found throughout Northland (except around the Kaipara where there is PZ) in what were swampy basins adjoining dunes, for example, in inter-dune swamps and the fringes of peaty sand plains. A representative profile of this low to very low fertility soil would have 150 mm of black fine sandy peaty loam, on 450 mm of black to reddish brown fine sandy peaty loam, on black loamy peat, which will contain wood fragments. There may well be ash layers where the swamp has been burnt and then peat has developed on top.

6.3. Catchment Hydrogeology

As Waiporohita is a perched dune lake sitting above the groundwater table, groundwater is not a feature which governs lake levels, which are regulated by rainfall and drought conditions. In any case, the Karikari Peninsula does not have an aquifer such as occurs on the Aupōuri Peninsula to the north, as shown in blue on the aquifer map below.

6.4. Catchment drainage and sedimentation rates

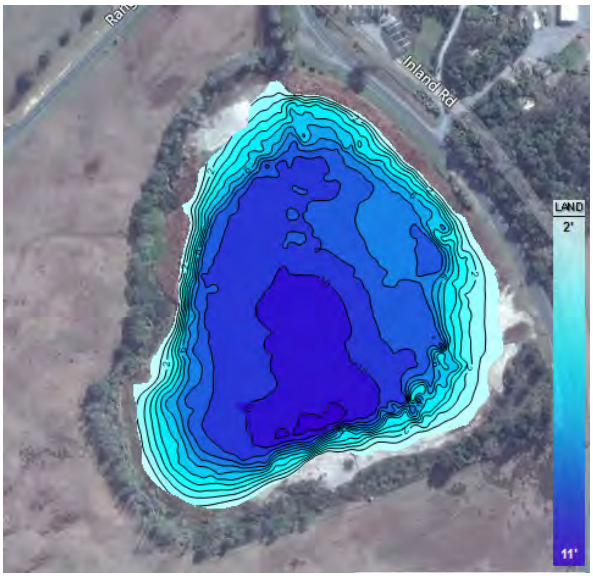
The NRC-defined catchment area, including the lake itself is 52.7 hectares and produces a mean annual flow, based on hydrological models, of 216,703.4 m^3/year. The lake has an estimated lake residence time of 0.317 years, meaning any water entering the lake will remain for just under four months. The average particle size of surface rock in the catchment is 1.88 on a scale of 5, a value of 1 being sand (FENZ database).

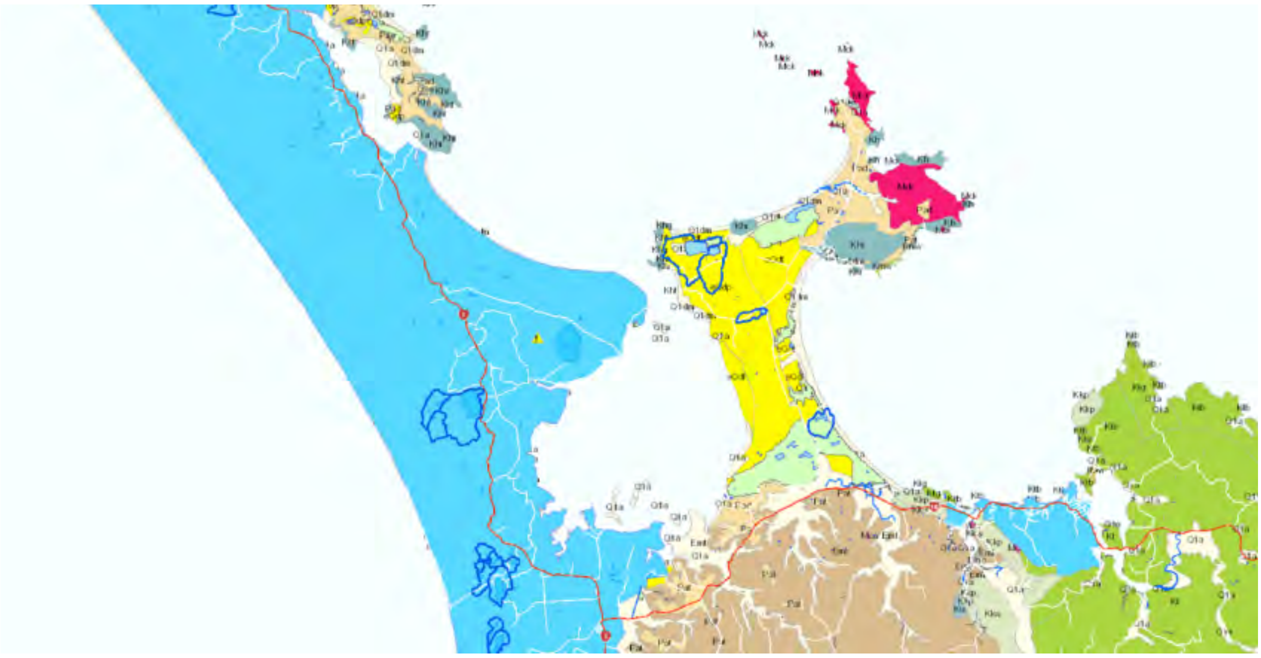
6.5. Geomorphology - Lake type and origin, area, depth, volume

In common with other dune lakes on the Peninsula (Rotokawau East and West, Rotopokaka/Coca Cola), Waiporohita is a shallow Class 1 perched lake originating as an elevated deflation hollow with a sealed organic basin and humic characteristics. The lake has a maximum depth of 3.45 m with a mean overall depth of 2.13 m. The surface area of the lake is 6.96 hectares with a volume of 158,085 m^3 (NIWA bathymetric survey). The NRC-defined catchment area, excluding the lake itself is 52.7 hectares.

6.6. Bathymetry map

The bathymetric depth map following comes from a survey done by NIWA for the NRC. The deepest point of the single basin and steeper convoluted contours occur along the southern shore. Please note that the scale of this map is in feet, not meters. The shallow and wide spacing of contours along Inland Road have led to vehicles and boats entering the lake to wash off salt after a trip to the beach.





Catchment hydrology

6.7. Natural inlets and outlets

The lake has no natural inlets or outlets. A farm drain flows to the lake on the western shore, but this has now been mitigated by a sediment weir and riparian planting. Stock access to the drain itself is still possible, however.

Wetland associations

6.8. Wetland associations

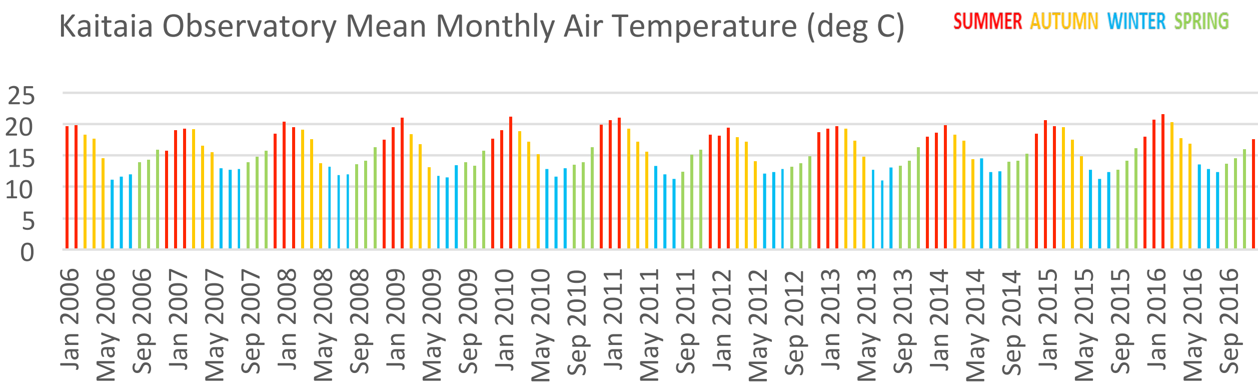
A shallow water wetland surrounds the lake edges, shown in the diagram below in light green. This is not a "Top 150" wetland.

6.9. Connectivity

The lake is not connected to any other water body.

6.10. Air Temperature

Kaitaia air temperature is used as a proxy for the Karikari sub-region. Temperature appears to be reflecting a cyclic pattern like based on El Nino/La Nina oscillations. Lake level will follow hot drought summers due to evaporation.

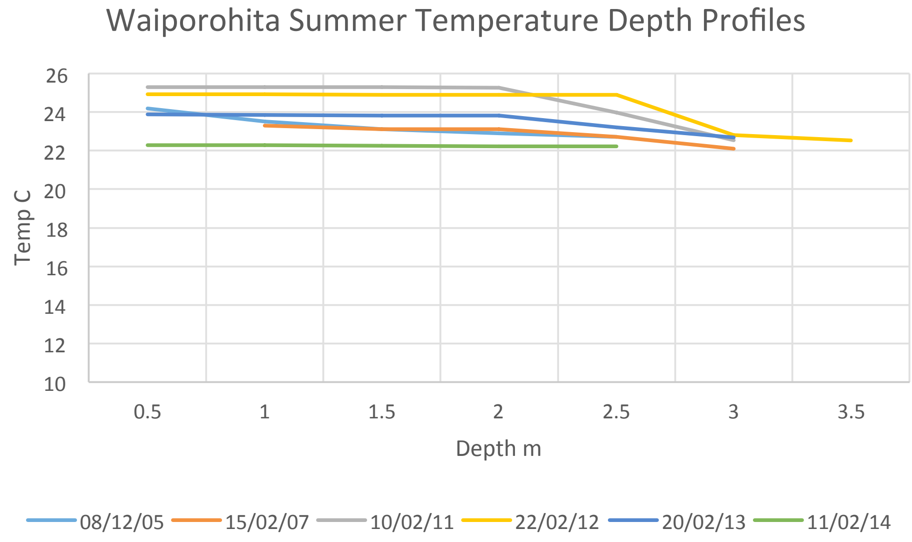


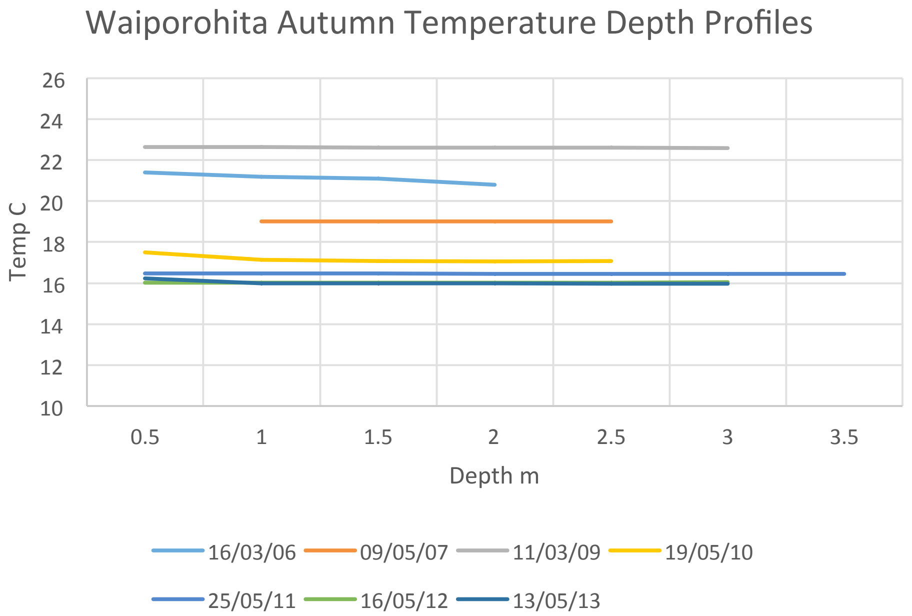
6.11. Temperature and Thermal stratification

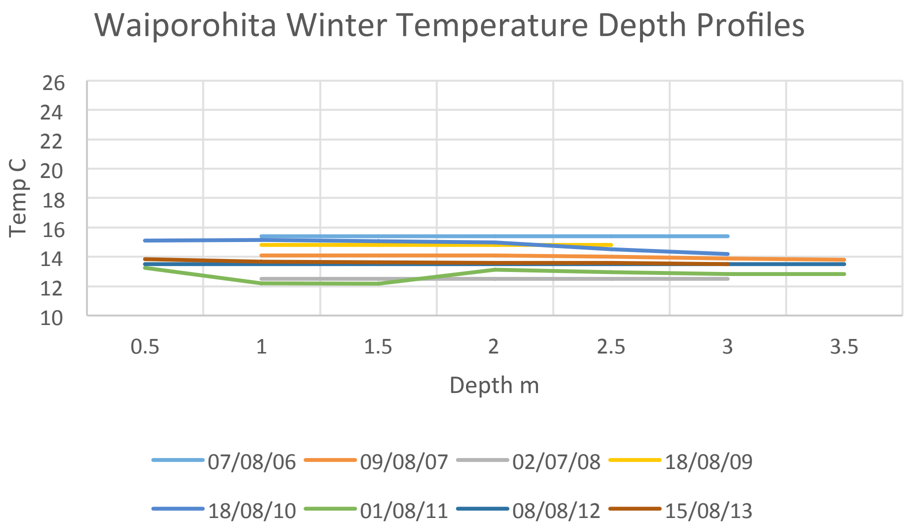
The graphs below show temperature at depth throughout the water column, by season. Each coloured line represents one sample. Water temperatures throughout the year range from 12.17 degrees C to 25.27 degrees C.

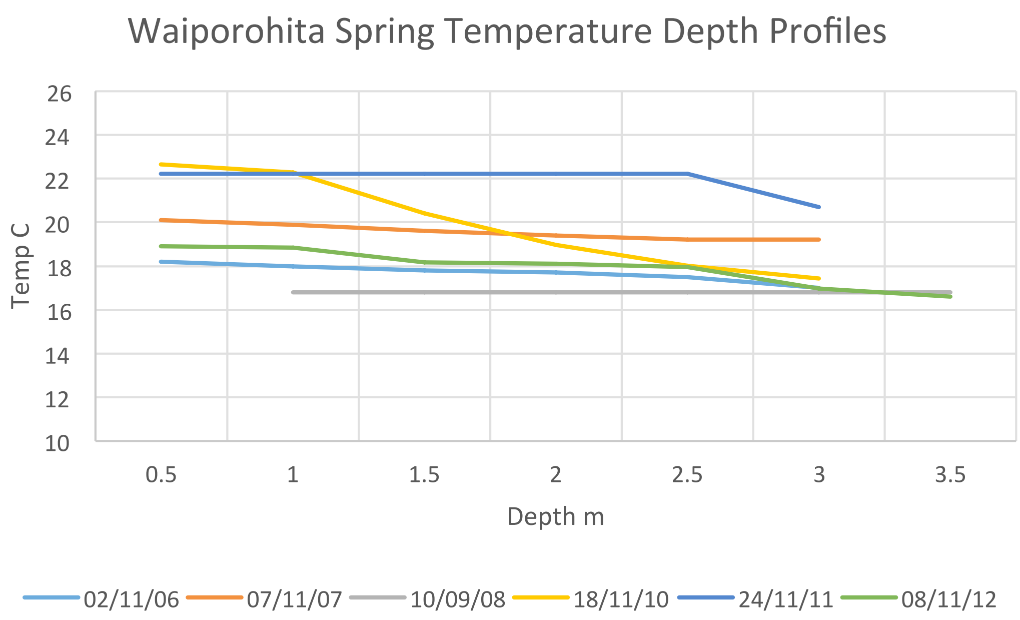
The lake, being very shallow at 3.5 metres maximum, does not thermally stratify in summer and temperature is fairly uniform at all depths year round. In order for a lake to stratify, water depth must exceed 10 meters.

Due to lack of stratification, nutrients are available throughout the water column throughout the year due to wind mixing.


Waiporohita Summer Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
10
0.5
1
1.5
2
2.5
3
3.5
Depth m
08/12/05
15/02/07
10/02/11
22/02/12
20/02/13
11/02/14

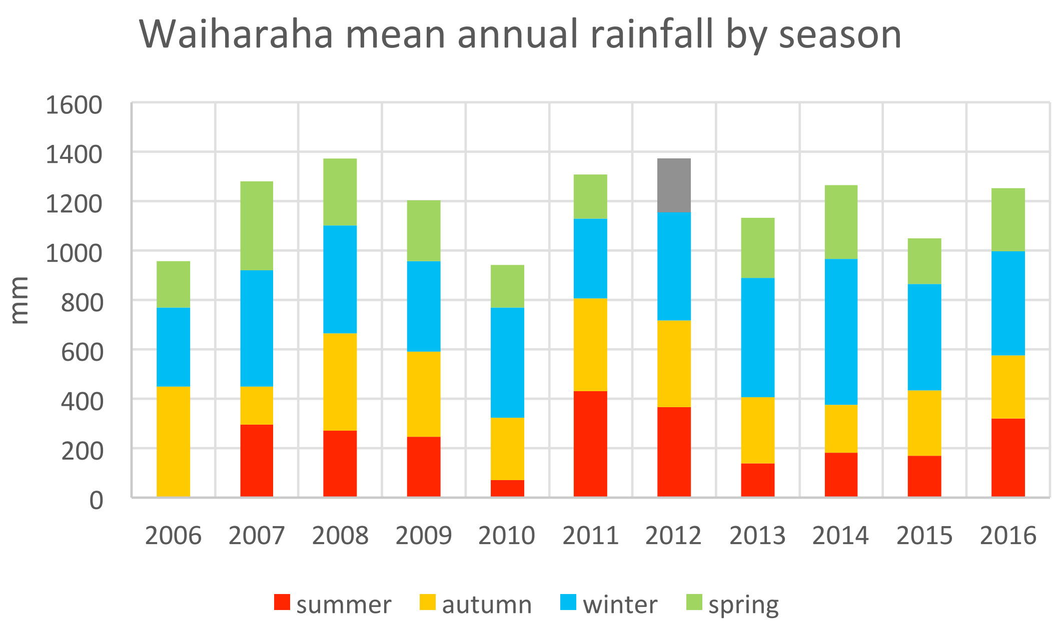

Waiporohita Autumn Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
10
0.5
1
1.5
2
2.5
3
3.5
Depth m
16/03/06
09/05/07
11/03/09
19/05/10
25/05/11
16/05/12
13/05/13


Waiporohita Winter Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
10
0.5
1
1.5
2
2.5
3
3.5
Depth m
07/08/06
09/08/07
02/07/08
18/08/09
18/08/10
01/08/11
08/08/12
15/08/13



6.12. Rainfall and drought

The Waiharaha rain gauge on the Aupōuri Peninsula nearly due west of Karikari serves as proxy for rainfall at the lake. The graph below shows cumulative rainfall per year by season. Spring 2012 is greyed due to only two out of three months of data being available, therefore this season is an underestimate.



6.13. Lake level

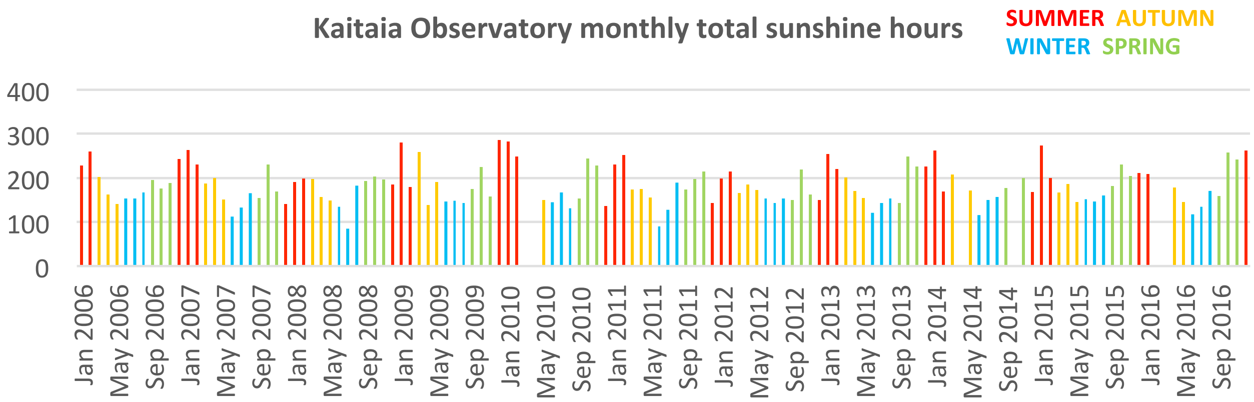
No lake level data exists for this lake. A staff gauge is due to be installed.

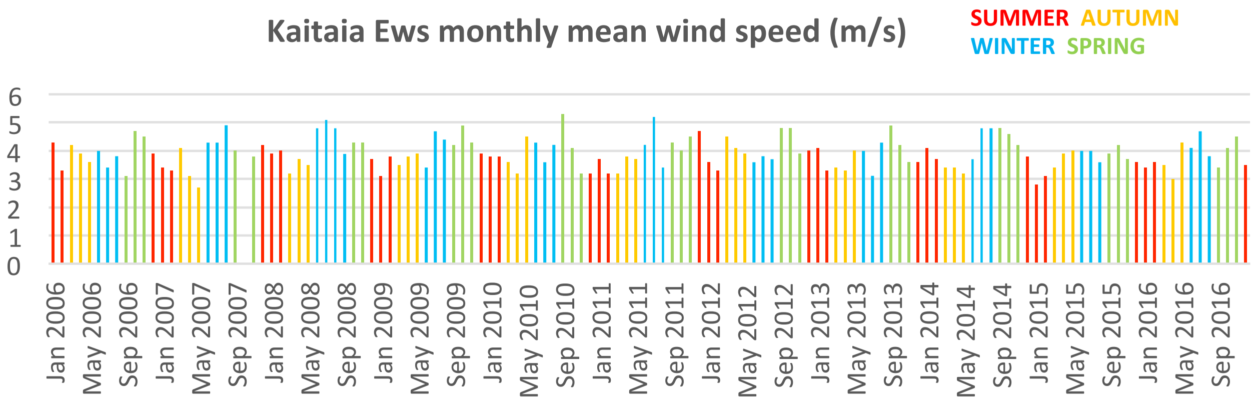
6.14. Sunshine

Kaitaia sunshine recordings are used as a proxy. Peak summer sun seasons likely affect the evaporation rates of the lake.

6.15. Wind speed

Kaitaia wind recording are used as a proxy. Wind is likely to be the key feature in algal bloom and water column nutrient levels at the lake. The November 2014 bloom is supported by evidence from the graph below of a sustained maximal spring wind.

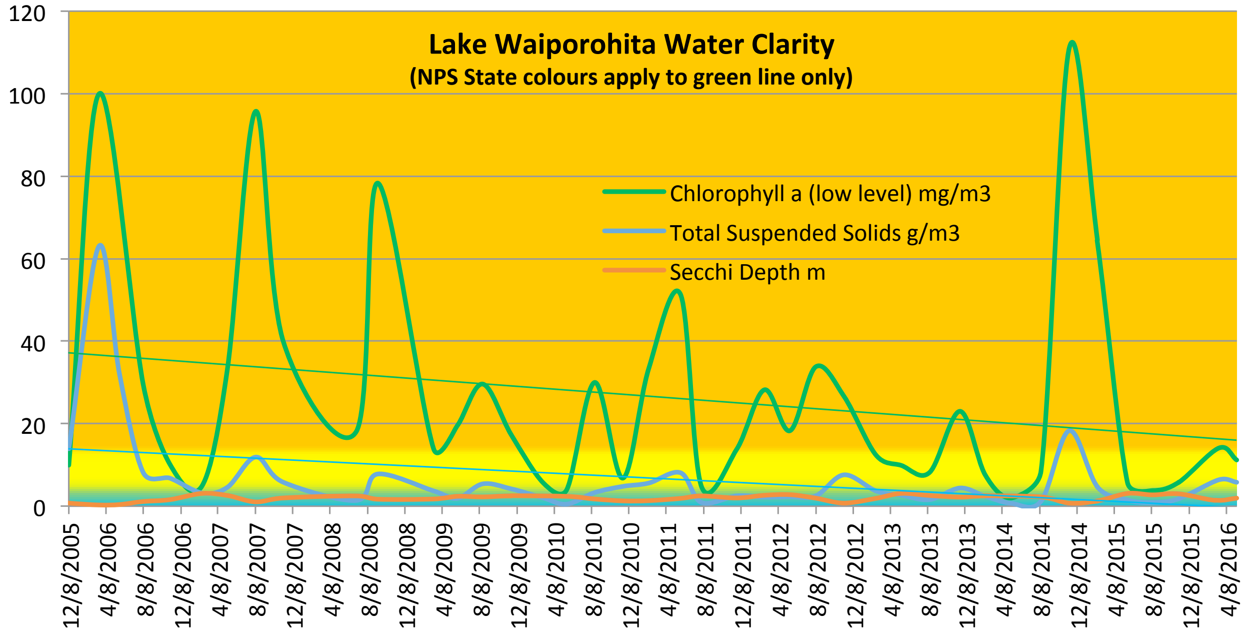




6.16. Light incidence (Secchi, Total Suspended Solids, Chlorophyll-a)

Three measures which are indicators of water clarity include chlorophyll-a (presence of micro-algal growth in the water column, total suspended solids and the direct measure of visibility at depth by lowering a black and white Secchi disk until it is no longer visible. As seen from the graph below, the lake experiences a regular pattern of algal blooms (green line), commonly in August and December. These blooms will likely be due to periods of good wind mixing for nutrients followed by prolonged sunshine. The peak bloom occurred as late as November 2014 at 111 mg/m³ chlorophyll-a.

The table below the graph shows the National Policy Statement for Freshwater Management states for phytoplankton (chlorophyll-a). A regime shift seems to be persistent with phytoplankton in State D threatening to displace the submerged plant community.



Attribute	Unit	Lake Type	State	Annual Median	Annual Maximum	Narrative State
Phytoplankton	mg Chlorophyll-a/m³	All	A	≤2	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Phytoplankton	mg Chlorophyll-a/m³	All	B	>2 and ≤5	>10 and ≤25	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrients levels that are elevated above natural reference conditions.
Phytoplankton	mg Chlorophyll-a/m³	All	C	>5 and ≤12	>25 and ≤60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.
Phytoplankton	mg Chlorophyll-a/m³	All	National Bottom Line	12	60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.
Phytoplankton	mg Chlorophyll-a/m³	All	D	>12	>60	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

7. CHEMICAL CHARACTERISTICS

7.1. Water Quality

7.1.1. Nutrients

7.1.1.1. Limiting nutrient assay

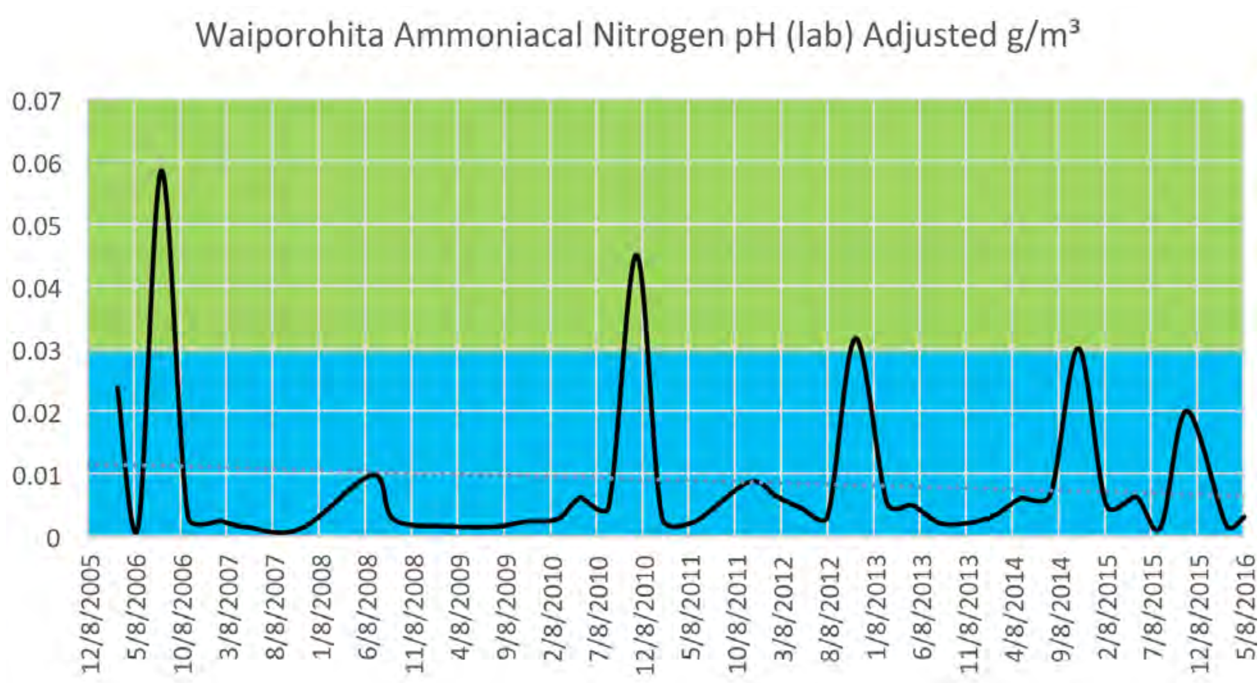
Max Gibbs (pers. comm.) from NIWA conducted limiting nutrient assays on several lakes including Waiporohita. Significant results are highlighted. For the years and seasons assayed, nitrogen plus phosphorus is the limiting nutrient combination in autumn and, in summer, both nitrogen and phosphorus are independently limiting, but not in combination. The summer 2015 sample contained peak chlorophyll a.

7.1.1.2. Ammoniacal Nitrogen (Toxicity)

Ammoniacal nitrogen (NH4-N), also often called 'ammonium', covers two forms of nitrogen; ammonia (NH3) and ammonium (NH4). It enters waterways primarily through point source discharges, such as raw sewage or livestock effluent. It is toxic to aquatic life at high concentrations.

The table following the graph shows the National Policy Statement Freshwater Management limits for lake state. Waiporohita shows periodic spikes into State B, returning to State A.

	Autumn 2014	Summer 2015	Autumn 2014	Summer 2015	Autumn 2014				Summer 2015		
Lake	Initial Chla	Initial Chla	Change in	Change in	Proportional change over control				Proportional change over control		
	(mg m^{-3})	(mg m^{-3})	Control	Control	+N	+P	+N+P	NP-P	+N	+P	+N+P
Waiporohita	1.4	13.6	1.86	0.62	1.04	0.99	1.10	0.11	1.32	1.25	1.29

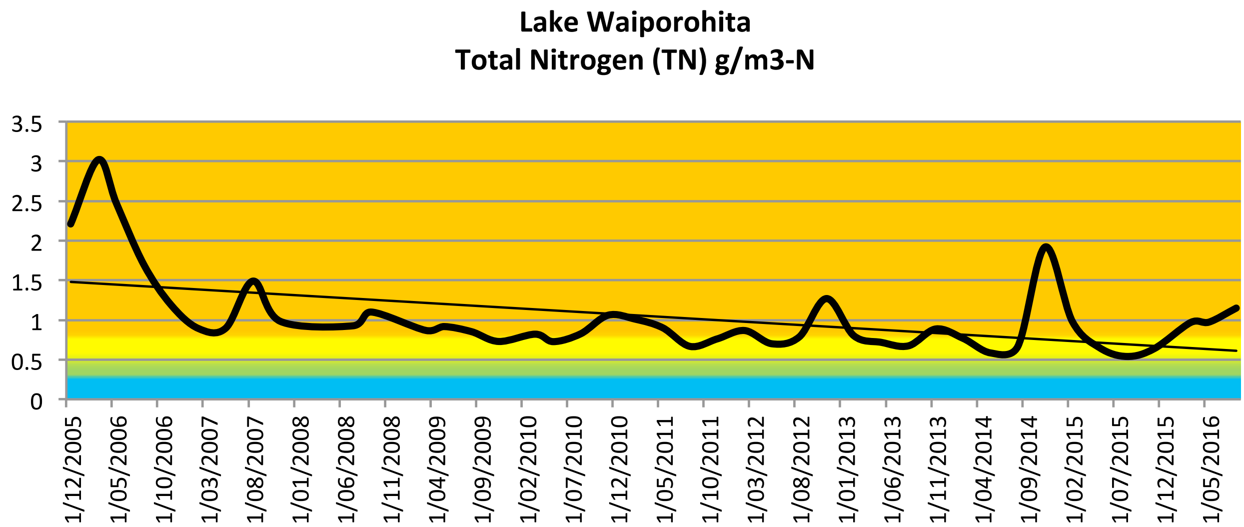


Attribute	Unit	Lake Type	State	Annual Median	Annual Maximum	Narrative State
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	C	>0.24 and ≤1.30	>0.40 and ≤2.20	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	National Bottom Line	1.3	2.2	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	D	>1.30	>2.20	Starts approaching acute impact level (ie risk of death) for sensitive species

7.1.1.3. Nitrogen

The following graph shows a total nitrogen timeline for the lake from 2005-2016. The trendline, although appearing to decline, may be due to the early peak in May 2006. This was followed by a relatively stable period and then by recent peaks, particularly in November 2014, when a peak algal bloom also occurred, as shown in the graph in section 4.15 above. A similar peak in total phosphorus shown below suggests that this was the result of a major rainfall event which greatly increased surface runoff as well as stirring the lake water and sediment.

The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. The lake is generally rides a line along NPS State C with frequent modes into State D.

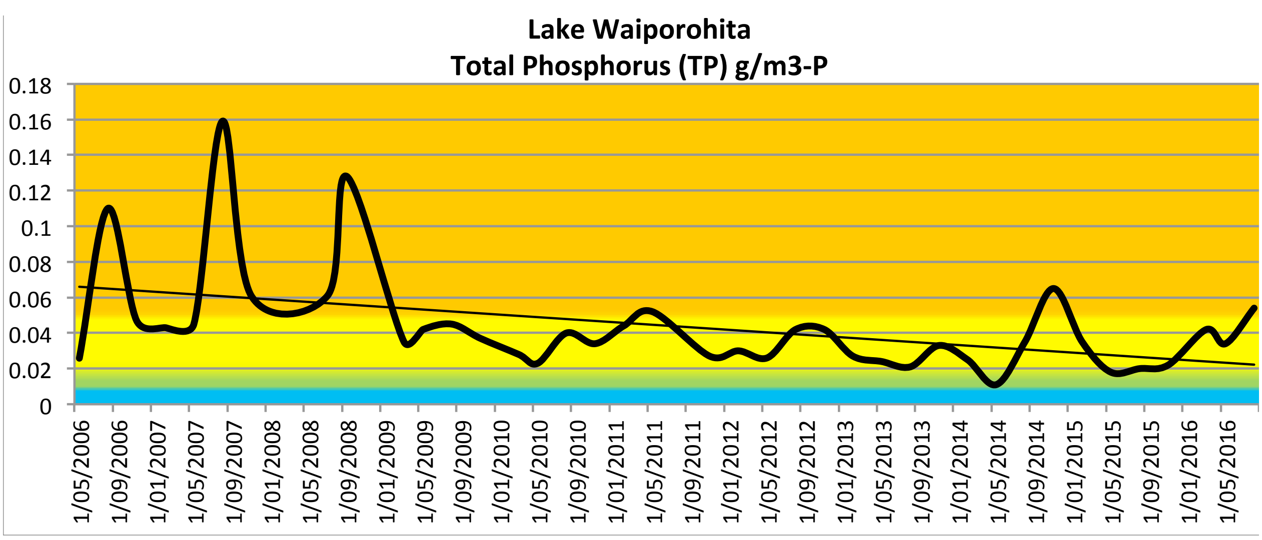


Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Nitrogen (Trophic state)	g/m3	Polymictic	A	≤.3	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Polymictic	B	>.3 and ≤.5	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrients levels that are elevated above natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Polymictic	C	>.5 and ≤.8	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Polymictic	National Bottom Line	0.8	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions
Total Nitrogen (Trophic state)	g/m3	Polymictic	D	>.8	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

7.1.1.4. Phosphorus

Total phosphorus levels, as seen in the graph below, mimic the pattern of total nitrogen above. As with that graph, it is unknown whether early peaks were actual or due to errors in equipment calibration in the early days of sampling. The similar pattern in later years suggests that both nutrients are being driven by the same cause, likely rainfall and wind.

The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. The lake wavers within State C with occasional passes into State D. From September 2008 and earlier, phosphorus loads were largely in State D which will be having long-term effect on this well-mixed lake.



Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Phosphorus (Trophic state)	g/m3	All	A	≤ .01	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	B	> .01 and ≤ .20	Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	C	> .02 and ≤ .05	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	National Bottom Line	0.05	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	D	> .05	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

7.1.2. Trophic Level Index

The trophic level index (TLI) is used in New Zealand as a measure of the nutrient status of lakes. The index combines four variables; phosphorus, nitrogen, visual clarity (Secchi disk depth) and algal biomass, each weighted equally.

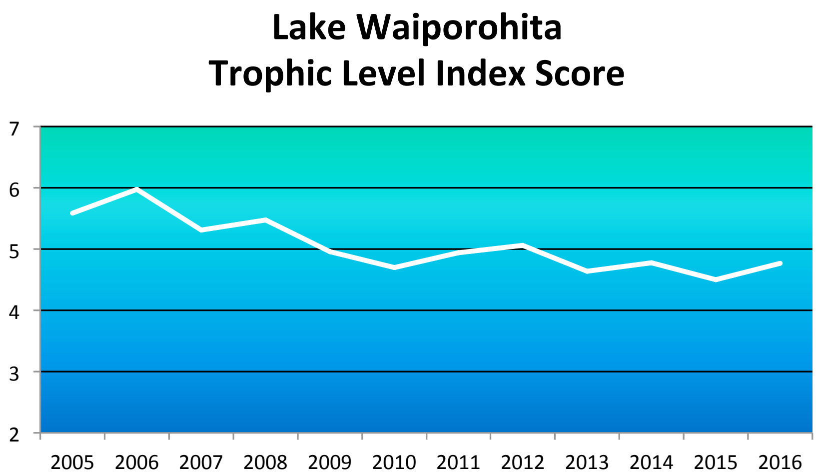
A low TLI score indicates a healthy lake with clear water and little algal bloom occurrence. A high TLI shows an overly nutrient-rich lake prone to algal blooms and poor light incidence, this shading affecting the health of submerged native plant communities. The 2005-1016 TLI trend, shown below, indicates a gradual improvement through time but, overall, the water quality of the lake has been very poor or supertrophic (prior to 2009) and poor or eutrophic since 2009.

This is likely due to multiple factors. Waiporohita is a very shallow lake which does not thermally stratify in summer. This means that there is constant mixing of the lake water by winds across its surface, pulling up nutrients from the sediment interface into the entire water column. As exotic trees have been removed from the lake margin and replanting in native trees has only just begun, the wind fetch has increased access to the lake.

This is particularly true for phosphorus, which binds readily to fine sediment as it enters the lake from the wider catchment. Years of runoff from land builds up a bank of legacy phosphorus which is recycled through the system continually.

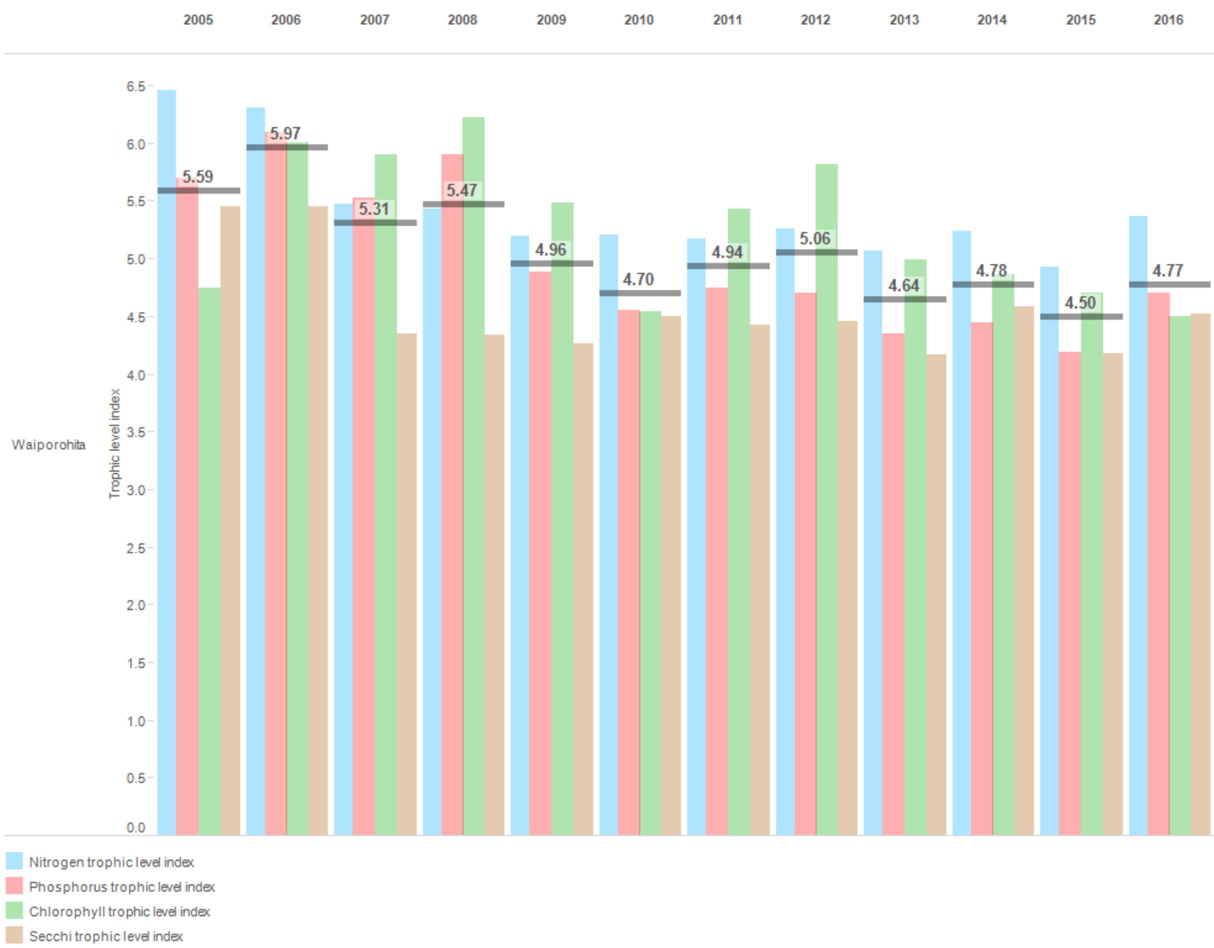
Phosphorus and nitrogen are used by native aquatic plants but when they are overly abundant, microscopic phytoplankton responds by blooming, shading the waters and lake bottom and competing with macrophyte plants for light.

The remedy to this cycle is, first, to limit future runoff of these nutrients and then to remove legacy nutrients by deliberate plant cultivation and removal.



Water Quality	Trophic Level	TLI Score
Very Good	Microtrophic	<2
Good	Oligotrophic	2-3
Average	Mesotrophic	3-4
Poor	Eutrophic	4-5
Very Poor	Supertrophic	>5
No Data	No data available	

The graph below is the TLI data presented in a new type of display developed by Andrew MacDonald at the NRC, allowing interpretation of the four contributing variables which make up the overall TLI score. In recent years, either total nitrogen or chlorophyll a can be seen to be the key contributing variable whereas in earlier years, phosphorus was the greater contributor. This suggests that the sheep farming practice may be the main source of nitrogen increases. However, the Rangiputa Station has recently undergone remedial work on stock exclusion fencing and set-back and sediment detention and Ngāti Kahu have done extensive riparian planting in the area of the drain outlet. It is anticipated that nitrogen levels will fall from 2017 onward as a result and the TLI scores will continue to improve (falling).



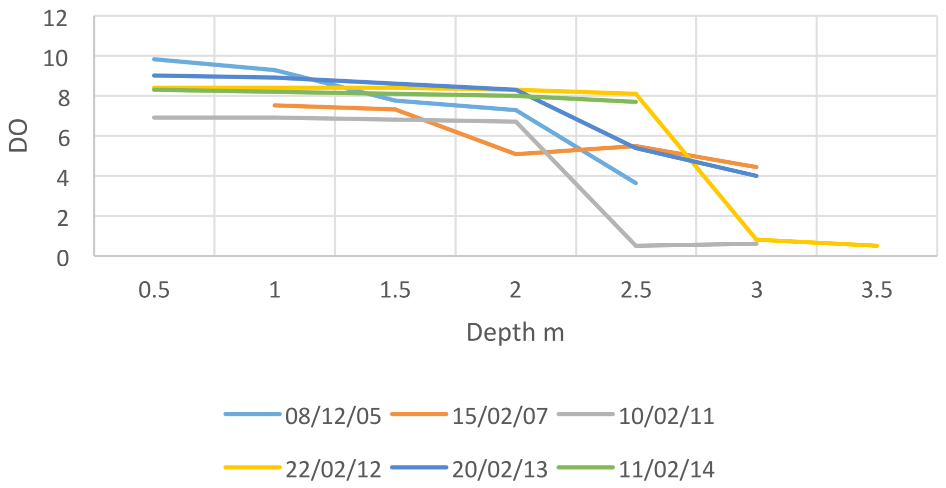
7.1.3. Dissolved Oxygen g/m³

Although the lake does not thermally stratify due to its shallow nature, there is an oxygen depletion in water below 2.5 meters between November and February.

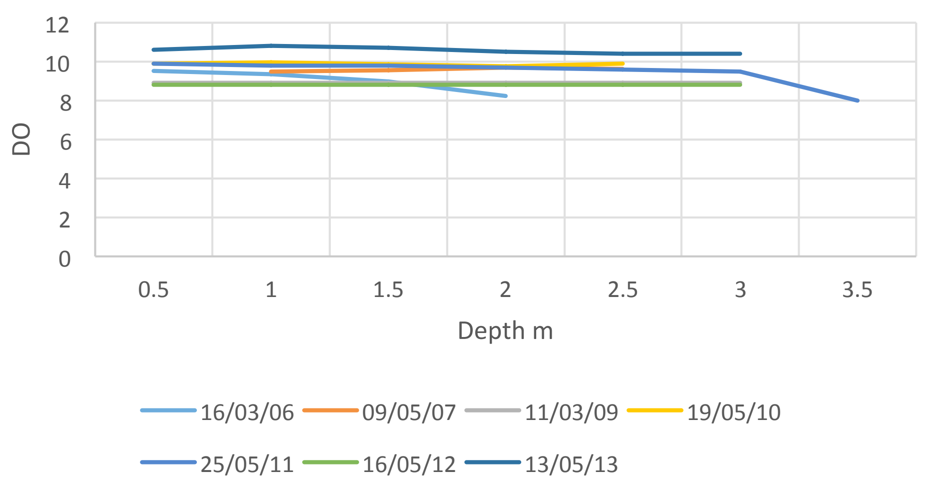
The table below shows the dissolved oxygen (at 15 degrees C) limits for New Zealand freshwater fish from **https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/dissolved-oxygen-criteria-for-fish.** These guidelines help interpret the depth profiles as to the depth of the water column usable by fish species during the different seasons displayed in the graphs.

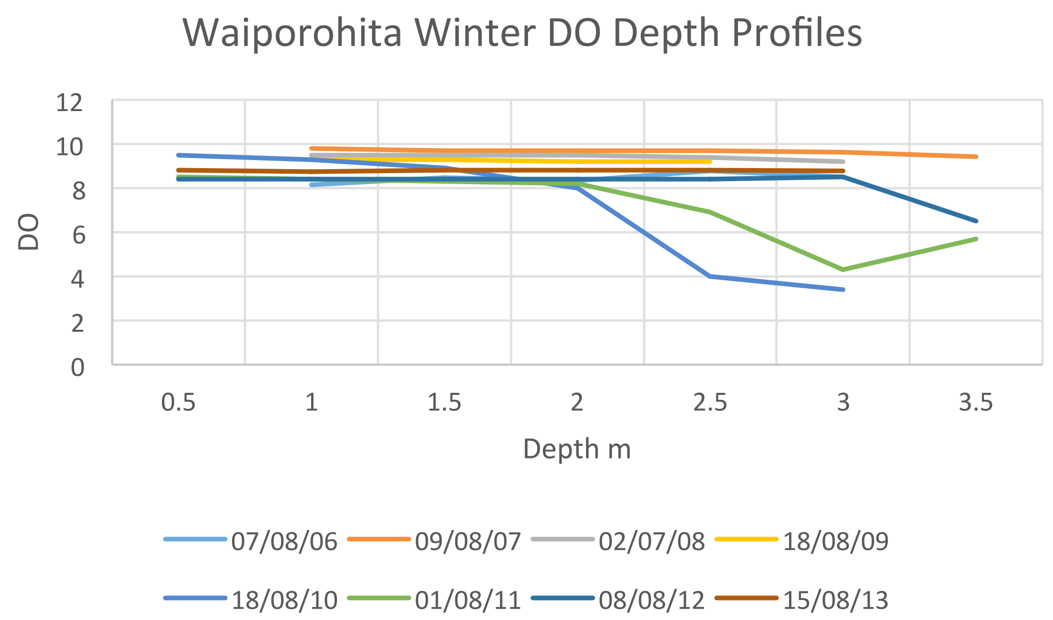
Dissolved Oxygen		Early life stages	Adults
30-day mean (mg L^{-1})	Guideline	9.0	8.0
	Imperative	6.5	6.0
7-day mean (mg L^{-1})	Guideline	7.5	6.5
	Imperative	5.5	5.0
7-day mean minimum (mg L^{-1})	Guideline	6.0	5.0
	Imperative	5.0	4.0
1-day minimum (mg L^{-1})	Guideline	6.0	4.0
	Imperative	4.0	3.0

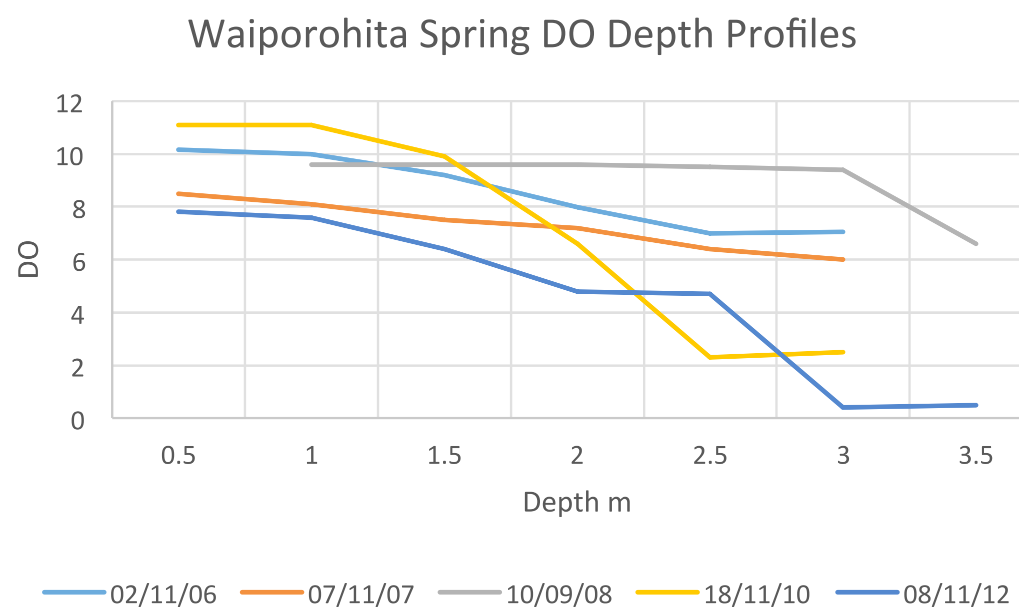
Waiporohita Summer DO Depth Profiles



Waiporohita Autumn DO Depth Profiles

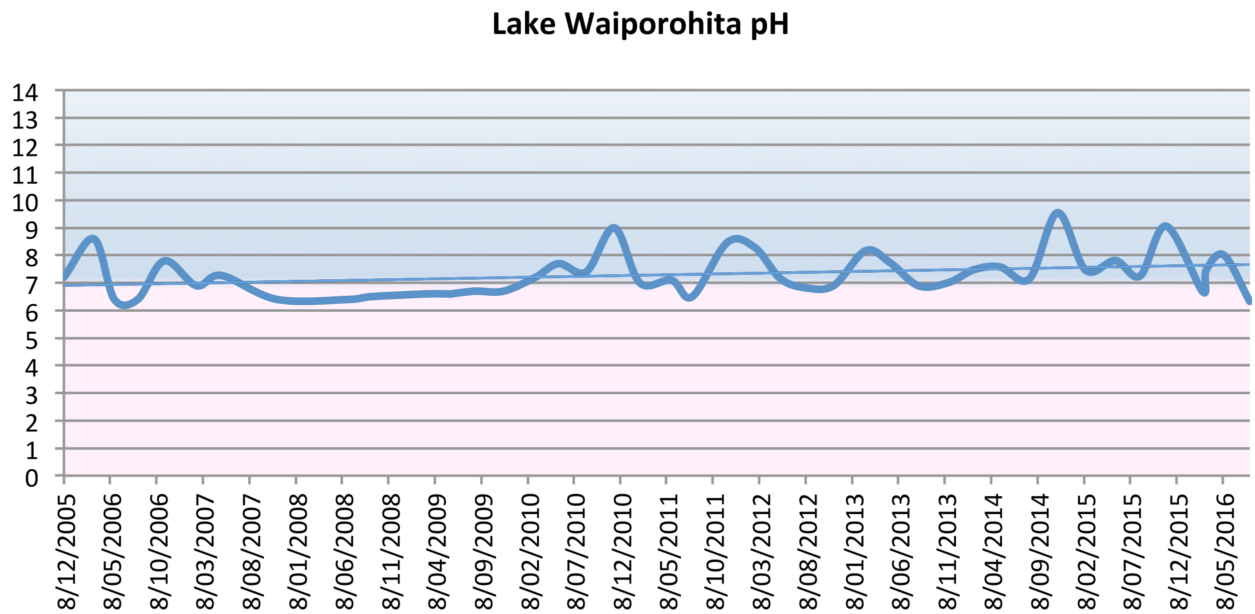



Waiporohita Winter DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5
1
1.5
2
2.5
3
3.5
Depth m
07/08/06
09/08/07
02/07/08
18/08/09
18/08/10
01/08/11
08/08/12
15/08/13


Waiporohita Spring DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5
1
1.5
2
2.5
3
3.5
Depth m
02/11/06
07/11/07
10/09/08
18/11/10
08/11/12

7.1.4. pH

There is an increasing trend of pulses of higher pH (increased alkalinity conditions) in the lake. This is most likely to be reflective of algal bloom activity using up dissolved carbon dioxide which would otherwise make the lake water relatively more acidic.



7.2. Lake and catchment water and nutrient dynamic drivers

7.2.1. Influence of nutrient loading

In general, the persistence of legacy nutrients and a continued, but now largely mitigated, influx of new nutrients from the catchment still poses a risk for such a shallow, wind-mixed lake. A Freshwater Improvement Fund project by NRC is in place to trial removal of legacy nutrients through macrophyte (native aquatic plants) aquaculture and their periodic removal from the system, essentially sponging the phosphorus from the water column.

8. BIOLOGICAL CHARACTERISTICS

8.1. Lake Biodiversity and Biosecurity species

8.1.1. Plants

One of the reasons that Waiporohita is among the top outstanding dune lakes in Northland is due to its diverse aquatic plant community. The lake supports 23 native plant species, shown in the table below. The table is organised as a depth gradient, from emergent plants to those which are submerged, for each of the invasive plants and native species. Rare natives are presented last. Waiporohita contains two of these; *Amphibromas fluitans* (Nationally Vulnerable), last seen in 1998 and *Centipeda aotearoana*.

Unusually, there are also four vagrant plant species, which have arrived from overseas without human transfer, first recorded in New Zealand from the margins of Lake Waiporohita including *Gratiola pedunculata, Alternanthera denticulata, Juncus polyanthemus* (all from Australia) and *Crassula natans var. natans* (from South Africa).

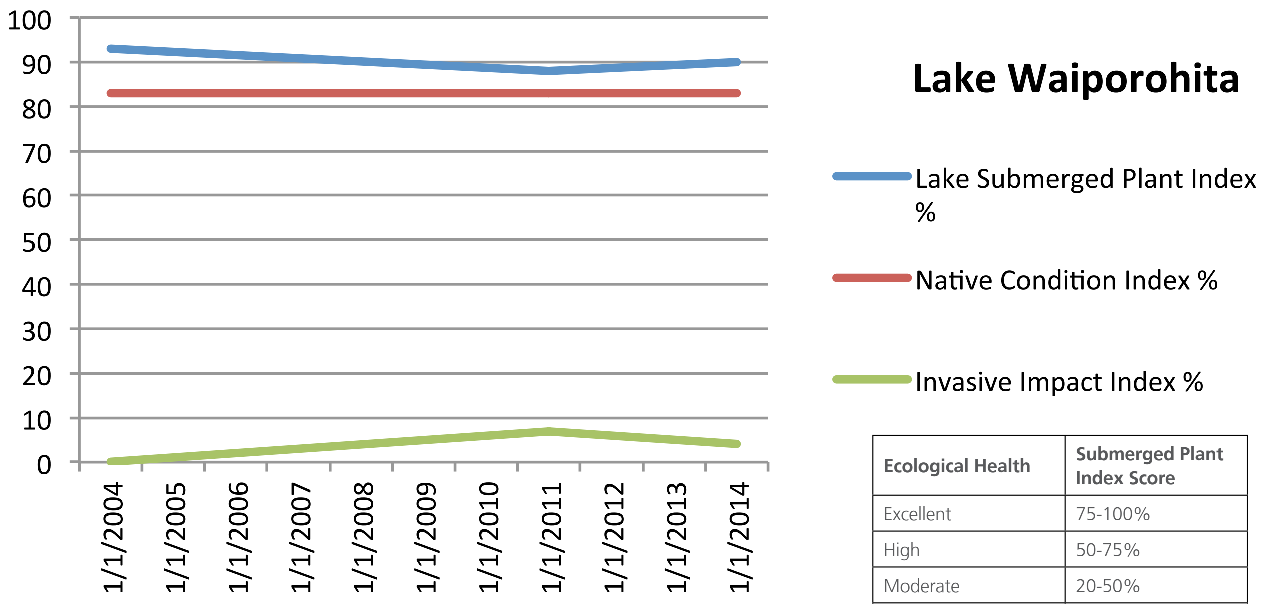
In addition to the natives, there are 10 exotic species, three being invasive, including alligator weed, primrose willow and mercer grass (*Paspalum distichum*). These are not among the four most serious invasive aquatic species, however. Of these, primrose willow would be the easiest to eradicate as it is restricted to an area of less than ten square metres. Also, it is the only known site of this plant north of Dargaville. The other two invasives are more widespread.

The table presents plant communities in nearby dune lakes as a comparison and indication of biosecurity species of concern which should be contained wherever possible. Data is derived from annual NIWA ecological surveys.

Depth and Plant Type Zone	Biogeography	Common Name	Species	Rotokawau West (KK)	Rotokawau East (KK)	Waiporohita	Rotopokaka/Coca Cola	Frequency
Erect emergent	Non-invasive exotic	willow weed, pale persicaria	Persicaria lapathifolia			x		1
Sprawling emergent	Invasive exotic	alligator weed	Alternanthera philoxeroides	x	x	x		3
Sprawling emergent	Invasive exotic	primrose willow, water primrose	Ludwigia peploides			x		1
Sprawling emergent	Invasive exotic	mercer grass, paspalum	Paspalum distichum			x		1
Sprawling emergent	Non-invasive exotic	clammy goosefoot	Chenopodium pumilio			x		1
Sprawling emergent	Non-invasive exotic	floating pigmyweed	Crassula natans var. minus			x		1
Sprawling emergent	Non-invasive exotic	Canadian fleabane	Erigeron canadensis (was Conyza parva)			x		1
Sprawling emergent	Non-invasive exotic	water purslane	Ludwigia palustris			x		1
Free floating	Non-invasive exotic	ferny azolla	Azolla pinnata			x		1
Free floating	Non-invasive exotic	bladderwort, yellow bladderwort	Utricularia gibba			x		1
Erect emergent	Native	oioi, jointed wire rush	Apodasmia similis			x	x	2
Erect emergent	Native	sharp spike sedge	Eleocharis acuta		x	x		2
Erect emergent	Native	bamboo spike sedge, tall spike sedge	Eleocharis sphacelata	x	x	x	x	4
Erect emergent	Native	wire rush, lesser wire rush	Empodisma minus		x			1
Erect emergent	Native	leafless rush	Juncus pallidus			x		1
Erect emergent	Native	none known	Juncus polyanthemus			x		1
Erect emergent	Native	sedge	Machaerina arthrophylla (syn. Baumea arthrophylla)	x				1
Erect emergent	Native	jointed baumea, jointed twig rush	Machaerina articulata (syn. Baumea articulata)			x		1
Erect emergent	Native	sedge, tussock swamp twig rush	Machaerina juncea (syn. Baumea juncea)	x	x		x	3
Erect emergent	Native	flax, harakeke, korari	Phormium tenax	x	x		x	3
Erect emergent	Native	softstem bulrush, grey club-rush, great bulrush	Schoenoplectus tabernaemontani		x	x	x	3
Erect emergent	Native	bog Schoenus, the stabber	Schoenus brevifolius		x			1
Erect emergent	Native	raupo	Typha orientalis		x	x	x	3
Erect emergent	Rare native	water brome	Amphibromus fluitans			x		1
Sprawling emergent	Native	lesser joyweed	Alternanthera denticulata			x		1
Sprawling emergent	Native	nahui	Alternanthera nahui			x		1
Sprawling emergent	Native	centella	Centella uniflora			x		1
Sprawling emergent	Native	tangle fern, swamp umbrella fern	Gleichenia dicarpa		x			1
Sprawling emergent	Rare native	New Zealand sneezewort	Centipeda aotearoana			x		1
Low growing turf	Native	none known	Glossostigma elatinoides		x	x	x	3
Low growing turf	Native	none known	Gratiola pedunculata			x		1
Low growing turf	Native	none known (sedge)	Isolepis prolifera			x		1
Low growing turf	Native	Zelandiae chain sword	Lilaeopsis novae-zelandiae			x		1
Low growing turf	Native	moss	Sphagnum sp.	x				1
Floating leaved	Native	red pondweed	Potamogeton cheesemanii			x	x	2
Submerged milfoil	Native	common water milfoil	Myriophyllum propinquum			x	x	2
Submerged tall pondweed	Native	blunt pondweed	Potamogeton ochreatus			x		1
Submerged charophyte	Native	stonewort	Chara australis			x		1
Submerged charophyte	Native	stonewort	Chara fibrosa			x		1
Submerged charophyte	Native	stonewort	Nitella sp. aff. cristata			x		1
			Total Plant Diversity	6	11	33	9	
			Exotic Plant diversity	1	1	10	0	
			Native Plant Diversity	5	10	23	9	

8.1.1.1.1. Lake Submerged Plant Index (LakeSPI), Native Condition Index and Invasive Impact Index

Three indices are valuable for considering the health of a lake's plant community; Lake Submerged Plant Index, Native condition Index and Invasive Plant Index. From the timeline below, it is seen that this lake is in good condition in relation to its plant community.



Ecological Health	Submerged Plant Index Score
Excellent	75-100%
High	50-75%
Moderate	20-50%
Poor	1-20%
Non-Vegetated	0%

8.1.2. Fish

The table below displays the fish of the Karikari Peninsula. Pest fish are shown in green and native fish in pink. Lake Waiporohita appears in yellow from among the lakes in the sub-region displayed. The lake has a low level of fish diversity, relative to other lakes on the peninsula. *Gambusia* is the only pest fish species. The only native species present is the common bully. Data is derived from annual NIWA ecological surveys.

common name	species	Conservation status	Degree of loss	Rotokawau West (KK)	Rotokawau East (KK)	Waiporohita	Rotopokaka/Coca Cola	frequency
Gambusia	Gambusia affinis			x	x	x		3
shortfinned eel	Anguilla australis			x	x			2
longfinned eel	Anguilla dieffenbachii	at risk	declining				x	1
inanga	Galaxias maculatus	at risk	declining	x	x		x	3
common bully	Gobiomorphus cotidianus			x	x	x	x	4
black mudfish	Neochanna diversus	at risk	relict	x	x		x	3
smelt	Retropinna retropinna							0
	diversity pest fish			1	1	1	0	
	diversity native			4	4	1	4	

8.1.3. Waterbirds

The table below displays the waterbirds of the Karikari Peninsula. Game birds are shown in green and non-game bird native species in pink. Lake Waiporohita appears in yellow. The lake has a moderate bird diversity and other lakes on the peninsula are popular duck-hunting sites. Of interest are the sole records of dabchick and chestnut-breasted shelduck, which is a vagrant from Australia, in the Karikari Peninsula area.

Canada geese, now removed from the Fish & Game Council game bird schedule, are a common problem in dune lakes, flocking at Waiporohita to such a degree that their droppings litter the entire lake-shelf edges, adding to already high nutrient levels. Large numbers of black swan could also be elevating nutrients. Wide beaches at the lake are favoured roost sites for these species. Canada geese are a particular concern because they feed off-site and bring fresh nutrients into the lakes. Data has been derived from annual NIWA ecological surveys.

common name	species	Conservation status (DOC, *Conservation status of NZ birds*, 2016)	Criteria / Degree of loss	Rotokawau West (KK)	Rotokawau East (KK)	Waiporohita	Rotopokaka/Coca Cola	frequency
grey duck	Anas superciliosa (resident native (not introduced) on game bird list)	threatened	nationally critical			x		1
black swan	Cygnus atratus (resident native (not introduced) on game bird list)	Not threatened			x	x		2
Canada goose	Branta canadensis (Introduced & naturalised, not protected, able to be hunted at any time)	Introduced & naturalised				x		1
New Zealand scaup	Aythya novazeelandiae	not threatened		x	x			2
Australasian bittern	Botaurus poiciloptilus	threatened	nationally critical	x	x	x	x	4
North Island fernbird	Bowdleria punctata vealeae	at risk	declining	x	x		x	3
Caspian tern	Hydroprogne caspia	threatened	nationally vulnerable	x	x	x		3
New Zealand dabchick	Poliocephalus rufopectus	at risk	recovering			x		1
marsh crake	Porzana pusilla affinis	at risk	declining	x	x			2
spotless crake	Porzana t. tabuensis	at risk	declining	x	x		x	3
Australasian little grebe	Tachybaptus n. novaehollandiae		coloniser	x	x			2
chestnut-breasted shelduck	Tadoma tadornoides		vagrant			x		1
diversity resident native (not introduced) on game bird list				0	1	2	0	
diversity introduced & naturalised				0	0	1	0	
diversity native				7	7	4	3	

8.1.4. Invertebrates

Invertebrates are of interest in lake systems as indicators of lake health. They are generally very sensitive to poor water quality. In the case of Waiporohita, the presence of two mite species which cannot tolerate more than mild pollution is encouraging. Likewise, the Diptera midge, Tanytarsini. Koura/kewai and freshwater mussels/torowai are absent. Data is a compilation of NIWA and Northtec surveys.

8.1.5. Catchment weeds

A range of exotic tree species have been removed from the riparian margins of the lake as part of an Environment Fund project which also controls nitrogen-fixing weeds. The Department of Conservation, who manages this marginal strip are maintaining weed control in this newly opened habitat and riparian planting has been done by Ngāti Kahu to in-fill this space.

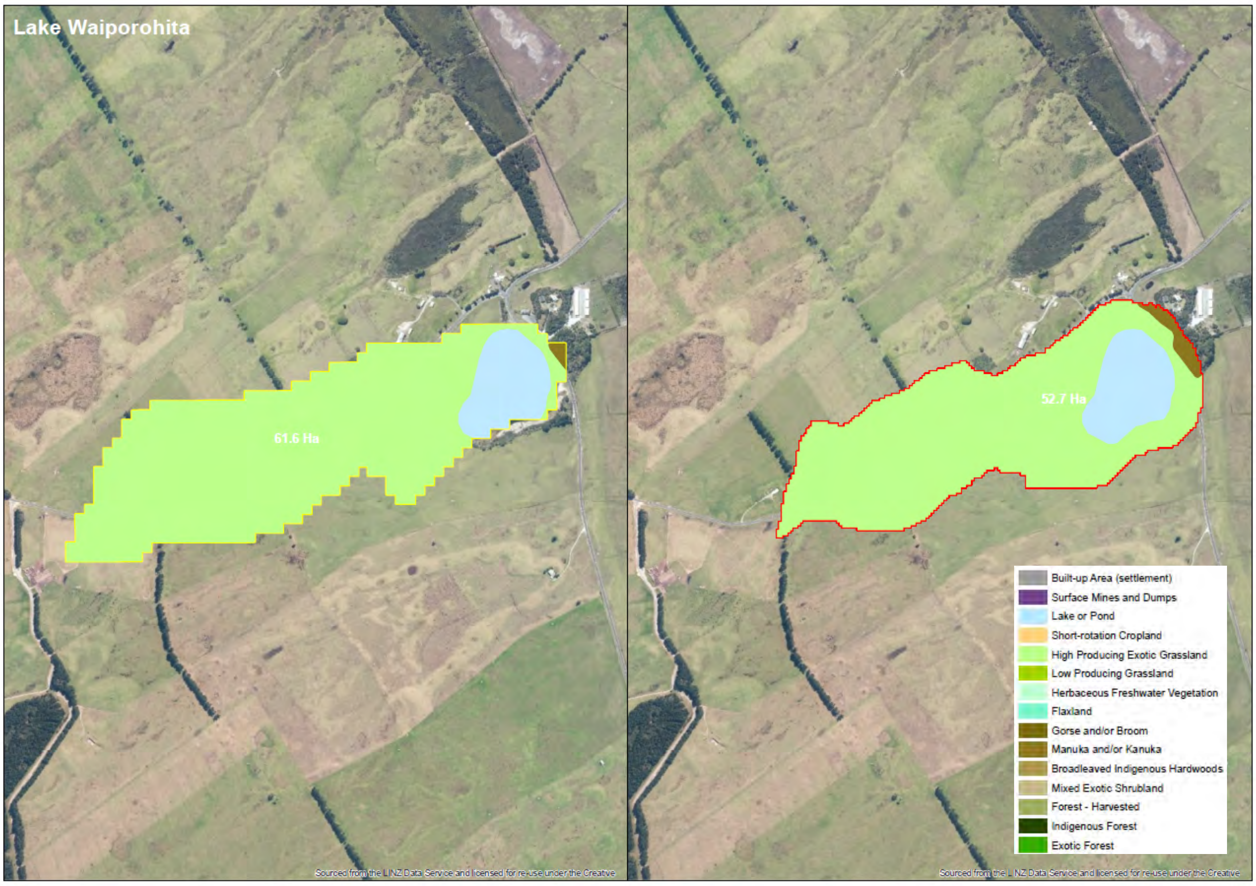
Order or phylum and common name	Family or species	Pollution minimum tolerance - Clean Water (>5.99) Mild Pollution (5.00-5.90) Moderate Pollution (4.00-4.99) Severe Pollution (<4.00)	Rotokawau West (KK)	Rotokawau East (KK)	Waiporohita	Rotopokaka/Coca Cola	frequency
Acarna, mite	Hydrachnidae	5.2			x		1
Acarna, mite	Oribatida	5.2			x		1
Crustacea, Decapoda, freshwater shrimp	*Paratya curvirostris*	*3.6*	x	x			2
Crustacea, Ostracoda, koura	*Paranephrops planifrons*	8.4					0
Crusteacea, Ostracoda	*Herpetocypris*	*1.9*			x		1
Diptera, midge, non-biting, Chironomid	Tanytarsini	4.5			x		1
Diptera, midge, non-biting, Chironomid	*Chironomas sp*	3.4			x		1
Hemiptera, bug, backswimmer	*Sigara arguta*	2.4			x		1
Hirudinea, leech	Hirudinea				x		1
Hirudinea, leech	*Richardsonianus mauianus*				x		1
Oligocheate worm	Oligochaeta sp	3.8			x		1
Ostracod crusteacean	*Ilyodromus*				x		1
	diversity invasive		0	0	0	0	0
	diversity native		1	1	10	0	12

9. LAND USE

9.1. Catchment land cover (ha) and map

The catchment is dominated by farmed high-producing exotic grassland with some manuka/kanuka scrub.

Lake	Cover Type	Total FENZ (ha)	Total Hand-drawn (ha)
Lake Waiporohita	High Producing Exotic Grassland	54.44	44.41
Lake Waiporohita	Lake or Pond	6.89	7.27
Lake Waiporohita	Manuka and/or Kanuka	0.26	1.04
Lake Waiporohita Total		61.59	52.72

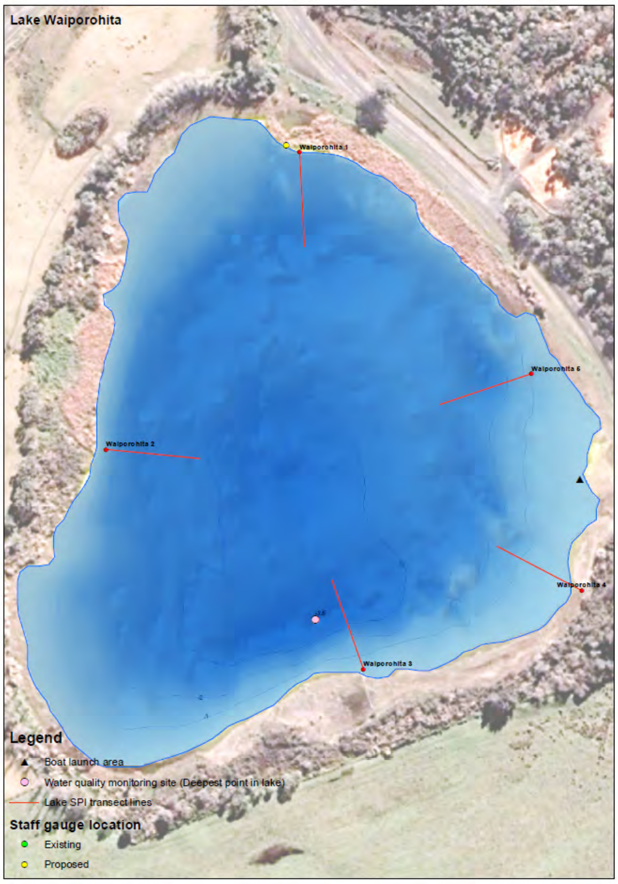


9.2. Pastoral farming and horticulture

The Landcorp Rangiputa Station is a well-maintained sheep farm with low impact on the catchment.

10. MONITORING PLAN

The diagram below shows the five transect lines surveyed during ecological surveys. The dark triangle to the south-east is the access point for the NRC vessel for water quality sampling. The pink point in the south of the lake is the water quality sampling point, corresponding to the deepest part of the single basin.



10.1. NIWA ecological monitoring

The lake is scheduled to be fully ecologically monitored every five years with a weed survey annually. There have been seven full surveys since 1991 with the last one done in 2017. The value class of the lake has held at Outstanding. The next full survey is likely to be done in 2020.

Lake	Eco Survey (yr)	Weed survey (yr)	1984	1985	1986	1987	1988	1989	1990	1991	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rotokawau East															M																
Rotokawau West															M																
Rotopokaka/Coca Cola														M 7											M-H						
Little Black Lake (south of Coca Cola)																															
Waiporohita	5	1												O	O						O			O			SPI				
Roadside Pond, Matai															L																

KEY
O = Outstanding
H = High
M = Medium
L= Low
Ecological Survey
Reconnaissance or Visit
Weed Surveillance
Grass Carp Assessment
Endothall Assessment
SPI = Submerged Plant Index
Surveillance

10.2. NRC Ecological monitoring

10.2.1.Water quality and quantity monitoring

Water quality sampling occurs quarterly in February, May, August and November.

Numbers of samples per year appear below.

Row Labels	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Grand Total
Waiporohita lower																	1	4	4	2	3	4	4	4	4	4	4	5	1	44
Waiporohita surface			1					1								1	1	4	4	2	4	4	4	4	4	4	5	5	1	49

11. WORK IMPLEMENTATION PLAN

Recent NRC Environment Fund work over 2016-2017 has mitigated many of the threats and has included:

- Riparian planting by Ngāti Kahu.
- Removal of exotic trees and nitrogen-fixing weeds
- Terrestrial weed control by DOC
- Set-back fencing by Landcorp
- Installation of a sediment detention weir by Landcorp

The NRC/NIWA ecological surveys will continue every five years with weed surveillance annually. The next full survey is likely in 2020. Quarterly NRC water quality monitoring will continue.

Freshwater Improvement Fund work, due to begin in early 2018, includes longline-basket aquaculture of native macrophytes to remove legacy nutrients from the water.

Further mitigation work to consider includes:

- Fencing and riparian planting of the farm drain length and infill riparian planting through Million Metres project
- Blocking vehicle and boat access from Inland Road
- Continued functional riparian planting
- Covering alligator weed patches to kill them by light deprivation
- Eradication of primrose willow
- Trialled control of *Gambusia* by Gee minnow trapping
- Installation of a lake level staff gauge and electronic recorder
- Assessing methods to control primrose willow and Paspalum
- Culling of Canada geese

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13. APPENDIX 1. GLOSSARY

Largely adapted from https://www.lawa.org.nz/Learn

Aquatic - Refers to anything that is related to water. For example, aquatic organisms are plants or animals that live in or near water.

Algal or phytoplankton bloom - A rapid increase in the population of algae in an aquatic system. Blooms can reduce the amount of light and oxygen available to other aquatic life.

Bathymetry – The measurement of depth of water.

Biodiversity - The variety of lifeforms at a given time in a given place.

Biosecurity - The precautions taken to protect against the spread harmful organisms and diseases.

Catchment (area) - The total area of land draining into a lake, expressed in hectares (ha).

Chlorophyll a – Chlorophyll a is a green pigment in all plants, including algal phytoplankton, that is used for photosynthesis and is a good indicator of the total quantity of algae present. It can be measured in micrograms per litre (ug/l) or reflective florescence units (RFU). Large amounts of algae in a lake can decrease the clarity of the water, make the water green, form surface scum, reduce dissolved oxygen and alter the pH of the water.

Clarity (of water) - Refers to light transmission through water and has two important aspects: visual clarity and light penetration. Visual clarity indicates how much sediment or runoff is in the water. Light penetration is also important as it controls light availability for growth of aquatic plants.

Classification of dune lakes (Timms, 1982)
See table below

Dune lake class (Timms, 1982)	Description
1. Perched lakes in deflation hollows	Perched in leached dunes, in deflation hollows in elevated leached dunes where organic material has sealed the basin floor and provided humic (tea-stained) water.
2. Swamp-associated perched lakes	Similar to Class 1 but close to the sea, associated with extensive swamps.
3. Window lakes	Water table window lakes in a drowned valley or interdune basin, fed by springs with clear water character.
4. Dune contact lakes	Waterbodies where at least one shore is in contact with a coastal dune, often but not exclusively humic.
5. Marine contact lakes	Freshwater lakes with marine contact, where there may be intermittent connection with the sea.
6. Ponds in frontal sand dunes	Ponds where wind erodes sand to form deflation hollows.

Deoxygenation – Also called hypoxia. Air is 20.9% oxygen, whereas water contains around 1% oxygen and this fluctuates depending on the presence of photosynthetic organisms (higher submerged plants and microalgae) and the distance to the surface, as air diffuses oxygen into surface waters. Hypoxia can occur throughout the water column as well as near sediments on the bottom. It usually extends throughout 20-50% of the water column, but depending on the water depth, it can occur in 10-80% of the water column. For example, in a 10-meter water column, it can reach up to 2 meters below the surface. In a 20-meter water column, it can extend up to 8 meters below the surface. Oxygen depletion can result from a number of natural factors, but is most often a concern as a consequence of pollution and eutrophication in which plant nutrients enter a lake, and phytoplankton blooms are encouraged. While phytoplankton, through photosynthesis, will raise Dissolved Oxygen (DO) saturation during daylight hours, the dense population of a bloom reduces DO saturation during the night by respiration. When phytoplankton cells die, they sink towards the bottom and are decomposed by bacteria, a process that further reduces DO in the water column. If oxygen depletion progresses to hypoxia, fish kills can occur and invertebrates like freshwater mussels on the bottom may be killed as well.

Dissolved oxygen (DO) - The oxygen content of water. Dissolved oxygen is important for fish and other aquatic life to breathe. For example, water quality guidelines recommend that water should be more than 80 percent saturated with DO for aquatic plants and animals to be able to live in it.

Eutrophic – A trophic level referring to a lake having an abundant accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which may deplete the shallow waters of oxygen in summer resulting in potential death of animal life. In the Trophic Level Index (TLI), a trophic level of 4-5, meaning the water quality is poor.

Exotic species (also called introduced, alien, non-indigenous or non-native) - A species living outside its native distributional range, which has arrived by human activity, either deliberate or accidental. Exotic species can have various effects on the local ecosystem. Exotic species that become established and spread beyond the place of introduction are called invasive species.

Hapū - Te reo Māori for a sub-tribe or a clan. Each iwi can have a number of hapū. For example, the Ngāti Whātua iwi has hapū including Te Uri-o-Hau, Te Roroa, Te Taou, and Ngāti Whātua ki ōrākei.

Humic - Of, relating to, or derived from humus, which is a dark brown or black mass of partially decomposed organic matter in the soil. Humic acids are present in peats. Humic acids are produced by the bacterial decomposition of dead plant residues and by the prolonged action of atmospheric oxygen or water on organic matter. Run-off from land of this soil type can stain lake-water a dark brown (known as humic or tanin staining), limiting light for plant growth. Forestry harvest has been shown to disturb this soil type, leading to lake water quality decline.

Invasive exotic plant – An exotic species that becomes established and spreads beyond the place of introduction, posing a risk to native ecology.

Invasive Impact Index - The percentage of invasive weeds within a lake. A high Invasive Impact is undesirable.

Invertebrate - An animal that has no backbone or spinal column, such as insects, worms, snails and freshwater mussels.

Lake Submerged Plant Index (SPI) - A method of characterizing the ecological health of lakes based on the amount of native and invasive plants growing in them. Higher Lake SPI scores are associated with the better ecological health.

Limiting nutrient assay – An analytic procedure to determine what nutrient is limiting algal growth in a lake. If the limiting nutrient becomes available, increased growth of algal phytoplankton will occur.

Macrophyte - Large water plants and algae that live in freshwater and are visible to the naked eye, as opposed to the microscopic periphyton and phytoplankton. Macrophytes can be either submerged, floating or emergent. Most macrophytes in Northland are rooted to the bottom.

Mana whenua – Te reo Māori for territorial rights, power from the land, authority over land or territory, jurisdiction over land or territory - power associated with possession and occupation of tribal land. The tribe's history and legends are based in the lands they have occupied over generations and the land provides the sustenance for the people and to provide hospitality for guests.

Mesotrophic - A trophic level of 3-4 meaning the water quality is average. The lake has moderate levels of nutrients and algae.

Native Condition Index - The percentage of native vegetation within a lake. A high native condition is desirable. It is one of the measures used to determine the Lake Submerged Plant Index.

Native species (also indigenous species) - A species found naturally in an ecosystem, including naturally-arriving migrant species which may be found in other countries as well. Endemic natives are found only in one place or country.

Non-invasive exotic plant - Exotic species of plants that become established and do not readily spread beyond the place of introduction, posing little threat to native species.

Oligotrophic - A trophic level of 2-3 meaning the water quality is good. The lake has low levels of nutrients and algae, high oxygen levels due to a lack or decaying organic material. The lake is clear and blue, with very low levels of nutrients and algae.

pH - The degree of acidity or alkalinity as measured on a scale of 0 to 14 where 7 is neutral, less than 7 is more acidic, and greater than 7 is more alkaline. Most natural waters fall within the range between pH 6.5 to 8.0 and in the absence of contaminants most waters maintain a pH value that varies only a few tenths of a pH unit.

Phytoplankton - Microscopic algae and cyanobacteria that drift or float in the water column and are able to produce oxygen through photosynthesis. When overgrowth or algal bloom occurs, it is an indication that excess nutrients are a problem. Algal blooms can shade light from reaching submerged plants and if a bloom collapses, deoxygenation of the water may occur.

Quaternary dunes – We are currently still living in the Quaternary period of geological time. The Quaternary period is subdivided into the Pleistocene epoch (2.6 million years ago to 11,700 years ago), the Holocene epoch (11,700 years ago to 1950) and the Anthropocene epoch (1950-present or the period when the Industrial Revolution began to alter climate). When we refer to dune sand types, they are informally divided into Early/Lower Quaternary (dunes formed 2.6 million-78,000 years ago) and Late/Upper Quaternary (dunes formed 12,000 years ago to the present, basically during the Holocene epoch).

The material in present-day river valleys and beaches has been mainly deposited since the last glacial stage ended, about 14 000 years ago. From then, until about 6000 years ago, there was a substantial warming of climate which caused a rise in sea level; some dune deposits are recognised as having formed at the time that sea level rise ended.

Sea level has dropped again slightly since that time. Lakes are collecting mud and sand and will eventually fill. Sand dunes naturally advance, blown by the wind until stabilised by vegetation.

Periods of cold climate occurred throughout the Quaternary, not only in New Zealand but globally. The worldwide glaciations caused sea level to drop, as much water was bound up in ice and snow. During warmer interglacial periods, the ice melted and sea level rose. The effect of these oscillating sea levels is clearly seen in uplifted coastal terraces, each flat surface marking the position of an earlier high sea level. Periods of low sea level and cold climate created expanses of bare earth and sand with little vegetation. Winds blew the coastal sand into dunes. In the North Island, there was little active glaciation except in the very highest mountain areas. The build-up of sand dunes was a result of low sea levels and cold climate.

Rare native plant - A rare plant is one that is not commonly found in the wild. It may be naturally rare or sparse or may have a restricted range. Rare plants may or may not be of conservation concern. A threatened plant is a rare plant which is at risk of extinction in the wild. An endangered plant is a category of threatened plant. It is a technical term for describing the degree of risk of extinction a plant is under. Some technical terms, such as endangered, are commonly and inaccurately used to refer to all threatened plants.

Residence time (also retention time, water age or flushing rate) – A calculated quantity expressing the mean time that water spends in a particular lake.

Riparian zone - A strip of land, usually of varying width, that is directly adjacent to a waterway and which contributes to maintaining and enhancing the natural functioning, quality, and character of the waterbody. This area is commonly planted in native species to reduce sediment and nutrient inflows.

Sp. aff. or aff. (short for "species affinis") indicates a potentially new and undescribed species has an affinity to, but is not identical to, the named species. ... spp.; short for "species") indicates potentially new species without remarking on its possible affinity.

Secchi disk - Lake clarity is measured using a Secchi disc attached to a measured line. The disc is lowered into the water until it disappears and this depth is noted. The disc is lowered a little further and then slowly raised until it reappears, this depth is noted. The average of the two readings is the final Secchi depth visibility depth.

Supertrophic - A trophic level greater than 5 meaning the water quality is very poor. The lake is fertile and saturated in phosphorus and nitrogen, often associated with poor water clarity.

Thermal stratification - Refers to a change in the lake water temperature at different depths in the lake, and is due to the change in water's density with temperature. Cold water is denser than warm water and the epilimnion, or shallower waters, generally consists of water that is not as dense as the water in the hypolimnion, or deeper waters. When stratification occurs, the two water masses are not mixing, leading to nutrients and lower oxygen levels being captured in deeper, colder water. This generally occurs in warmer months. When the upper water cools in colder months, mixing will occur, providing nutrients throughout the lake, which can lead to algal bloom conditions.

Total Phosphorus (TP) - Total phosphorus is a measure of all forms of phosphorus that are found in a sample, including dissolved and particulate, organic and inorganic. High levels of total phosphorus in water can come from either wastewater or run-off from agricultural land. Too much phosphorus can encourage the growth of nuisance plants such as algal blooms.

Total Nitrogen (TN) - Total Nitrogen is a measure of all organic and inorganic forms of nitrogen that are found in a sample. High total nitrogen, like total phosphorus can be a cause of eutrophication in lakes, estuaries and coastal waters and can cause algal blooms.

Total Suspended Solids (TSS) - Solids in water that can be trapped by a filter for measurement. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can adversely affect aquatic life.

Trophic Level Index (TLI) - Used in New Zealand as a measure of nutrient status of lakes. The TLI is calculated from data from 4 parameters: water clarity (Secchi), chlorophyll a content, total phosphorus and total nitrogen.

Volumetric flow rate (as a mean annual total) - The amount of water entering a lake in a year, expressed in m3/s or cubic meters per second.

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