Lake Humuhumu

MANAGEMENT PLAN

CONTENTS

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1. PURPOSE

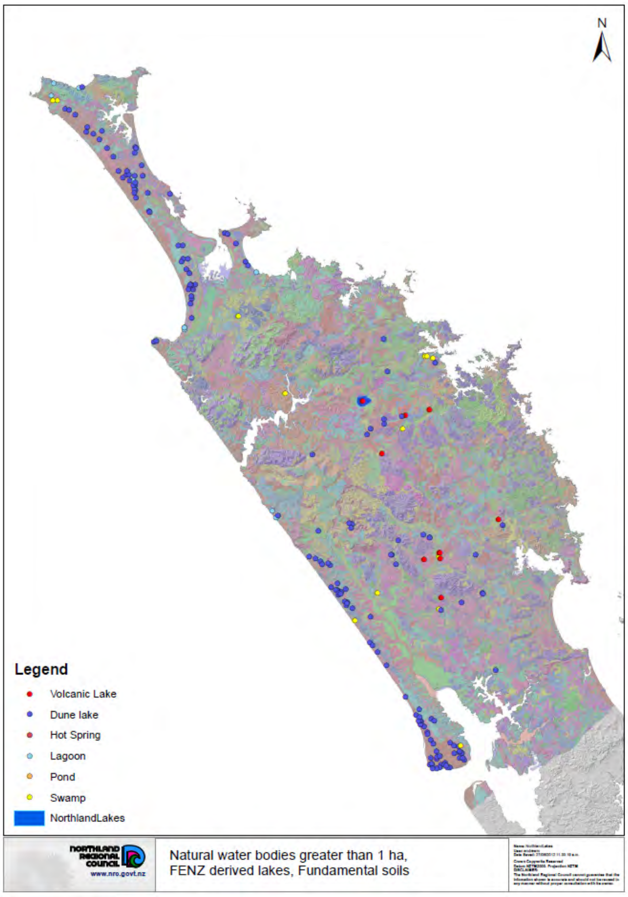
The purpose of the Outstanding Northland Dune Lakes Management Plans is to implement the recommendations of the Northland Lakes Strategy Part II (NIWA 2014) by producing Lakes Management Plans, starting with the 12 'Outstanding' value lakes, and by facilitating actions with mana whenua iwi, landowners 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 Humuhumu (NRC Lake Number 350) is a deep, 134.97 ha (15.22 m max and 6.32 m mean depth) lake located on private farmland to the west of Pōuto Road on the southern end of the Pōuto Peninsula in south-western Northland. The lake is classified as a Class 4 Dune Contact dune lake (Timms, 1982), as its western shore sits in contact with more geologically recent uncemented to loosely-cemented dune with its eastern shore sitting on older cemented dune geology.

The catchment is dominated by harvested pine forest, high producing exotic grassland (alternating pastoral and dairy farming on the northern side) and manuka/kanuka scrub. The catchment area as defined by LiDAR, including the lake, is 471.5 hectares. The surface area of the lake is 134.97 ha.

The lake thermally stratifies in summer and into March. The lake has experienced increasing algal blooms into National Policy Statement for Freshwater Management (NPS) State D for phytoplankton (chlorophyll-a) and a loss of water clarity, the latest bloom being a peak in February 2015. The chlorophyll-a trend is likely due to the gradual rise in nitrogen levels.

Nitrogen levels are trending upward, leaving a long-term NPS State B into State C in March 2014. Phosphorus levels are low other than pulse events in March 2006 and March 2011 where peaks are observed in NPS State D. Toxic ammonia is in NPS State A, but is rising.

The lake is high level mesotrophic (average water quality) but crossed the line into poorer water quality (eutrophic) in 2014. There is oxygen depletion in water below 8-11 meters between spring and autumn. On average, pH consistently varies around 8, alkalinity being more favourable to native fish.

Lake levels in Humuhumu are fairly stable with a slight rise through time. Variability is .87 m. The lake has an estimated water residence time of just under 20 months. Humuhumu is most heavily influenced by rainfall (49%), followed by groundwater (40%) and a minor surface water influence of 12%. Lake Rotopouua, which is in the same catchment, provides surface inflows.

Humuhumu has the highest native aquatic plant diversity of any Pōuto lake at 30 species and the key threat to the lake's ecology are six exotic water weeds, including the invasive alligator weed and royal fern.

There are no pest fish present. Common bully and dwarf inanga are present but there is a notable absence of short-finned eel, otherwise common in the sub-region.

The lake has a high level of native bird diversity and has no recorded game species. Dabchicks, Australasian bittern and New Zealand scaup occur widely in this sub-region.

5. SOCIAL AND CULTURAL DIMENSION

5.1. Mana whenua

Te Uri o Hau (yellow) and Te Runanga o Ngāti Whātua (orange) have rohe whenua Area of Interest in the area of Lake Humuhumu. Te Uri o Hau has reached Deed of Settlement with the Crown and the previously Crown-owned part the lakebed has been transferred to Te Uri o Hau. Other parts of the lakebed are in private ownership.

Rohe whenua is displayed in the diagramme 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

Six landowners own eight parcels of land within the lake catchment. The lake bed is owned by several landowners including two Māori trusts.

5.3. Community involvement

The Pōuto catchment group was formed in mid-2013 to help determine how the Pōuto Peninsula'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, Kaipara District Council and the Northland Fish and Game Council. The group is chaired by a Northland Regional Council councillor.

A planning initiative called Future Pōuto has recently been undertaken by Te Uri o Hau. The plan addresses cultural, social, economic and environmental aspirations for the peninsula.

5.4. Public use

5.4.1. Access

Access to the lake is from the road over firm grassed ground, but is restricted by the need to cross private farmland.

5.4.2. Boating

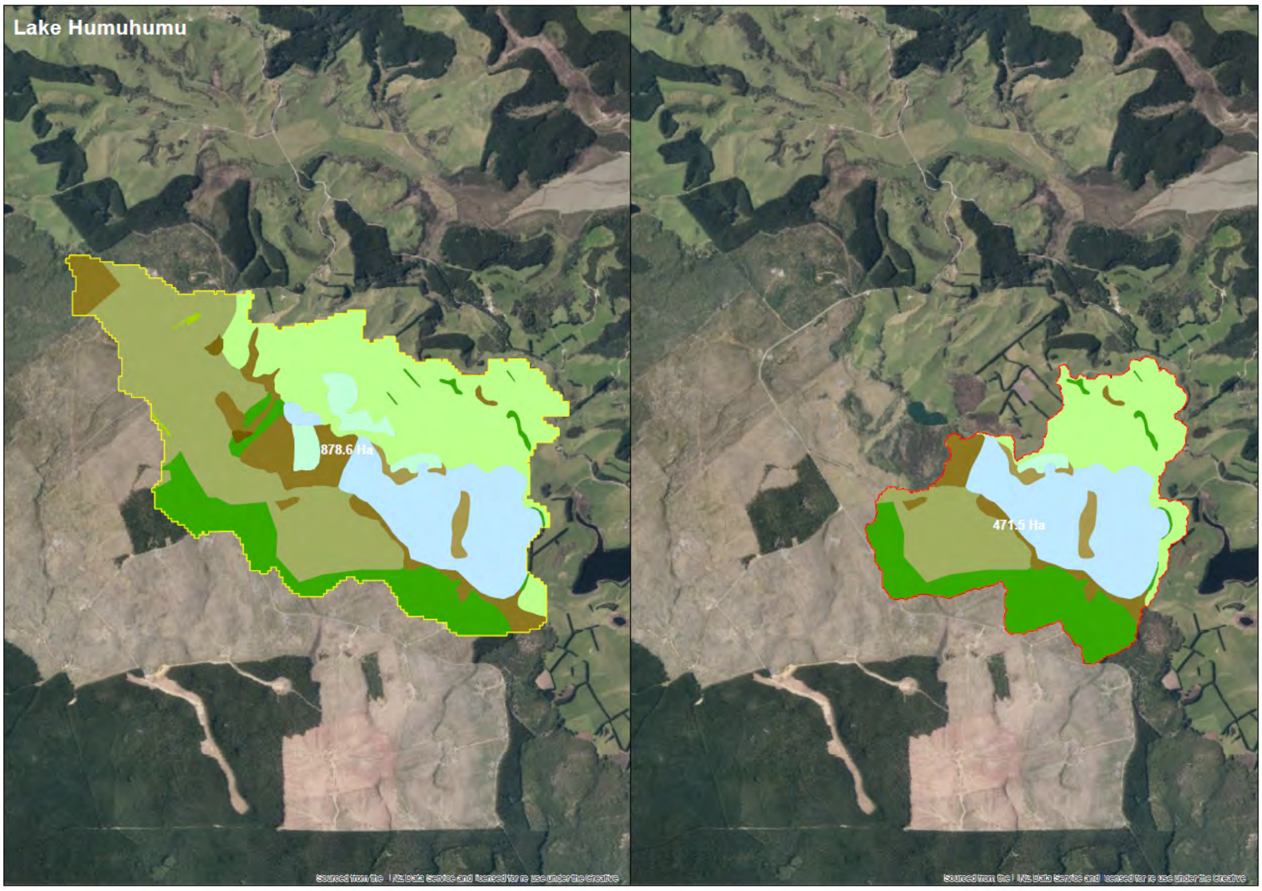
5.4.2.1. Boat access

Boat access to the lake is by 4WD, but is restricted by the need to cross private farmland. Thick reed beds and a soft base at the launching area make boat launching difficult.

6. PHYSICAL CHARACTERISTICS

6.1. Catchment area with map

The catchment area, defined by LiDAR and including the lake itself, is 471.5 hectares. LiDAR is an aerial surveying method using light and radar used to make high resolution 3D maps. Recent LiDAR survey has redefined the catchment and sub-catchment boundaries. From this work and nutrient modelling, it is now known that water travels through Lake Rotopouua first before entering Humuhumu. The old catchment FENZ boundary appears on the left in the map below, with the new catchment boundary on the right.

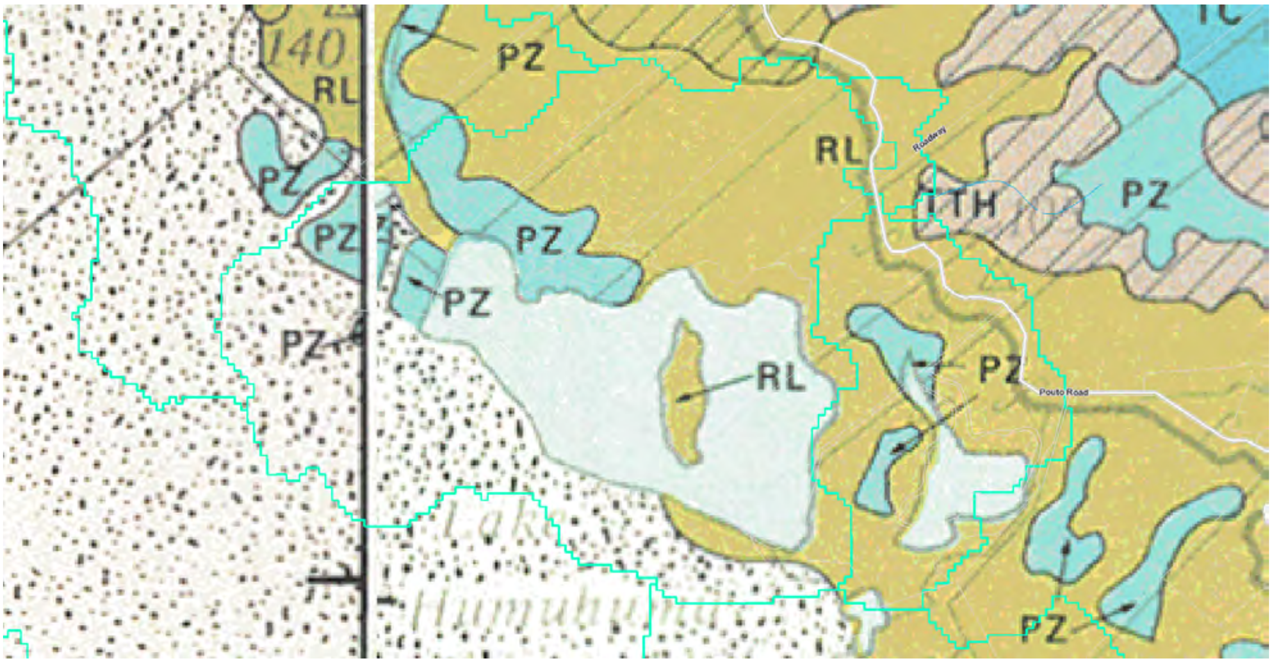


6.2. Catchment Geology and soil types

The following maps and tables display the geology and soil type of the lake catchment. The lake sits between an edge between a geological substrate of weakly cemented to uncemented early Quaternary dune (eQd) and more cemented late Quaternary dune (lQd) which dates to higher sea levels 12,000 or more years ago.

Lake Name/Plot Symbol	eQd	lQd (Q1d)
Humuhumu	x	x
Name	Early Quaternary dunes	Late 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.	Loose to poorly consolidated sand in mobile and fixed dunes locally with paleosols and peat. Minor sand, mud and peat in interdune lake and swamp deposits.
Geologic history	Early Quaternary	Late Quaternary
Simple name	Zealandia Megasequence Terrestrial and Shallow Marine Sedimentary Rocks (Neogene)	Zealandia Megasequence Terrestrial and Shallow Marine Sedimentary Rocks (Neogene)
Absolute minimum age (millions of years before present)	0.78	0
Absolute maximum age (millions of years before present)	2.6	0.12
Supergroup equivalent stratigraphic name	Pakihi Supergroup	Pakihi Supergroup
Terrane equivalent name		
Lithology	sand	sand

The following soil map and table shows the division of influence of catchment soils on the lake. The catchment features Redhill sandy loam (RL) to the east, which forms an iron pan, and Parore peaty sandy loam (PZ) to the west.



Soil Symbol	Genetic soil group	Geological origin	Suite	Subgroup	Series	Soil name	Description
RL	Yellow-brown sands	Yellow-brown sands	Pinaki	Moderately to strongly leached	Redhill	Redhill sandy loam	**Red Hill series** – recent geomagnetic and radiometric surveys of Northland suggest that soils of the Red Hill series, found along the two barrier arms of the Kaipara Harbour and, to a much lesser extent at Mangawhai and Bream Bay, were formed on a different parent material to most/all other sand soils in Northland. The Red Hill sands have developed on dunes of Taranaki iron sands (and from more local andesite volcanoes?) and have weathered to produce allophane clay. Basins or easier slopes are likely to have an accumulation of iron or even an iron pan in the subsoil. From a pasture management point of view, these are allophanic soils. Because, however, they overlay dune sands, their erosion characteristics are similar to other soil on deep sand deposits – they are prone to severe gully erosion in a similar fashion to the Tangitiki and Te Kopuru soils and also the Pohangina area in the Manawatu. A typical profile of **Red Hill sandy loam** (**RL** & RLH) will include: 80 to 170 mm of very dark brown to very dark greyish brown loamy sand to sandy loam, on 300 to 400mm of yellowish brown to strong brown sandy loam, with clay nodules and iron enrichment, on reddish yellow to yellowish red sandy loam to loamy sand with iron enriched surface layers on clay nodules. This all overlies brownish yellow to light yellowish brown very compact, massive or cemented layer of loamy sand to sand.
PZ	Organic soils		Ruakaka		Parore	Parore peaty sandy loam	**Parore peaty sandy loam** (**PZ**) has developed in narrow valleys draining the sand terrace and dune areas of the west coast of Northland south of the Hokianga Harbour. Alluvial sand from erosion of Tangitiki and Te Kopuru soils on the old dunes and terraces has been spread over the sand in layers of varying thickness, along with fine wind–blown sand. The downstream ends of many of these valley systems have been blocked off by either dune sand, where draining to the coast, river alluvium when draining to inland river valleys (such as the Kaihu) or estuarine sediment deposits where draining to the Kaipara Harbour. This damming has enhanced the development of swamps and peat. The proportions of sand and peat, the presence or absence of layers of sand in the peat and the grade of the valleys varies considerably. The upper reaches of the valleys are prone to gully erosion, which can be controlled by paired willow planting. Shrubby pussy willows appear to tolerate the salt spray and acid soil conditions experienced where this soil is located.

6.3. Catchment Hydrogeology

Only a conceptual understanding of the hydrogeology of Pōuto Peninsula is available as no specific investigations have taken place and bore-logs offer little information. The geology of the dune lakes likely relies on strata of cemented and uncemented dune sands. Paleo-channels and iron pans likely allow water flow collecting in cemented areas to provide water to the non-perched lakes occurring at lower elevations.

The Jacobs report (2017) models this lake as receiving most of its water by groundwater, followed by rainfall and a minor surface water influence.

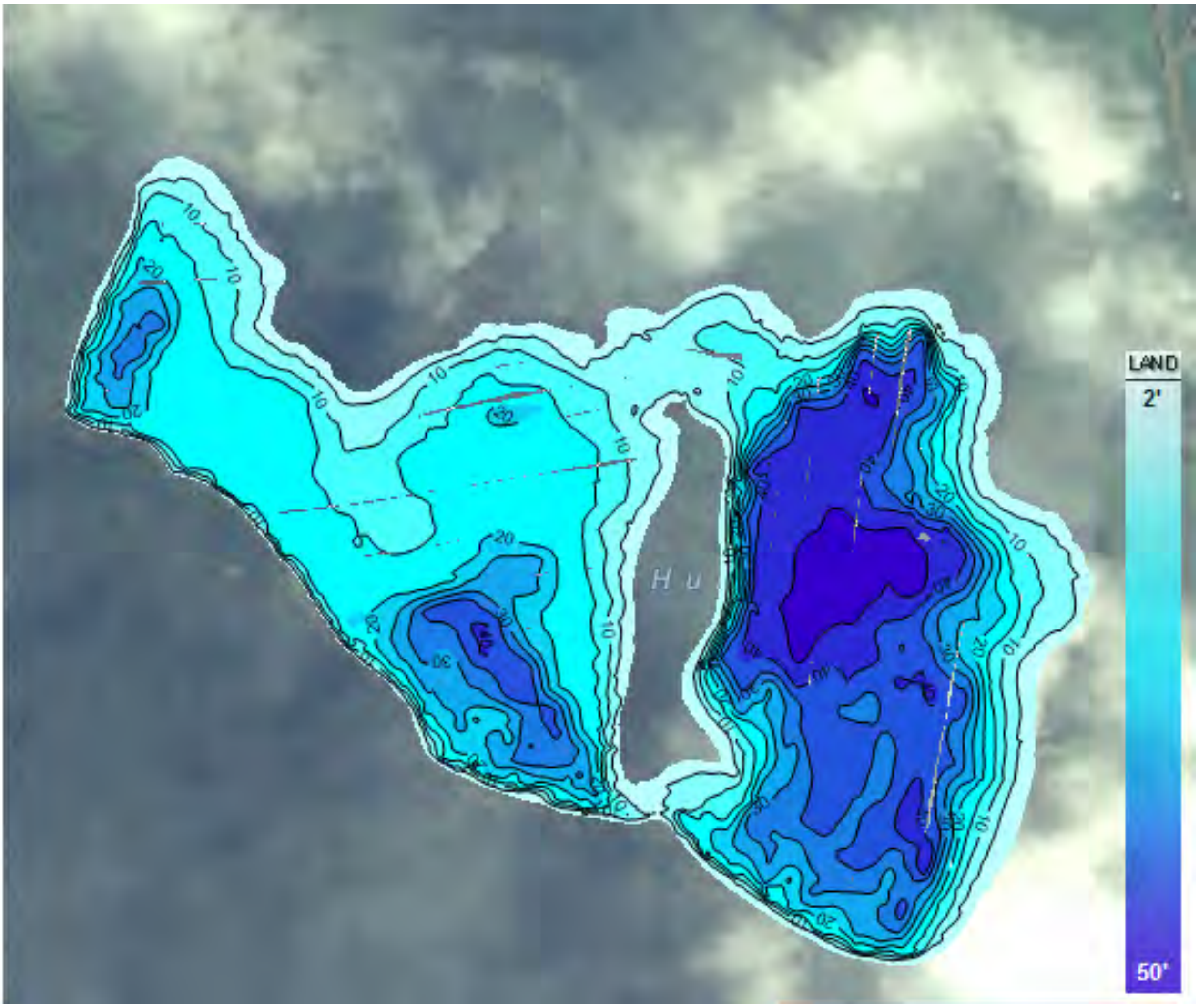
Lake	Lake class	% rainfall	% surface runoff	% rain + runoff	% groundwater
Humuhumu	dune contact	49	12	61	40
Kanono	dune contact	57	42	99	2
Kahuparere	dune contact	37	60	97	3
Rototuna	window	45	55	100	0
Roto-otuaruru	window	42	28	70	30
Rotokawau (Pōuto)	window	59	34	93	7

6.4. Catchment drainage and sedimentation rates

The LiDAR-defined catchment area, including the lake itself, is 471.5 hectares and produces a mean annual flow, based on hydrological models, of 4,414,063.1 m³/year. The lake has an estimated lake residence time of 1.581 years, meaning any water entering the lake will remain for just under 20 months. The average particle size of surface rock in the catchment is 1.98 on a scale of 5, a value of 1 being sand (FENZ database).

6.5. Bathymetry map

The following bathymetric depth map comes from a survey done by NIWA for the NRC. The lake is essentially divided in two by an island. The deepest point is the north-eastern 15.22 m basin with shallower basins in the centre (14 m) and far-west (10 m). Much of the western half of the lake is relatively shallow. Please note that the scale of this map is in feet, not meters. Mean depth is 6.32 m.

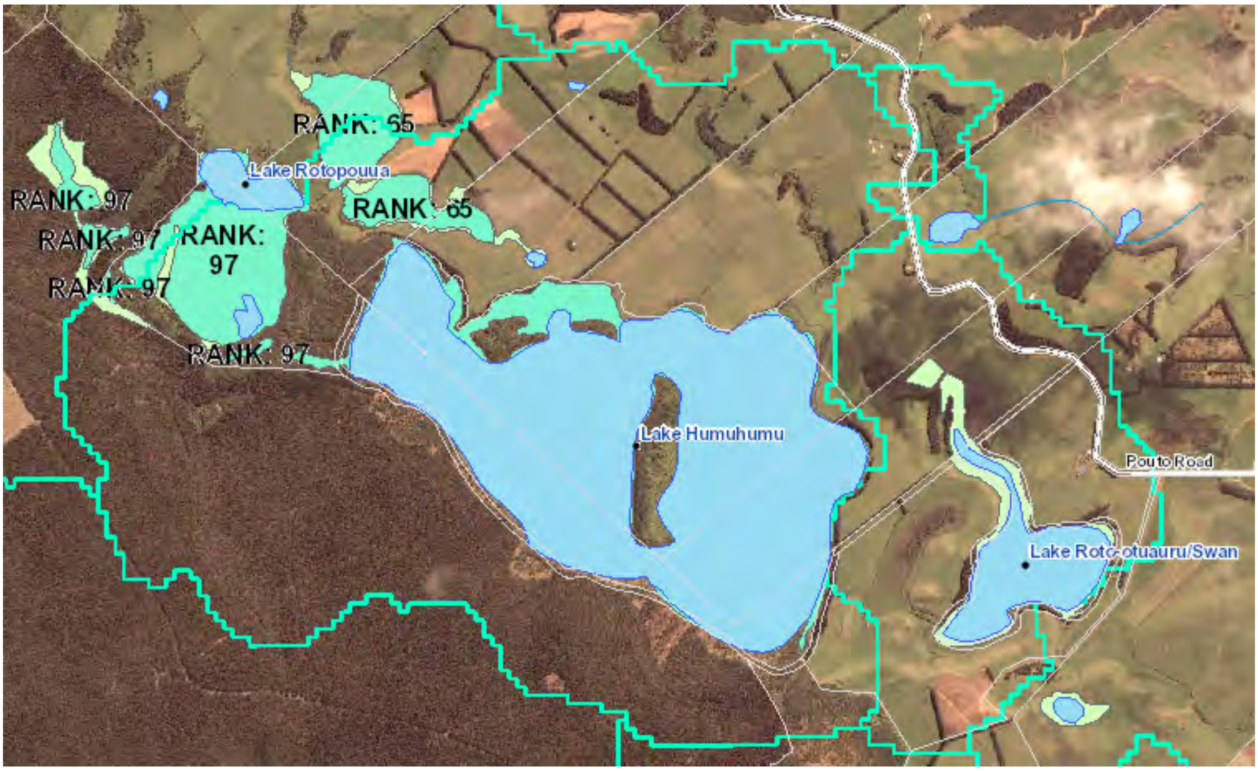


6.6. Natural inlets and outlets

There are no natural outlets from the lake. Inflows occur through Lake Rotopouua.

6.7. Wetland associations

Several of the region's highest value wetlands, ranked by NRC as "Top 150 wetlands", sit within the catchment to the north-west.

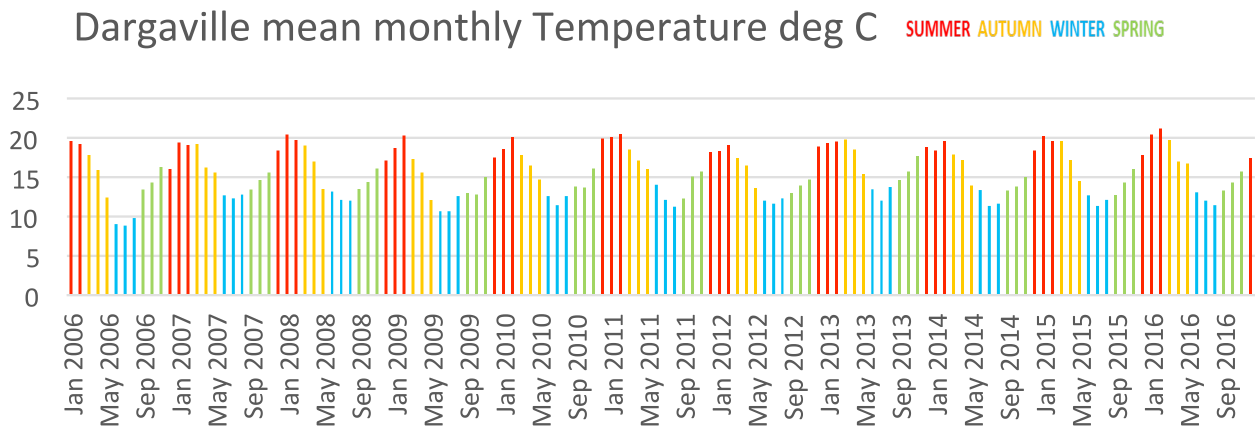


6.8. Connectivity

There is no connectivity to other water bodies.

6.9. Air temperature

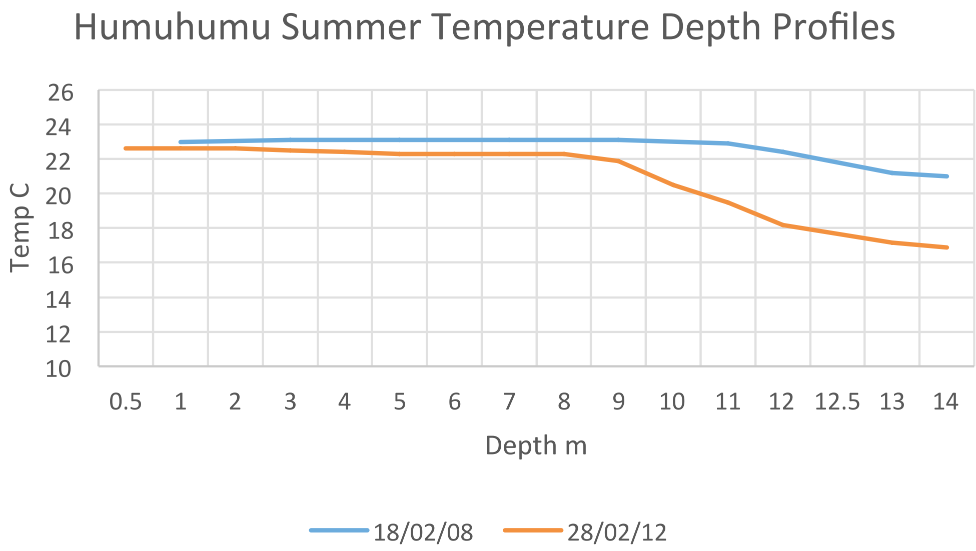
Dargaville air temperature data is used as a proxy for Pōuto.

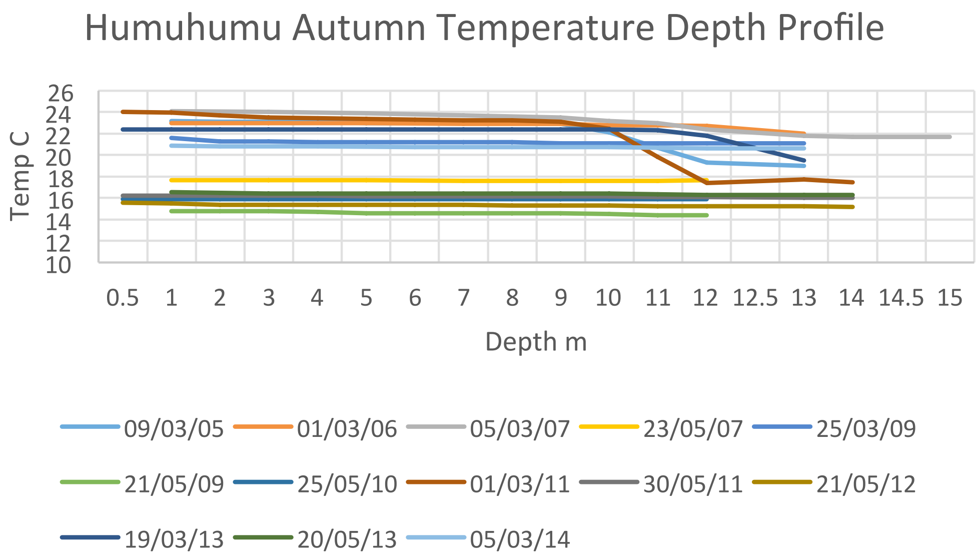


6.10 Thermal stratification

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 12.32 degrees C to 24.1 degrees C.

The lake stratifies in summer and into March to a minor degree, although only two summer profiles have been made.


Humuhumu Summer Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
10
0.5 1 2 3 4 5 6 7 8 9 10 11 12 12.5 13 14
Depth m
18/02/08
28/02/12


Humuhumu Autumn Temperature Depth Profile
Temp C
26
24
22
20
18
16
14
12
10
0.5 1 2 3 4 5 6 7 8 9 10 11 12 12.5 13 14 14.5 15
Depth m
09/03/05
01/03/06
05/03/07
23/05/07
25/03/09
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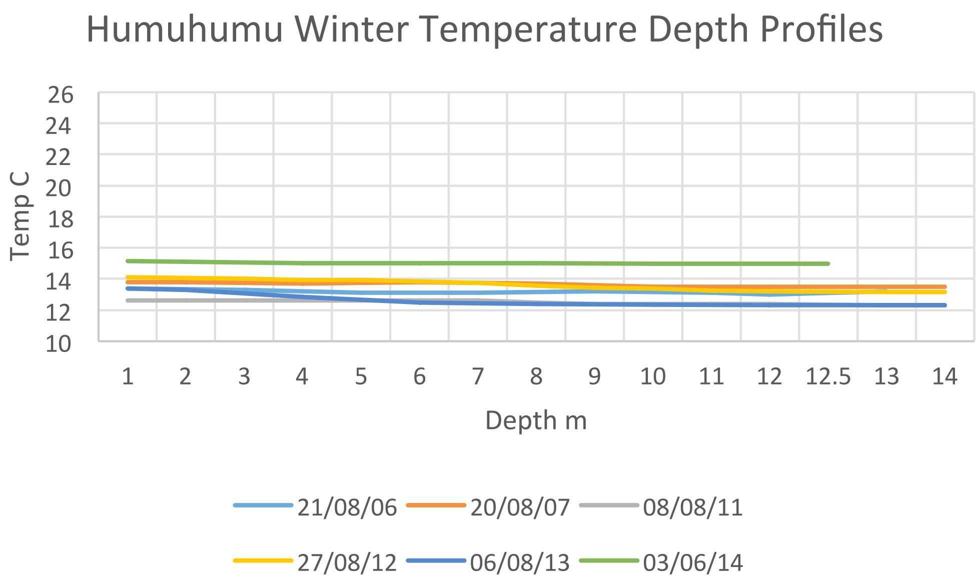
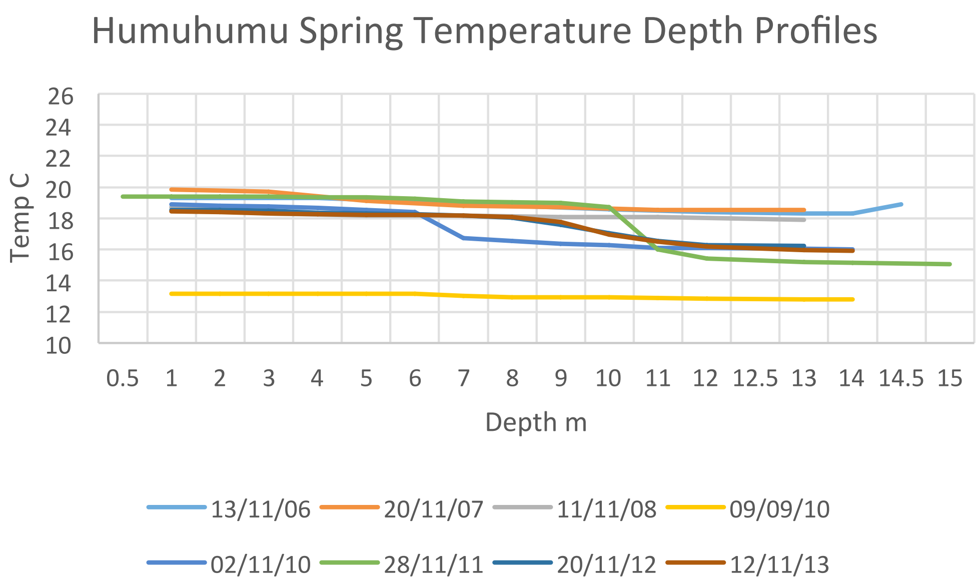
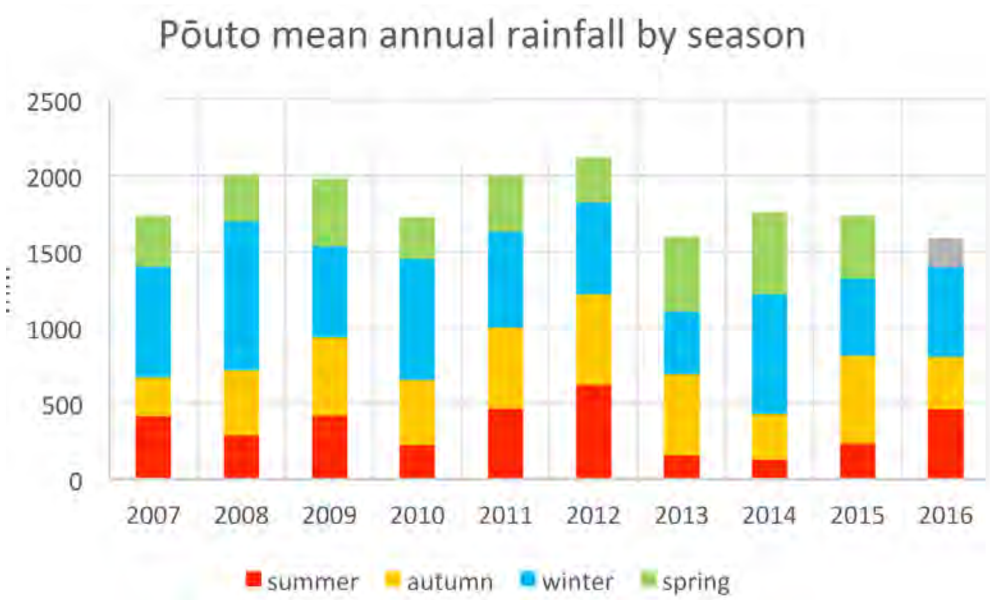
20/05/13
05/03/14


Humuhumu Winter Temperature Depth Profiles
Temp C
26
24
22
20
18
16
14
12
10
1 2 3 4 5 6 7 8 9 10 11 12 12.5 13 14
Depth m
21/08/06
20/08/07
08/08/11
27/08/12
06/08/13
03/06/14



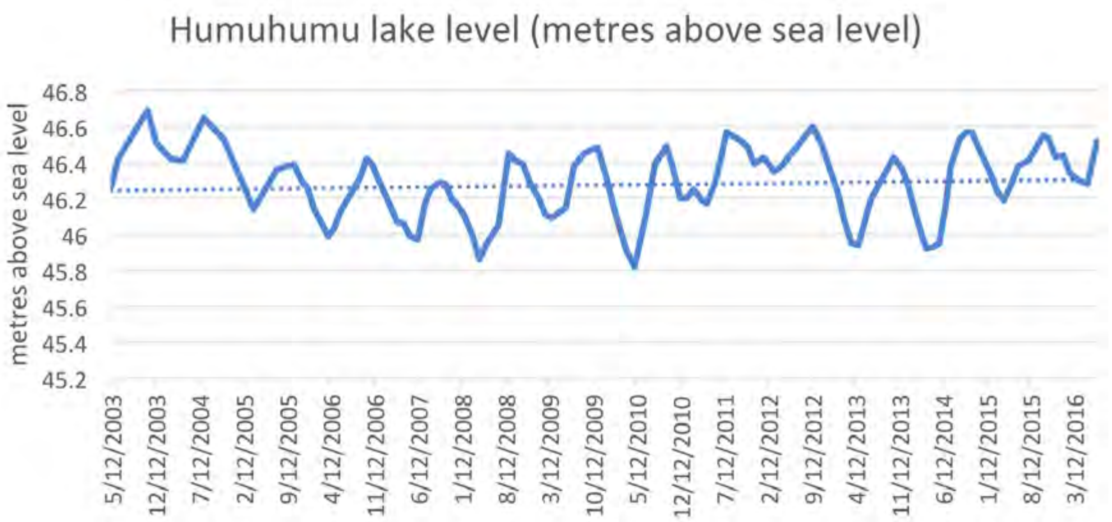
6.11 Rainfall and drought

The graph below shows cumulative rainfall by year displayed as seasons within each bar. Note that summer includes December from the year prior along with January and February of the year shown on the X axis. The grey bar on the graph indicates that a one month of the three months for that season, has no data available so this portion of the bar in underestimated.

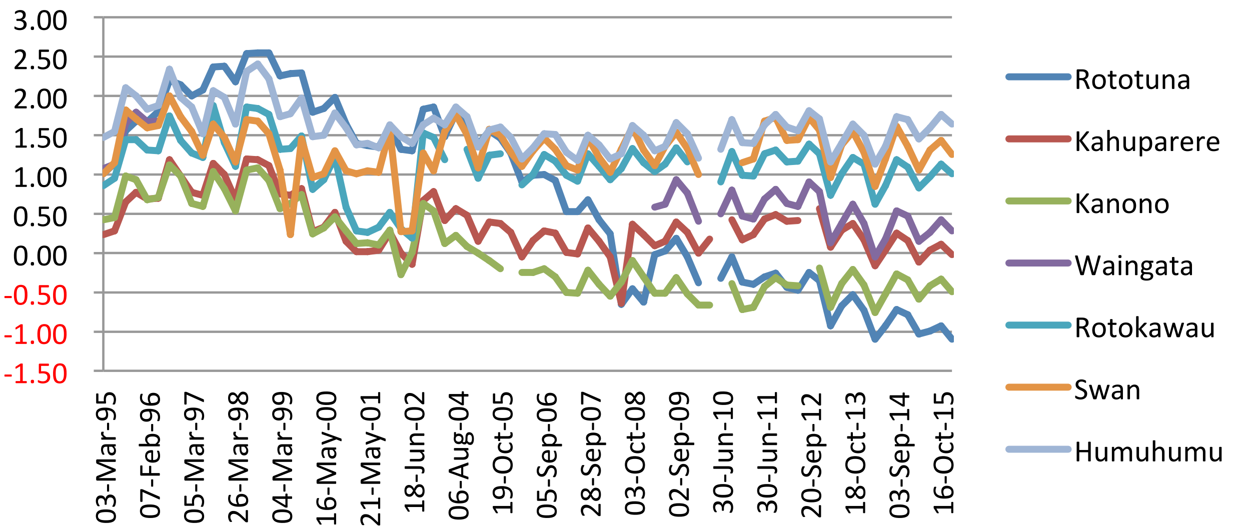


6.12 Lake level

Lake levels in Humuhumu are fairly stable with a slight rise through time. Variability is .87 m.

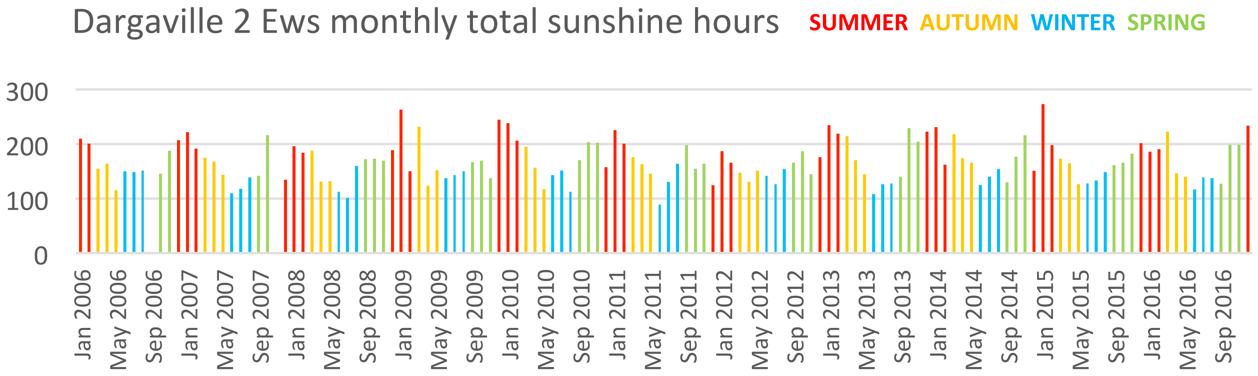


A longer time series comparing lake levels between Pōuto dune lakes shows that Humuhumu, like Rotokawau and Swan, is stable. The Y axis represents variation in mm from a fixed altitude mark on the staff gauge.



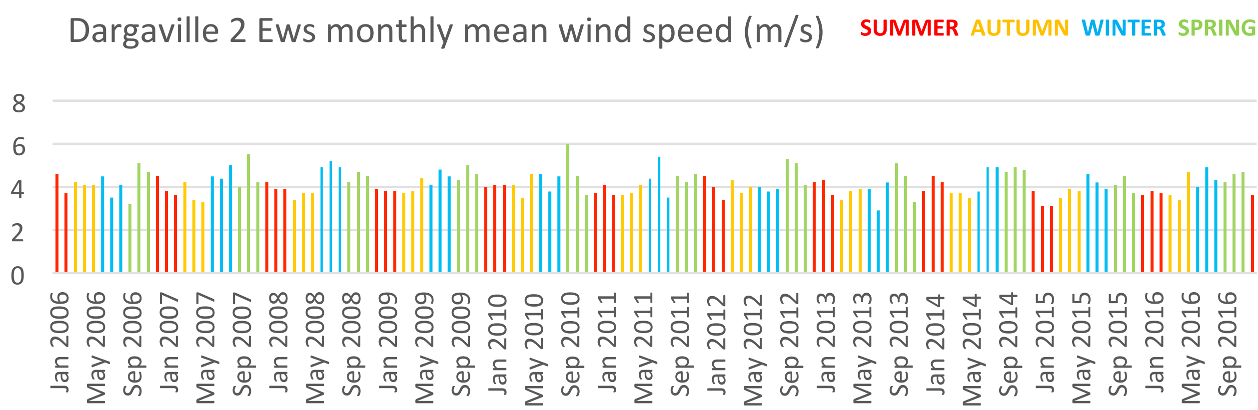
6.13 Sunshine

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



6.14 Wind speed

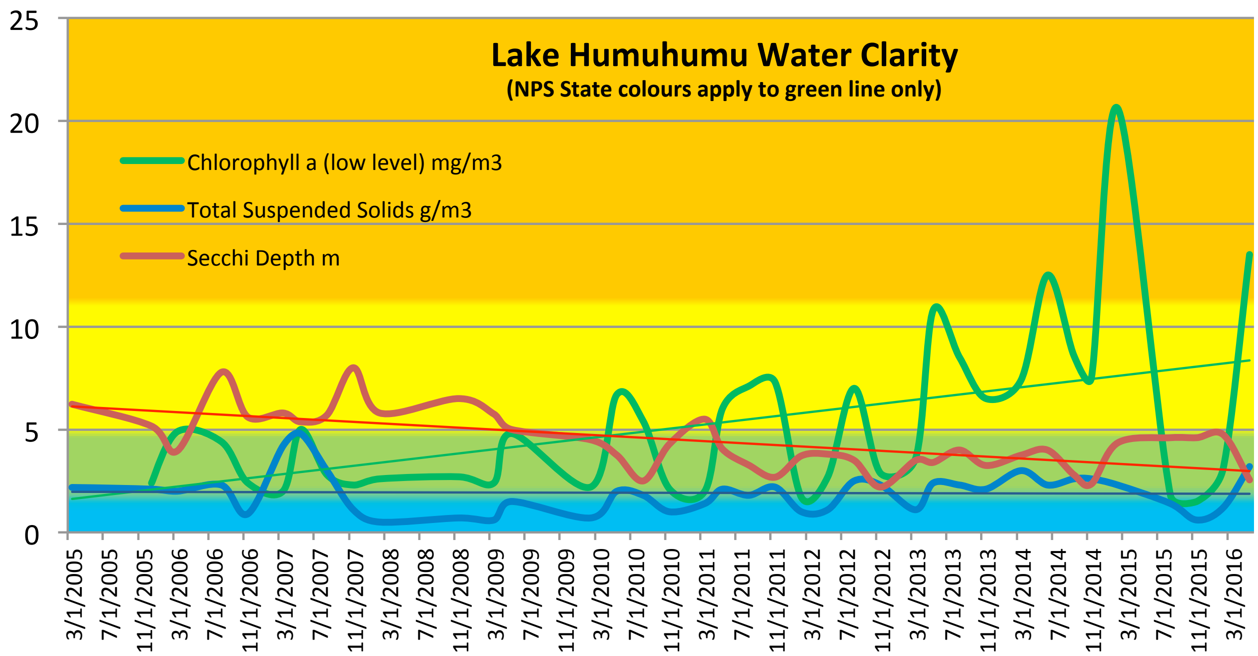
Measurements of wind at Dargaville wind are used as a proxy.



6.15 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 has experienced increasing algal blooms (green line) and an expected loss of water clarity (Secchi), the latest bloom being a peak in February 2015. The chlorophyll-a trend is likely due to the gradual rise in nitrogen levels.

The table below the graph shows the National Policy Statement for Freshwater Management states for phytoplankton (chlorophyll-a). A sharply increasing trend in chlorophyll-a with recent algal blooms into State D is a concern.



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

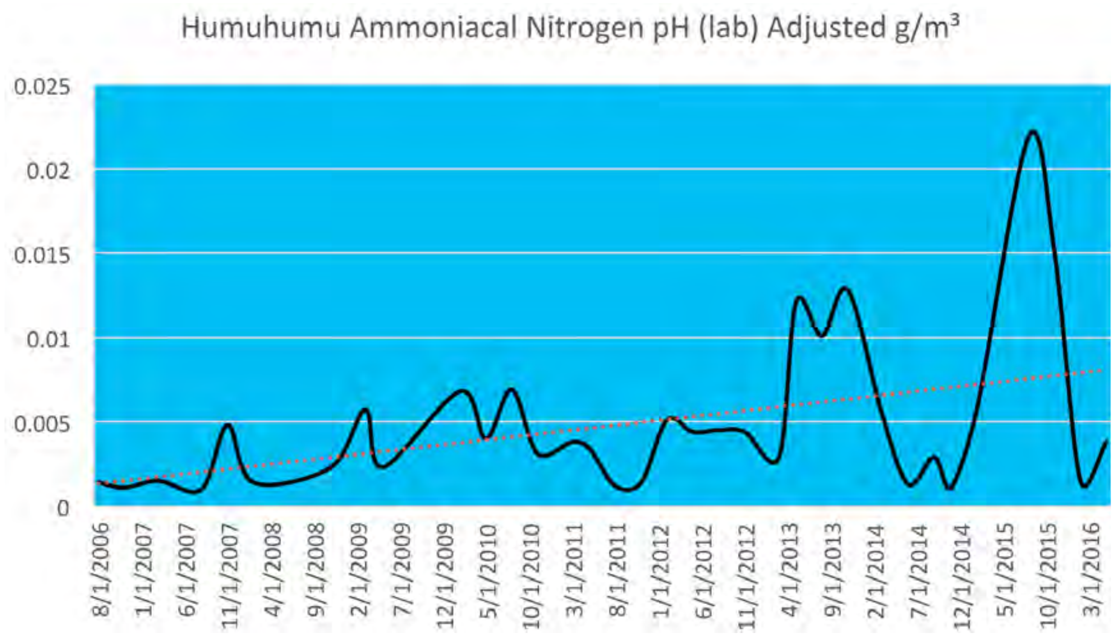
Max Gibbs (pers. comm.) from NIWA conducted limiting nutrient assays on several lakes including Rotokawau. Significant results are highlighted. For the years and seasons assayed, only phosphorus in autumn is a limiting nutrient. Limiting nutrient means that, between nitrogen and phosphorus, one will be harder to acquire for plant growth, thereby limiting the plant community's ability to grow.

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. Humuhumu has remained in State A or low ammonia toxicity levels.

	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
Humuhumu	3.5	1.9	0.64	0.85	1.06	1.29	1.23	-0.06	1.00	1.06	1.00

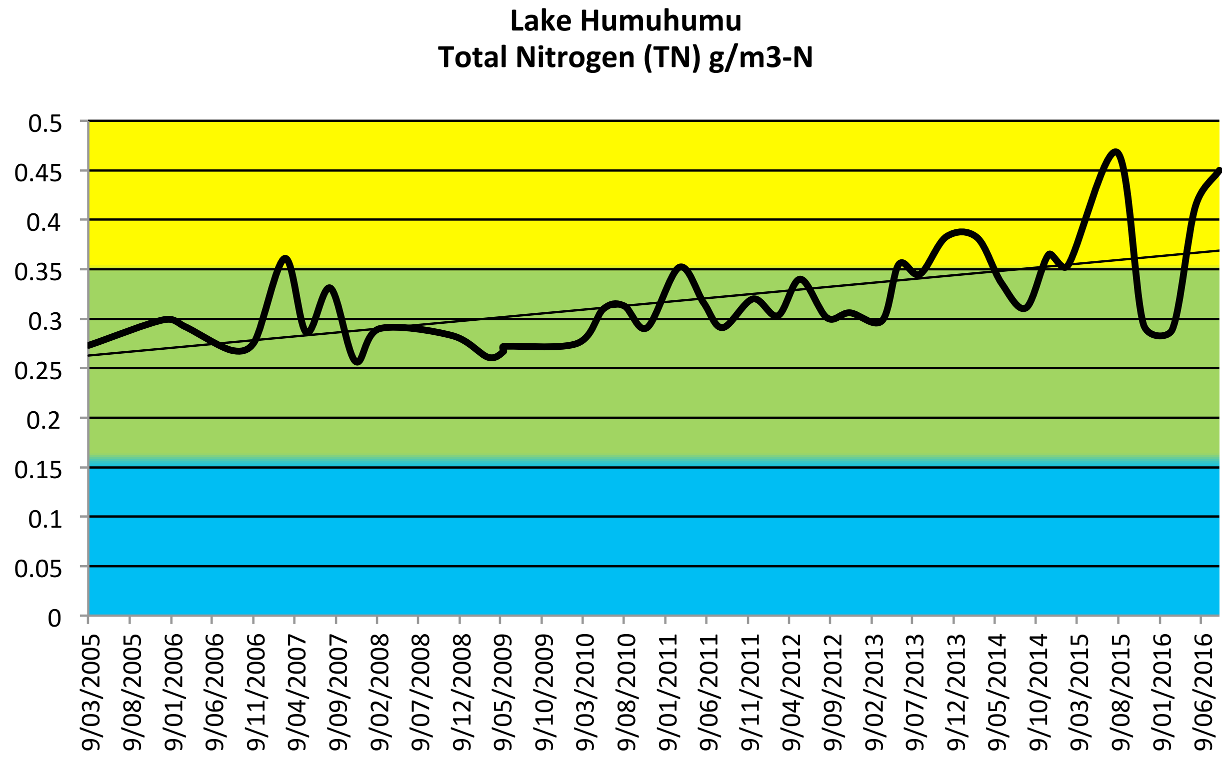


Attribute	Unit	Lake Type	State	Annual Median	Annual Maximum	Narrative State
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	B	>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

7.11.1.3 Nitrogen

The following graph shows a total nitrogen timeline for the lake from 2005-2016. The trendline shows a moderate and increasing total nitrogen level. It is likely that this is the driving cause behind increased algal blooms.

The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. Recent samples are in State C.

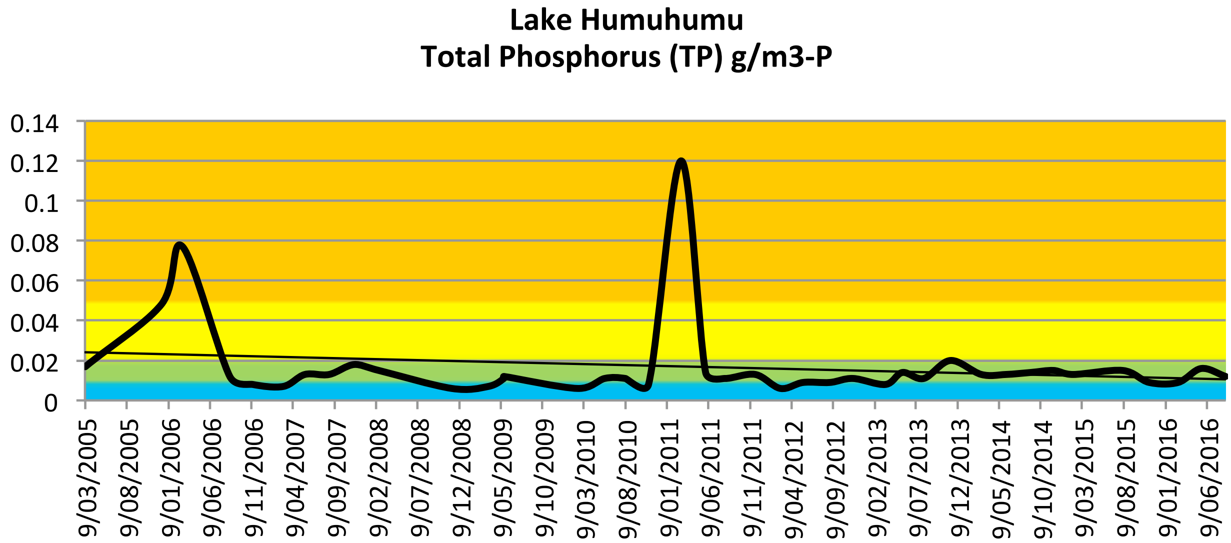


Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Nitrogen (Trophic state)	g/m3	Seasonally Stratified and Brackish	A	≤.16	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Nitrogen (Trophic state)	g/m3	Seasonally Stratified and Brackish	B	>.16 and ≤.35	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	Seasonally Stratified and Brackish	C	>.35 and ≤.75	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	Seasonally Stratified and Brackish	National Bottom Line	0.75	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	Seasonally Stratified and Brackish	D	>.75	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.

7.11.1.4 Phosphorus

Total phosphorus levels are low other than pulse events in March 2006 and March 2011 where the peaks are observed.

The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state. Pulses are in State D.



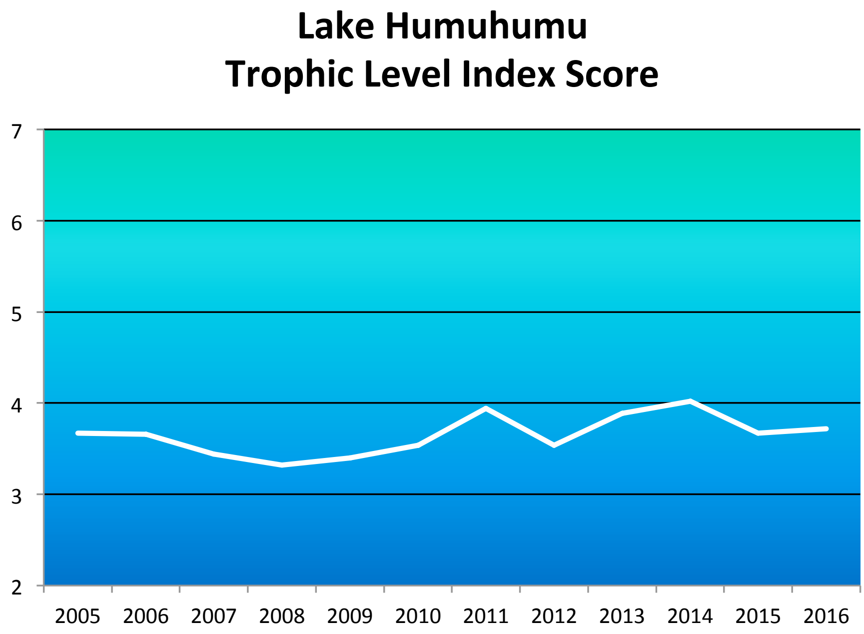
Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Phosphorus (Trophic state)	g/m3	All	A	≤ .01	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	B	> .01 and ≤ .20	Lake ecological communities are slightly 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.

7.11.1.5 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.

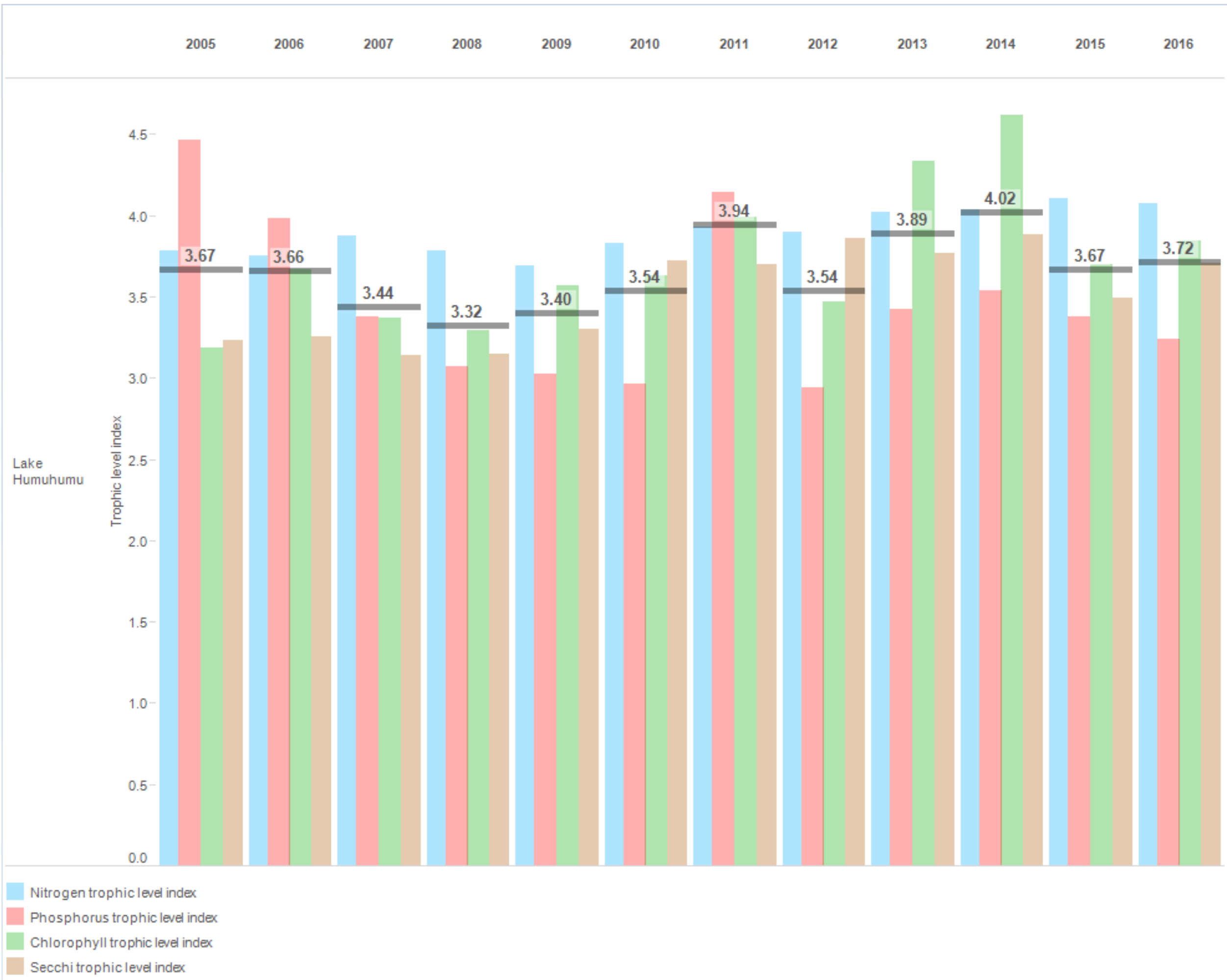
A low TLI score indicates a healthy lake with clear water and few algal blooms. A high TLI shows an overly nutrient-rich lake prone to algal blooms and poor light incidence, this shading affecting the health of submerged native plant communities.

The 2005-1016 TLI trend, shown below, indicates a stable TLI with the water quality of the lake being high mesotrophic (average water quality) with the lake crossing into poorer water quality (eutrophic) in 2014.



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 a new type of display of TLI scores. The graph allows interpretation of the four contributing variables which are combined into an overall TLI score. From this chart, nitrogen driving chlorophyll-a (algal bloom) is the key contributing variable to the overall TLI for this lake.

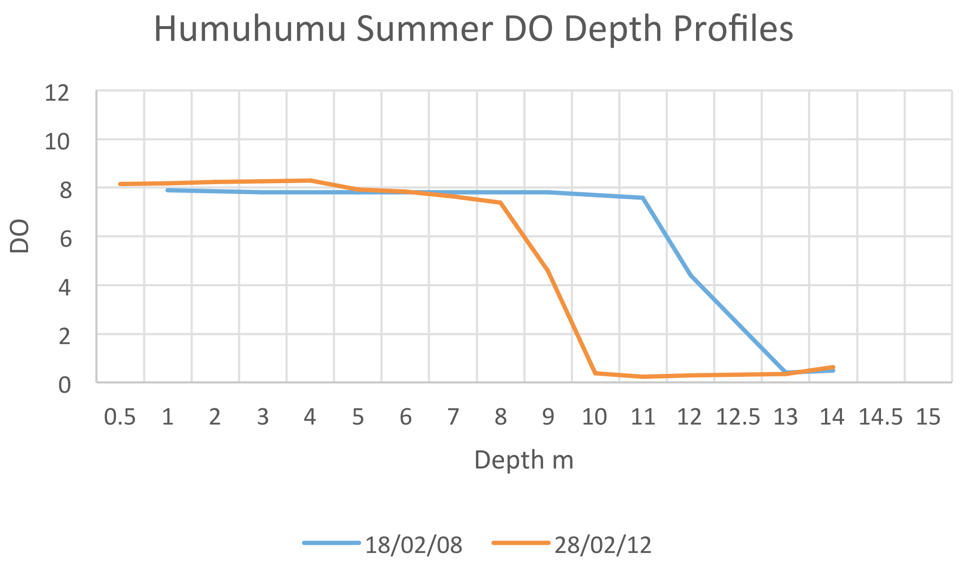


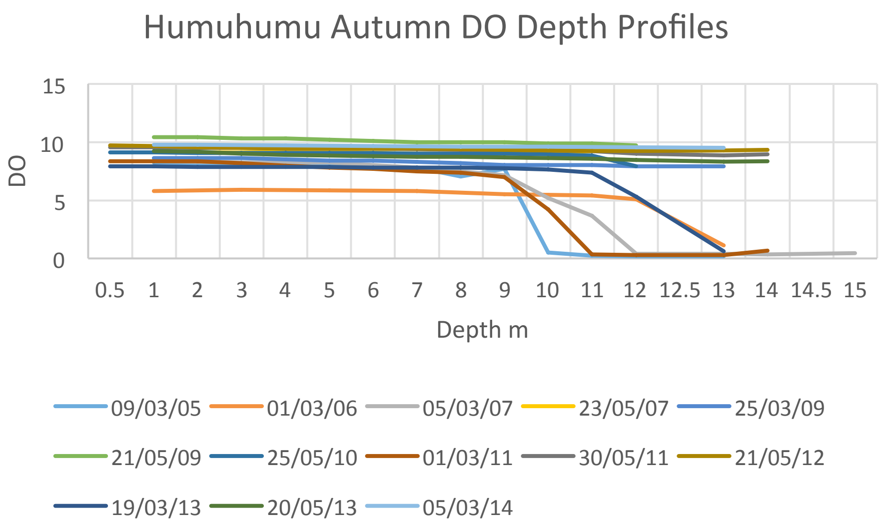
7.11.2 Dissolved Oxygen g/m³

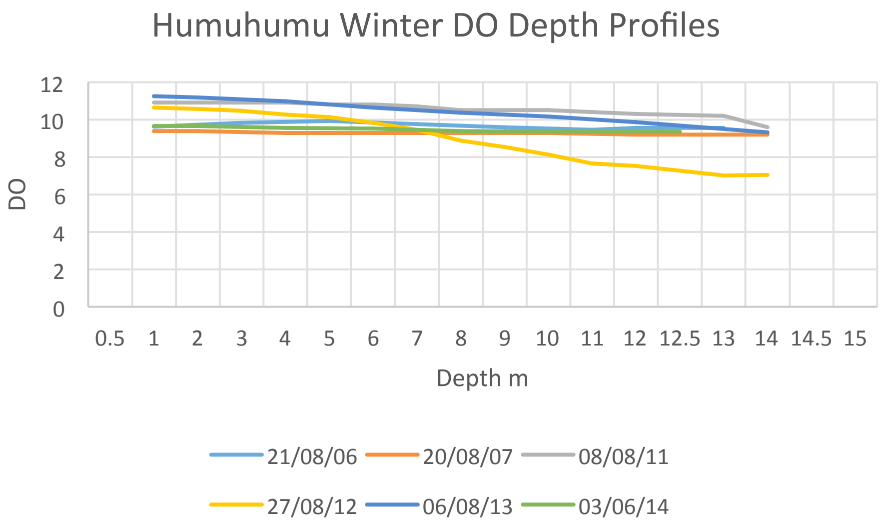
Although the lake only thermally stratifies marginally in summer due to its moderate shallowness, there is an oxygen depletion in water below 8-11 meters between spring and autumn, as seen in the graphs below.

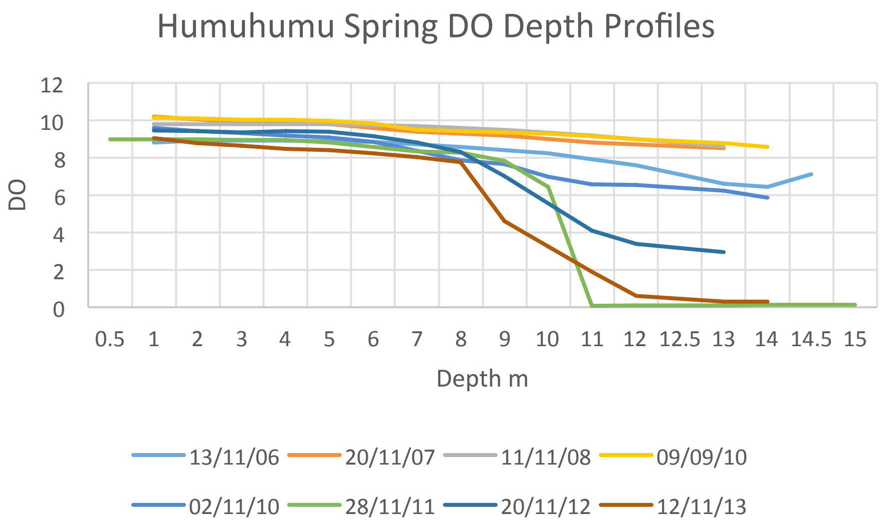
The table below shows the dissolved oxygen (at 15 degrees C) limits for New Zealand freshwater fish from **https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/dissolved-oxygen-criteria-for-fish.** These guidelines help interpret the depth profiles as to the depth of the water column usable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



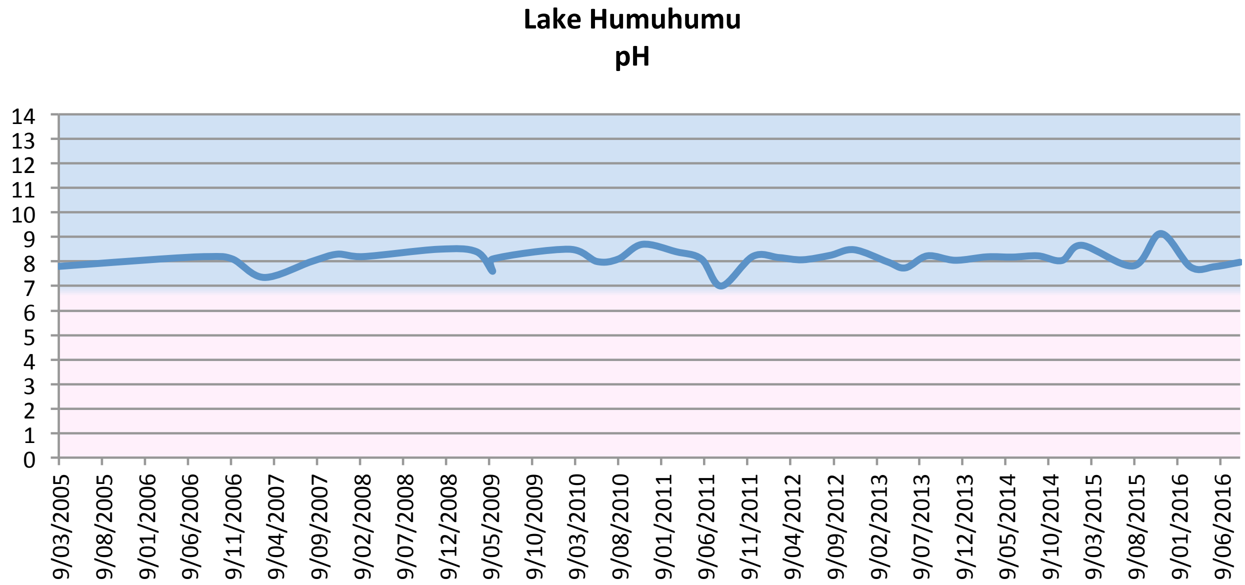

Humuhumu Autumn DO Depth Profiles
15
10
5
0
DO
0.5 1 2 3 4 5 6 7 8 9 10 11 12 12.5 13 14 14.5 15
Depth m
09/03/05 01/03/06 05/03/07 23/05/07 25/03/09
21/05/09 25/05/10 01/03/11 30/05/11 21/05/12
19/03/13 20/05/13 05/03/14


Humuhumu Winter DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5 1 2 3 4 5 6 7 8 9 10 11 12 12.5 13 14 14.5 15
Depth m
21/08/06 20/08/07 08/08/11
27/08/12 06/08/13 03/06/14


Humuhumu Spring DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5 1 2 3 4 5 6 7 8 9 10 11 12 12.5 13 14 14.5 15
Depth m
13/11/06 20/11/07 11/11/08 09/09/10
02/11/10 28/11/11 20/11/12 12/11/13

7.11.3 pH

On average, the pH of this lake consistently varies around 8. This alkaline condition is a positive environment for native fish species, perhaps explaining why dwarf inanga are thriving well there.



8. BIOLOGICAL CHARACTERISTICS

8.1. Lake Biodiversity and Biosecurity species

8.1.1. Plants

Humuhumu, by far, has the highest diversity of native aquatic plants among all Pōuto lakes at 30 native 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 exotics and natives. Rare natives are presented last. Humuhumu contains three of these; *Thelypteris confluens, Trithuria inconspicua* and *Myriophylum votschii.*

In addition to the natives, there are six exotic species, two being invasive; alligator weed and royal fern. Alligator weed is well established near the boat launch area and royal fern, a serious wetland weed, has been recorded in the past and should not be allowed to establish.

Lakes Roto-otuauru/Swan and Waingata (Pōuto) have introduced grass carp (green column colouration on the table below) as a management tool to rid these lakes of *Egeria densa* (from Swan) and *Elodea* (from Waingata). These operations were successful, with grass carp due for removal. Other species of plants in these lakes have been largely de-vegetated, but will likely return once the carp are removed.

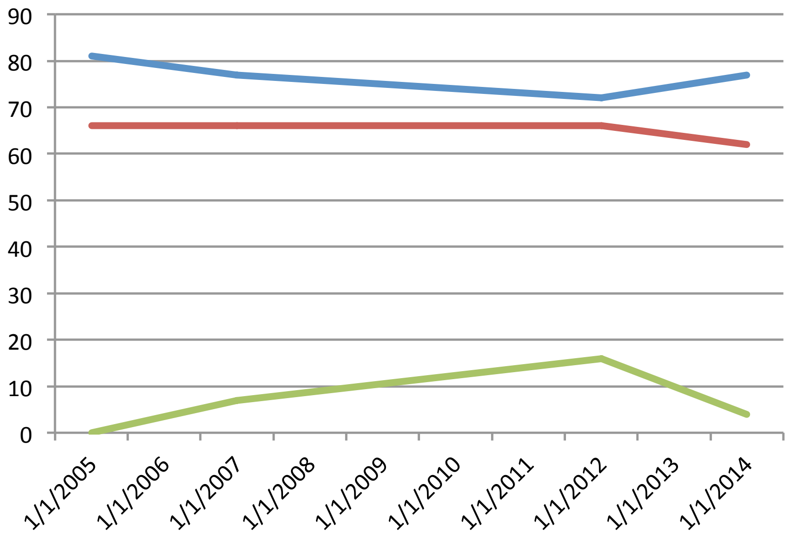
Phoebe's Lake has been successfully treated with endothall for the eradication of *Lagarosiphon major* (purple absence on the chart).

The table presents plant communities in Pōuto 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	Grevilles Lagoon	Kapoai	Parawanui	Wainui	Rototuna	Wairere	Phoebe's	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Waingata (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	Frequency
1	Erect emergent	Invasive exotic	African feather grass	Cenchrus macrourus		x																1
1	Erect emergent	Invasive exotic	royal fern	Osmunda regalis									x		x					x		3
1	Erect emergent	Invasive exotic	Manchurian wild rice	Zizania latifolia							x											1
1	Erect emergent	Non-invasive exotic	bulbous rush	Juncus bulbosus					x						x							2
2	Sprawling emergent	Invasive exotic	alligator weed	Alternanthera philoxeroides	x								x	x		x						4
2	Sprawling emergent	Invasive exotic	glyceria, swamp grass, water meadow grass	Glyceria maxima					x													1
2	Sprawling emergent	Invasive exotic	primrose willow, water primrose	Ludwigia peploides				x														1
2	Sprawling emergent	Invasive exotic	mercer grass, paspalum	Paspalum distichum						x												1
2	Sprawling emergent	Non-invasive exotic	water purslane	Ludwigia palustris									x		x			x				3
4	Floating leaved	Non-invasive exotic	swamp lily	Ottelia ovalifolia				x														1
5	Free floating	Non-invasive exotic	ferny azolla	Azolla pinnata									x									1
5	Free floating	Non-invasive exotic	bladderwort, yellow bladderwort	Utricularia gibba						x	x	x	x	x	x			x				7
7	Submerged tall pondweed	Invasive exotic	lakeweed, egeria	Egeria densa										x	x							2
7	Submerged tall pondweed	Invasive exotic	canadian pondweed	Elodea canadensis											x	x						2
7	Submerged tall pondweed	Invasive exotic	lagarosiphon, lakeweed, oxygen weed	Lagarosiphon major																		0
7	Submerged tall pondweed	Non-invasive exotic	curly leaved pondweed, curled pondweed	Potamogeton crispus			x		x				x				x					4
1	Erect emergent	Native	oioi, jointed wire rush	Apodasmia similis									x		x				x			3
1	Erect emergent	Native	marsh clubrush	Bolboschoenus fluviatilis									x				x	x				3
1	Erect emergent	Native	maori sedge	Carax maorica						x									x			2
1	Erect emergent	Native	pukio	Carex secta						x		x						x	x	x		5
1	Erect emergent	Native	swamp sedge, pukio, toitoi, toetoe	Carex virgata						x												1
1	Erect emergent	Native	giant umbrella sedge, Upokotangata	Cyperus ustulatus						x			x				x	x	x			5
1	Erect emergent	Native	sharp spike sedge	Eleocharis acuta				x	x	x			x	x	x		x	x	x	x	x	11
1	Erect emergent	Native	bamboo spike sedge, tall spike sedge	Eleocharis sphacelata		x		x	x	x	x	x	x	x	x			x		x	x	12
1	Erect emergent	Native	leafless rush	Juncus pallidus						x			x		x			x	x			5
1	Erect emergent	Native	manuka, tea tree, kahikatoa	Leptospermum scoparium																x		1
1	Erect emergent	Native	sedge	Machaerina arthrophylla (syn. Baumea arthrophylla)						x			x						x	x		4
1	Erect emergent	Native	jointed baumea, jointed twig rush	Machaerina articulata (syn. Baumea articulata)				x	x	x	x	x	x	x	x		x	x	x	x	x	13
1	Erect emergent	Native	sedge, tussock swamp twig rush	Machaerina juncea (syn. Baumea juncea)						x		x	x		x				x	x		6
1	Erect emergent	Native	baumea	Machaerina rubiginosa (syn. Baumea rubiginosa)																x		1
1	Erect emergent	Native	flax, harakeke, korari	Phormium tenax																x		1
1	Erect emergent	Native	softstem bulrush, grey club-rush, great bulrush	Schoenoplectus tabernaemontani	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x	15
1	Erect emergent	Native	raupo	Typha orientalis	x			x	x	x	x	x	x	x	x		x	x	x	x	x	14
1	Erect emergent	Rare native	Fimbristylis	Fimbristylis velata		x	x															2
1	Erect emergent	Rare native	Marsh fern, swamp fern	Thelypteris confluens								x	x						x	x		4
2	Sprawling emergent	Native	nahui	Alternanthera nahui		x																1
2	Sprawling emergent	Native	centella	Centella uniflora											x							1
2	Sprawling emergent	Native	swamp millet	Isachne globosa						x			x						x		x	4
2	Sprawling emergent	Native	swamp willow weed	Persicaria decipiens						x								x			x	3
2	Sprawling emergent	Rare native	New Zealand sneezewort	Centipeda aotearoana		x																1
3	Low growing turf	Native	starwort	Callitriche petriei		x																1
3	Low growing turf	Native	waterwort	Elatine gratioloides												x						1
3	Low growing turf	Native	none known	Glossostigma elatinoides					x				x	x	x	x	x			x		7
3	Low growing turf	Native	gratiola	Gratiola sexdentata										x								1
3	Low growing turf	Native	none known (sedge)	Isolepis prolifera						x			x		x				x			4
3	Low growing turf	Native	Zelandiae chain sword	Lilaeopsis novae-zelandiae					x				x		x	x	x			x		6
3	Low growing turf	Native	mudwort	Limosella lineata		x							x		x		x					4
3	Low growing turf	Native	arrow grass	Triglochin striata									x	x	x							3
3	Low growing turf	Rare native	hydatella	Trithuria inconspicua (syn Hydatella inconspicua)									x	x	x							3
4	Floating leaved	Native	red pondweed	Potamogeton cheesemanii	x			x	x	x			x		x		x		x	x		9
6	Submerged milfoil	Native	common water milfoil	Myriophyllum propinquum		x							x		x			x				4
6	Submerged milfoil	Native	water milfoil	Myriophyllum triphyllum				x	x	x			x				x	x		x	x	8
6	Submerged milfoil	Rare native	small water milfoil	Myriophyllum votschii									x		x							2
7	Submerged tall pondweed	Native	blunt pondweed	Potamogeton ochreatus	x	x		x	x	x	x	x	x		x		X	x		x		12
7	Submerged tall pondweed	Native	horses mane weed, lakeweed	Ruppia polycarpa									x				x					2
7	Submerged tall pondweed	Native	fennel-leaved pondweed, sago pondweed	Stuckenia pectinata					x								x					2
8	Submerged charophyte	Native	stonewort	Chara australis	x			x	x	x		x	x		x	x	X	x	x	X	x	13
8	Submerged charophyte	Native	stonewort	Chara fibrosa									x		x		x					3
8	Submerged charophyte	Native	stonewort	Chara globularis				x		x			x				X		x	x		6
8	Submerged charophyte	Native	stonewort	Nitella hyalina					x													1
8	Submerged charophyte	Native	stonewort	Nitella leonhardii											x							1
8	Submerged charophyte	Native	stonewort	Nitella pseudoflabellata					x				x		x		x					4
8	Submerged charophyte	Native	stonewort	Nitella sp. aff. cristata	x			x	x		x	x	x		x		X					8
				Total Plant Diversity	**7**	**10**	**3**	**13**	**18**	**22**	**7**	**11**	**36**	**12**	**30**	**6**	**20**	**16**	**17**	**20**	**9**	
				Exotic Plant diversity	**1**	**1**	**1**	**2**	**3**	**2**	**2**	**1**	**6**	**3**	**6**	**2**	**1**	**2**	**0**	**1**	**0**	
				Native Plant Diversity	**6**	**9**	**2**	**11**	**15**	**20**	**5**	**10**	**30**	**9**	**24**	**4**	**19**	**14**	**17**	**19**	**9**	

8.11.1.1.1 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 overleaf, we see that this lake is in good ecological health, due to its relative high native plant diversity compared to the exotic plant species present.



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 Pōuto Peninsula. Pest fish are shown in green and conservation species in pink. Lake Humuhumu appears in yellow. The lake has a low level of fish diversity and is free of pest fish.

Gambusia are found at Lake Rototuna to the north and pose a threat to all Pōuto lakes south of Rototuna.

Common bully and dwarf inanga are commonly found in the Pōuto lakes, including Lake Humuhumu. Lake Humuhumu is notable for the absence of short-finned eel, otherwise common in the sub-region.

common name	species	Conservation status	Degree of loss	Kapoai	Parawanui	Wainui	Rototuna	Wairere	Phoebe's	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Waingata (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	frequency
golden bell frog	Litoria aurea								x											1
grass carp	Ctenopharyngodon idella											x		x						2
goldfish	Carassius auratus			x																1
koi carp	Cyprinus carpio				x															1
Gambusia	Gambusia affinis						x													1
orfe	Leuciscus idus				x															1
rudd	Scardinius erythrophthalmus			x	x		x													3
tench	Tinca tinca			x																1
shortfinned eel	Anguilla australis			x	x			x	x			x	x				x	x		8
longfinned eel	Anguilla dieffenbachii	at risk	declining					x									x			2
giant kokopu	Galaxias argenteus	at risk	declining														x			1
dwarf inanga	Galaxias gracilis	at risk	naturally uncommon				rare			x	x	rare	rare	extinct	x	x				8
inanga	Galaxias maculatus	at risk	declining															x		1
common bully	Gobiomorphus cotidianus			x	x		x			x	x	x	x	x	x	x	x parasites	x	x	13
grey mullet	Mugil cephalus																	x		1
smelt	Retropinna retropinna																	x		1
	diversity pest fish			3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
	diversity native			2	2	0	2	2	1	2	2	3	3	2	2	2	4	5	1	

8.1.3 Waterbirds

The table below displays the waterbirds of the Pōuto Peninsula. Game birds are shown in green and non-game bird native species in pink. Lake Humuhumu appears in yellow. The lake has a high level of bird diversity and has no recorded game species. Dabchicks, Australasian bittern and New Zealand scaup occur widely in this sub-region. Spotless crake and fernbird have also been recorded at the lake in other records.

common name	species	Conservation status (DOC, *Conservation status of NZ birds*, 2016)	Criteria / Degree of loss	Grevilles Lagoon	Kapoai	Parawanui	Wainui	Rototuna	Wairere	Phoebe's	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Waingata (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	frequency
Australasian (NZ) shoveler	Anas rhynchotis (resident native (not introduced) on game bird list)	Not threatened (resident native)																	x		1
grey duck	Anas superciliosa (resident native (not introduced) on game bird list)	threatened	nationally critical		x														x		2
grey duck - mallard hybrid	Anas superciliosa x platyrhynchus (resident native (not introduced) on game bird list)	Not threatened																x			1
black swan	Cygnus atratus (resident native (not introduced) on game bird list)	Not threatened			x		x	x					x			x					5
pukeko	Porphyrio m. melanotus (resident native (not introduced) on game bird list)	not threatened															x				1
paradise shelduck	Tardorna variegata (resident native (not introduced) on game bird list)	Not threatened					x	x		x				x							4
Cape Barren goose	Cereopsis novaehollandiae (Introduced & naturalised)	Introduced & naturalised												x							1
brown teal	Anas chlorotis	at risk	recovering															x		x	2
New Zealand scaup	Aythya novazeelandiae	not threatened			x		x	x	x			x		x	x	x	x	x	x	x	12
Australasian bittern	Botaurus poiciloptilus	threatened	nationally critical	x			x	x	x		x	x	x	x		x	x	x	x	x	13
North Island fernbird	Bowdleria punctata vealeae	at risk	declining									x	x					x	x	x	5
banded rail	Gallirallus philippensis assimilis	at risk	declining															x	x	x	3
Caspian tern	Hydroprogne caspia	threatened	nationally vulnerable									x				x	x		x		4
black shag	Phalacrocorax carbo novaehollandiae	at risk	naturally uncommon		x																1
shag spp.	Phalacrocorax spp.																		x		1
New Zealand dabchick	Poliocephalus rufopectus	at risk	recovering	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	17
marsh crake	Porzana pusilla affinis	at risk	declining															x			1
spotless crake	Porzana t. tabuensis	at risk	declining						x		x	x				x	x		x	x	7
Eastern little tern	Sternula albifrons sinensis		migrant													x	x				2
diversity resident native (not introduced) on game bird list				0	2	0	2	2	0	1	0	0	1	1	0	1	1	1	2	0	
diversity introduced & naturalised				0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
diversity native				2	3	1	3	3	4	1	3	6	3	3	2	6	6	7	8	7	

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 Humuhumu, the presence of koura/kewai, which require a standard of clean water to survive is a good sign but the midge and mite species seen in other lakes in Pōuto seem to be lacking, possibly due to poorer water quality in Humuhumu.

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)	Parawanui	Wainui	Rototuna	Rotopouua	Humuhumu	Roto-otuauru/Swan	Rotokawau (P)	Kanono	Kahuparere	Karaka	Mokeno	Whakaneke	frequency
Hydrozoa, freshwater jellyfish medusae	*Craspedacusta sowerbyi*						x						x		2
Mollusc, snail	*Physa (Physella) acuta*	0.1			x										1
Mollusc, snail	*Physa (Physella) sp*	0.1		x							x			x	3
Acarna, mite	Hydrachnidae	5.2							x		x		x		3
Acarna, mite	Oribatida	5.2		x					x	x	x		x		5
Acarna, mite	Oxidae	5.2							x		x				2
Amphipoda, hopper	Paracalliope sp			x											1
Crustacea, Cladocera	sp	0.7		x					x		x		x		4
Crustacea, Copepoda	sp	2.4		x					x		x		x		4
Crustacea, Ostracoda, koura	*Paranephrops planifrons*	8.4					x			x	x				3
Crusteacea, Ostracoda	*Herpetocypris*	*1.9*		x					x	x	x				4
Diptera, house fly	Muscidae	1.6							x						1
Diptera, midge, biting	Ceratopogonidae	6.2							x	x	x		x		4
Diptera, midge, non-biting, Chironomid	Tanytarsini	4.5		x					x		x		x		4
Diptera, midge, non-biting, Chironomid	*Chironomas sp*	3.4		x					x	x	x		x	x	6
Diptera, midge, non-biting, Chironomid	Orthocladiinae	3.2		x					x	x	x		x		5
Diptera, midge, non-biting, Chironomid	Tanypodinae	6.5									x		x		2
Ephemeroptera, mayfly	*Deleatidium*	5.6							x						1
Hemiptera, bug	*Microvelia macgregori*	4.6											x		1
Hemiptera, bug, backswimmer	*Sigara arguta*	2.4		x							x			x	3
Hemiptera, bug, waterboatman	*Diaprepocoris sp*	4.7									x				1
Hirudinea, leech	Hirudinea			x							x		x		3
Hirudinea, leech	*Richardsonianus mauianus*			x					x						2
Hydrozoa, hydra	*Hydra* sp					x							x		2
Lepidoptera, aquatic moth	*Hygraula nitens*	1.3									x		x		2
Mollusca, bivalve	Sphaeridae			x					x						2
Mollusca, freshwater mussel	*Echyridella menziesi*					shells	x	x	x				x		5
Mollusca, freshwater mussel	*Hyridella menziesi*	6.7	x							x	last 2001				3
Mollusca, snail	*Gyraulus corinna*	1.7		x											1
Mollusca, snail	Lymnaea sp			x											1
Mollusca, snail, native	*Glyptophysa variabilis*	0.3					x			x	x				3
Mollusca, snail, native	*Potamopyrgus antipodarum*	2.1				x			x			x		x	4
Nematoda, roundworm	sp	1.8		x					x	x			x		4
Nemertea, proboscis worm	sp	1.8		x							x				2
Odonata, damselfly	*Xanthocnemis sp*	1.2		x							x				2
Odonata, dragonfly	*Aesha brevistyla*	1.4		x					x						2
Odonata, dragonfly	*Hemianax papuensis*	1.1		x							x				2
Odonata, dragonfly	*Hemicordulia australiae*	0.4		x					x	x	x				4
Oligocheate worm	Oligochaeta sp	3.8							x	x	x		x		4
Ostracod crusteacean	*Cypretta*										x				1
Ostracod crusteacean	Cypridopsis								x	x					2
Ostracod crusteacean	*Ilyodromus*								x	x	x		x		4
Platyhelminthes, flatworm	sp	0.9		x					x	x	x				4
Porifera, freshwater sponge	sp					x									1
Trichoptera, caddisfly	*Paroxyethira hendersoni*	3.7		x					x	x	x				4
	diversity invasive		0	1	1	0	1	0	0	0	1	0	1	1	6
	diversity native		1	22	0	4	3	1	24	15	27	1	17	3	

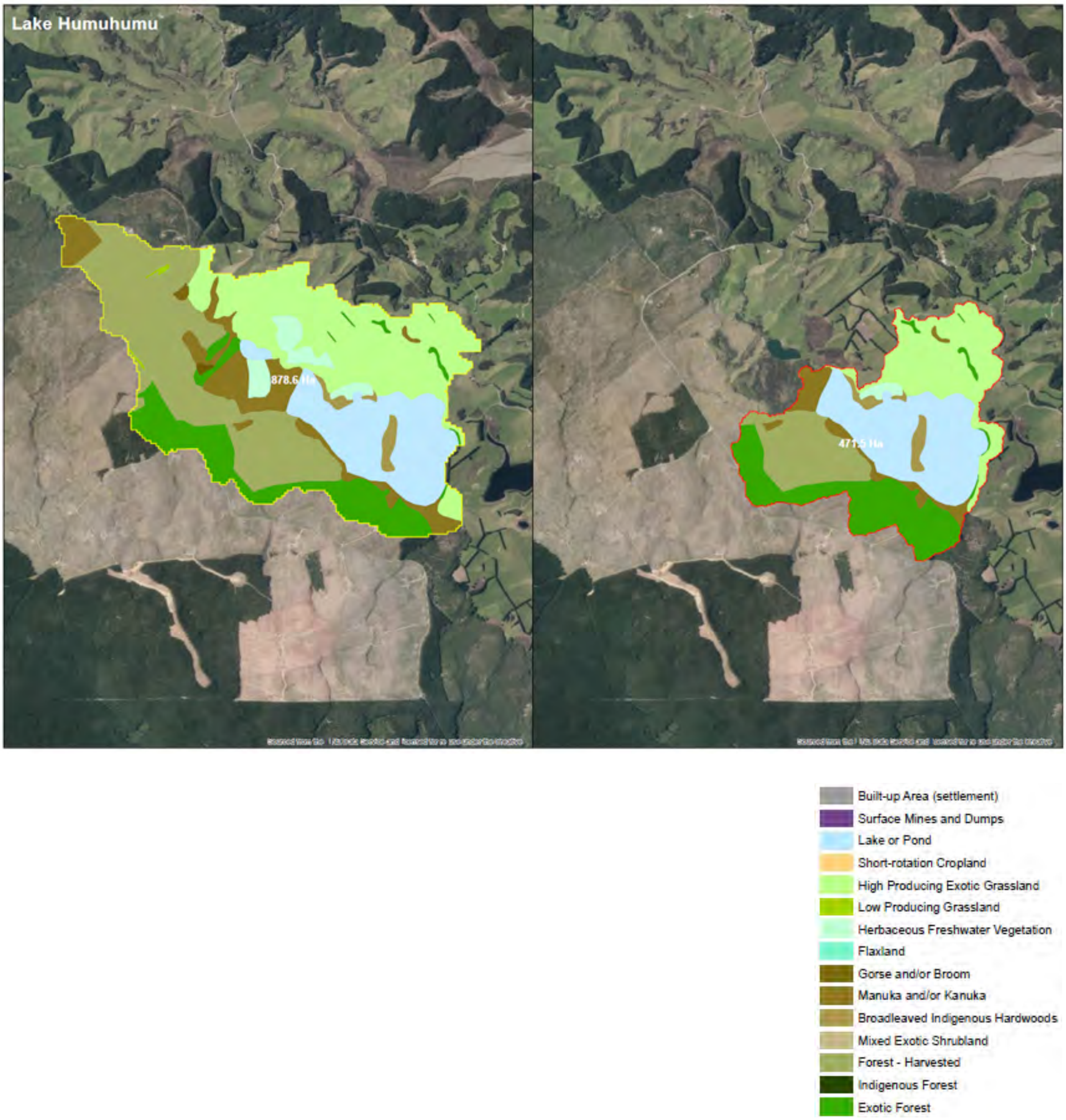
9. LAND USE

9.1. Catchment land cover table and map

The following catchment cover areas are based on the FENZ database. This has now been superseded by newer LiDAR catchment boundaries for which cover areas are not yet available. The catchment is dominated by harvested pine forest, high producing exotic grassland, and manuka/kanuka scrub.

The northern side of the lake is bordered by strips of alternating pastoral (light green in the map) and dairy farming (grey in the map).

Lake	Cover Type	Total FENZ (ha)	Total LiDAR (ha)
Lake Humuhumu	Broadleaved Indigenous Hardwoods	12.64	12.64
Lake Humuhumu	Exotic Forest	113.90	103.46
Lake Humuhumu	Fernland	1.47	0.00
Lake Humuhumu	Forest - Harvested	251.05	74.57
Lake Humuhumu	Gorse and/or Broom	2.00	0.00
Lake Humuhumu	Herbaceous Freshwater Vegetation	31.58	5.36
Lake Humuhumu	High Producing Exotic Grassland	235.01	110.09
Lake Humuhumu	Lake or Pond	138.22	134.71
Lake Humuhumu	Low Producing Grassland	1.94	0.00
Lake Humuhumu	Manuka and/or Kanuka	90.80	30.70
Lake Humuhumu Total		878.62	471.52

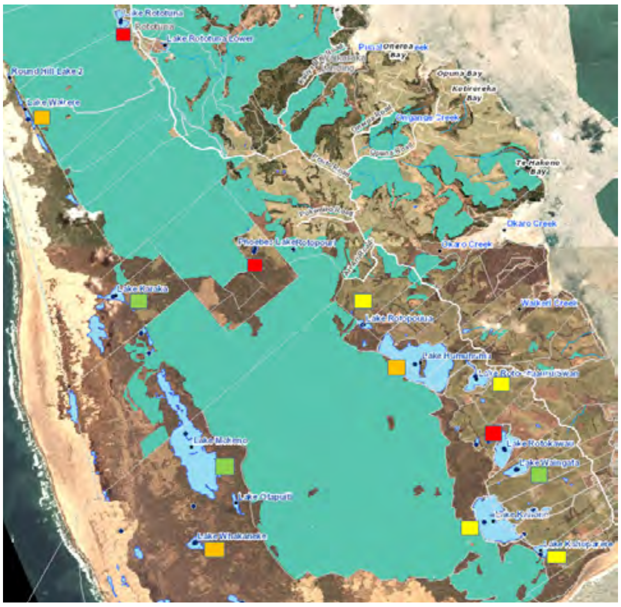


9.2 Stock exclusion

All areas of the lake abutting farmland have been fenced (purple and orange lines on the map below).

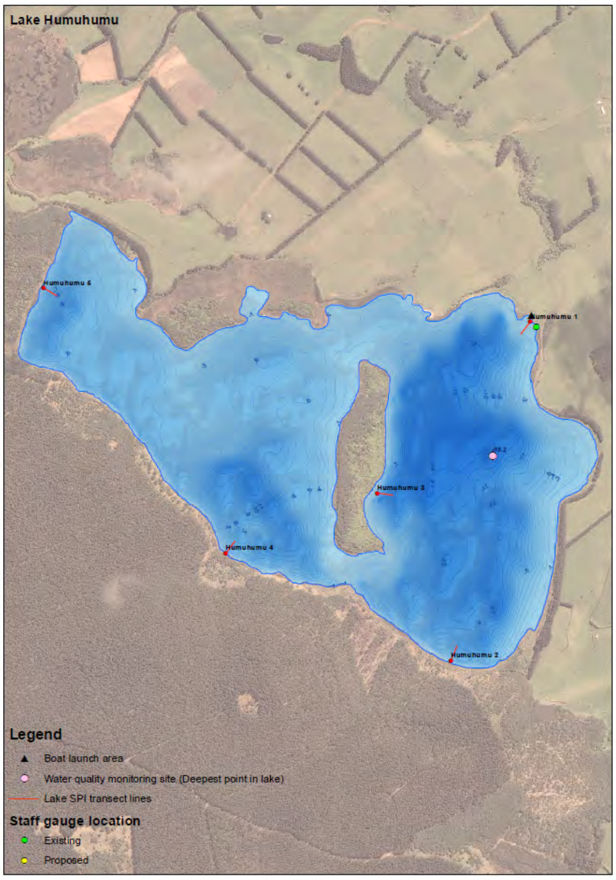
9.3 Fire-fighting mitigations

Humuhumu, due to the presence of the invasive water weed alligator weed, has been identified as a moderate-risk water take for fire-fighting, indicated by the orange marker at this lake in the map below. Lake Waingata to the south is a safe alternative.



10 MONITORING PLAN

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



10.1 NIWA ecological monitoring

Lake Humuhumu was ecologically surveyed by NIWA in 1984, 1985, 1988, 2001, 2005, 2007, 2012, 2014 and 2017.

Monitoring recommendations by NIWA include an annual invasive weed surveillance at access points, condition monitoring every three years and surveying for populations of the Nationally Endangered *Trithuria inconspicua* not seen during 2014 survey.

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
Grevilles Lagoon															M																
Humuhumu	5	1													O		O					O		O							
Kahuparere	5														H		H					H			O						
Kanono	5	3-5													O		O						O		O			?			
Kapoai	5														L-M		L-M							L				?	?	?	
Karaka	10	5-10													H		H					H			O			?			
Mokeno	5	5													O		O					O			M-H	H					
Parawanui															L											M-H		?			
Phoebe's																		L													
Rotokawau (P)	5														H		H					H			O						
Roto-otuauru/Swan		1													M				M carp	M	M	M	M		carp			carp	carp	carp	carp
Rotopouua	5																	O				O									
Rototuna	5														H		H					H		M				?			
Waingata (P)															L					L					L						
Wainui	5														M-H		M-H							H				?			
Wairere and Round Hill Lake 2	10														M-H									M-H							
Whakaneke															H							M						?			

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.

Number of samples taken per year are shown 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
Humuhumu lower								1					1			1	2	3	4	2	1	4	4	4	4	4	3	4	2	44
Humuhumu surface		1				1		1								1	2	3	4	2	2	4	4	4	4	4	3	4	2	46

11 WORK IMPLEMENTATION PLAN

Ongoing work includes:

The NRC/NIWA ecological surveys will continue every three years with weed surveillance annually. The next full survey will be in 2020. Specific monitoring will occur for populations of the Nationally Endangered *Trithuria inconspicua*, not seen during 2014 survey. Quarterly NRC water quality monitoring will continue.

The NRC's Freshwater Improvement Fund (FIF) Dune Lakes project includes work at Lake Humuhumu, including:

- Lake Humuhumu has been selected for a more detailed modelling benefit-cost analysis for nutrient mitigation. This process involves walking the catchment and its sub-catchments, documenting works required to mitigate nutrient inputs and improve water quality. The model, based on monitoring of nutrient loads in each drain will estimate the nutrient load mitigated by works such as sediment detention structures and compare it to the cost of the work. The FIF work commits to earthworks for sediment/phosphorus detention on the eastern side of the lake at $5000.

Further mitigation work to consider includes:

- Humuhumu, due to its invasive water weeds, has been identified as a moderate-risk water take for fire-fighting. Lake Waingata to the south is a safe alternative.
- Assessment of the effects of prior forestry harvest on indicators of nutrient enrichment such as receding bottom limits by aquatic plant cover and a change in charophyte species dominance and cover.
- Surveying for populations of the Nationally Endangered *Trithuria inconspicua* not seen during the 2014 and 2017 surveys.
- Comprehensive planning for dwarf inanga conservation in the Pōuto lakes
- Riparian planting through the Million Metres initiative.
- Eradicate incursions of royal fern, if found.

Proposed sub-catchment-specific work includes (see Appendix 2 for detail):

Reduce phosphorus loss from sub-catchment 1 by:

- Fencing the gully, with planting.
- A fenced detention bund and planting of sedges and harakeke at the bottom of the sub-catchment to reduce the contribution of phosphorus-rich sediments.
- Diversion of water to a pasture area from gate ways and other disturbed areas.
- Shift gates and fence lines to reduce connection of disturbed pasture areas to the lake and to reduce the area of disturbed pasture. This could be done by making paddocks smaller.
- Riparian weed management.

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13 APPENDIX 1. NOTES FROM FIELD VISIT TOWARDS NUTRIENT MITIGATIONS

Review of mitigation strategies for individual sub-catchments of Lake Humuhumu and Lake Kanono on the Pōuto Peninsula, Northland

Graeme Doole, 30 November 2016
Summary of field visit (1 November 2016) and GIS review (2 November 2016)
Lake Humuhumu

Sub-catchment 1

The sub-catchment is shown in Figure 1. It is a sub-catchment of significant size (around 65 ha) that drains productive pastures currently used for grazing bulls.

Figure 1. Sub-catchment 1 in the centre of this photo drains a particularly large sub-catchment of the lake and contains pastoral land.

Sub-catchment 1 contains a long, wooded valley that is currently unfenced along most of its length (Figure 2). The most important source of phosphorus (P) in this sub-catchment is this gully and the fingers of this gully.

Figure 2. Photos of the bottom end of the stream system located in sub-catchment 1, close to the lake.

P losses are especially significant given the tendency of bulls to disturb the pasture in the valley and around gateways (Figure 3).

Figure 3. Evidence of disturbed areas of pasture around a gate way in sub-catchment.

There are a number of key strategies to reduce phosphorus loss from this sub-catchment:

1. The gully and the fingers of the gully could be fenced, with vegetation allowed to become more dense through appropriate planting and/or management.

2. The bottom of the sub-catchment is highly suited to the establishment of a detention bund (Figure 4A) to reduce the contribution of P-rich sediments during large flow events in the stream. The head of the detention bund would provide stock access when stock are being moved from one side of the bottom of the stream gully to the other side. The area behind the detention bund would be planted with native plants, such as sedges. The detention bund would be fenced. The head would act as a lane way, with the fencing on the lakeward side linking into that of the riparian area. This area

would be vegetated also. This design may require a change of access to the track going up the hill on the northern side of the lake (Figure 4B).

3. Contributions from gate ways and other disturbed areas could be reduced through diversion of water to a pasture area.

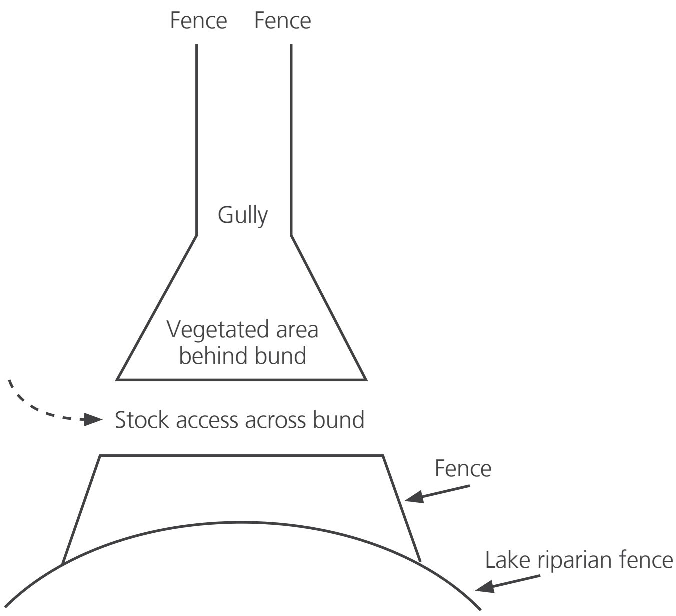
4. Gates and fence lines could be shifted to reduce connection of disturbed pasture areas to the lake.

5. Gates and fence lines could be shifted to reduce the area of disturbed pasture. This could be done by making paddocks smaller.

6. Weed management in the riparian area of the lake could help support a healthier ecosystem.

Figure 4. (A) Site suited to the development of a detention bund, close to the lake. (B) Access on the northern side of the bund site.

Figure 5. Diagram of a proposed detention bund for sub-catchment 1.



Sub-catchment 2

This sub-catchment contains a race system (Figure 6A), with a direct flow line to the lake that terminates in a highly-eroded gully (Figure 6B). The key here therefore is to try to reduce the speed of the water.

Key strategies to reduce phosphorus loss from this sub-catchment to the lake are:

1. Construction of small, lateral drains running in an opposite direction to the laneway. These will decrease channelling in the race way and divert contaminants towards vegetated areas away from the lake. They will also reduce the speed of the water, and hence the erosivity of the water flowing across the landscape.
2. Fence off the gully at the base of the sub-catchment, close to the lake. Take this fence quite wide and capture the kanuka present on the face above the lake (Figure 7). Plant this fenced area with native vegetation (e.g. sedges, harakeke).
3. The eroded gully itself, which is heavily eroded, should be planted with willows because its roots will help to reduce sediment loss from this source.
4. A flume is a channel that holds run-off water to prevent it from eroding soil. Such a strategy could be used to reduce further scouring out of the gully at the bottom of the sub-catchment.
5. The presence of pugging throughout this sub-catchment suggests that there are gains to be had, both for production and the environment.

Figure 6. (A) Stock race within sub-catchment 2.

(B) Highly-eroded gully at base of sub-catchment.

Figure 7. Hill containing kanuka that should be fenced, to join the existing riparian area.

Sub-catchment 3

This sub-catchment contains a long drain, leading into a large wetland area (Figure 8A). The large wetland area is dominated by raupo, which indicates that it is likely to be receiving a high amount of nutrients from the connecting pastoral land.

Figure 8. (A) Drain leading into a large wetland area. (B) Fencing of this drain could help to reduce nutrient inputs.

Key strategies to reduce phosphorus loss from this sub-catchment to the lake are:

1. Fencing of the drain on the other side to reduce nutrient inputs (Figure 8B). This area should be vegetated.
2. The connection between the drain and wetland should be improved. The riparian area for the lake should be extended outwards and planted, such that the water from the drain runs through an extended wetland area before reaching the lake. This is especially important to improve the capture of phosphorus-rich sediments.

Sub-catchment 4

This contains a small wetland by a trough; the trough is surrounded by phosphorus-rich soil that would easily enter the wetland (Figure 9).

Key strategies to reduce phosphorus loss from this sub-catchment to the lake are:

1. Fence the small wetland and let it regenerate from the natural seed source. This may be costly due to the need for water reticulation, which would require the installation of two troughs. This development is important because it will help to provide treatment of the water before it reaches the Top 150 wetland located to the east of Lake Rotopoua.

Figure 9. Sub-catchment 4 drains to a small wetland, located next to a trough.

Non-pastoral side of lake

The western shore of the lake is being converted to manuka. There is a need to understand nitrogen and phosphorus losses under this type of land cover; though it is likely to be very low.

Confirm the exact catchment boundary on the western, non-pastoral side.

Identify the potential for gully erosion to occur on the western, non-pastoral side of the lake and explore the potential utility of different mitigation options.

14. APPENDIX 2. 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)

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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