Kai Iwi Lakes

MANAGEMENT PLAN

Lake Kai Iwi - Lake Taharoa - Lake Waikare

Northland
REGIONAL COUNCIL

CONTENTS

KAI IWI LAKES MANAGEMENT PLAN

1. PURPOSE

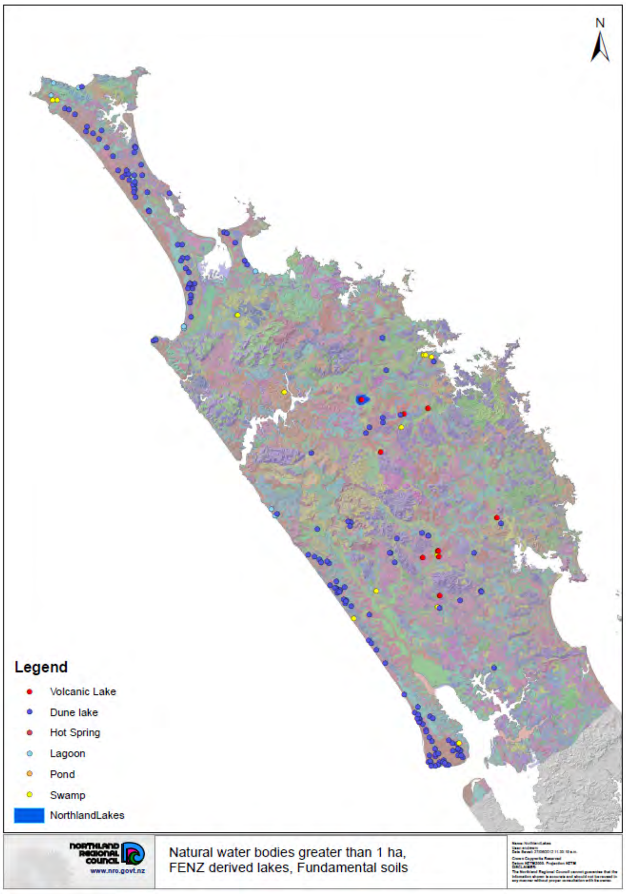
The purpose of the Outstanding Northland Dune Lakes Management Plans is to implement the recommendations of the Northland Lakes Strategy Part II (NIWA 2014) by producing Lakes Management Plans, starting with the 12 'Outstanding' value lakes, and by facilitating actions with mana whenua iwi, landowners 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.

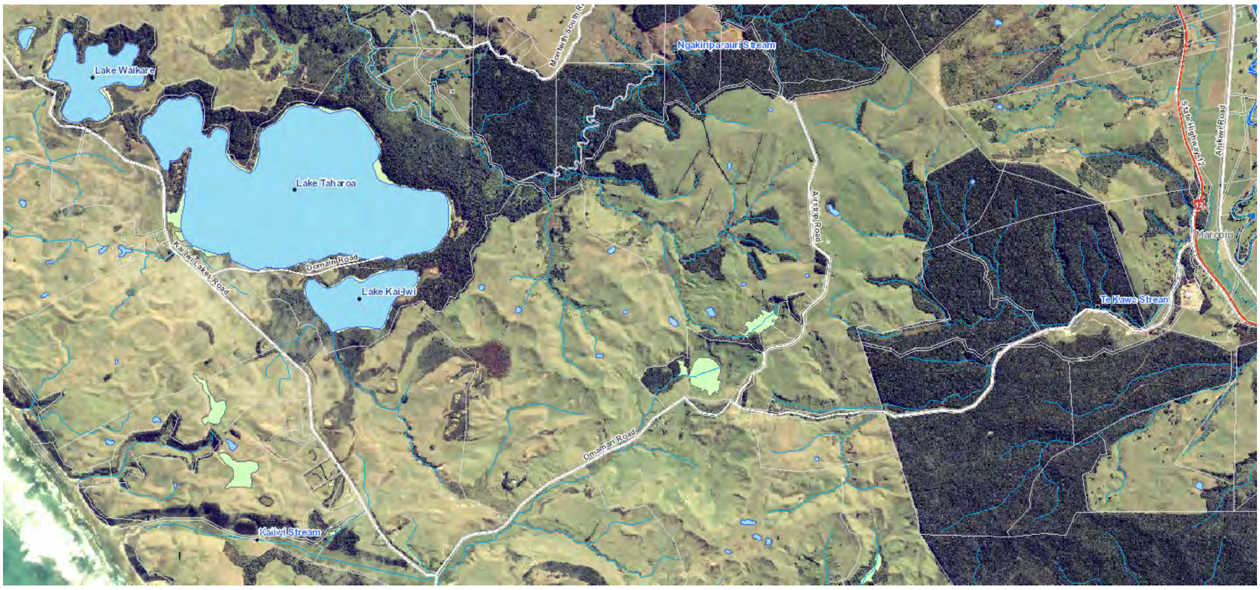
Further south within Northland, on the west coast north of Dargaville, are the three Kai Iwi Lakes (Lake Kai Iwi itself, and Lakes Taharoa and Waikare, sometimes referred to as Waikere).

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. LAKES OVERVIEW

Lakes Kai Iwi, Taharoa and Waikare (NRC Lake Numbers 236, 229 and 227, respectively), referred to collectively as the Kai Iwi Lakes, are situated north of Dargaville and west of Highway 12, via Omamari and Kai Iwi Lakes Roads. These closely situated lakes are some of the most pristine dune lakes in Northland and are a popular tourism and recreation destination. The three lakes and Lake Shag to the north-west are classified as window dune lakes (Timms, 1982), meaning they sit within the water table and are fed by both rainfall, springs and overland flows. There is a possibility that Lake Kai Iwi is a Perched dune lake, sitting above the water table.

Kai Iwi is formed as a single basin with maximum depth of 15.65 m and an overall mean lake depth of 8.15 m. The lake has a fringe of dense emergent plants to the north-east which is important for catchment nutrient-scrubbing.

Taharoa has complex bathymetry with a deep central basin of 38.81 m linked to two shallower basins, as well as a discrete, nearly closed basin at its western end and some gently sloping beaches. The many steep drop-offs do not provide much habitat for a littoral fringe of emergent plants. Mean lake depth is 16.42 m.

Lake Waikare has three basins with the central basin deepest at 29.48 m and a mean lake depth of 10.95 m. The undulating shoreline has steep drop-offs to the west and more gradual slopes to the east of each arm. Habitat favours the eastern edges for littoral emergent plant communities.

The lakes are situated in contiguous catchments primarily covered in high producing exotic grassland pasture, exotic pine forest and manuka/kanuka scrubland. There are also a few other mixed covers.

The lake surface areas, NRC-defined catchment areas, including the lakes, and volumes of the lakes are: Kai Iwi - 22.6 ha, 120.9 ha and 1.43 million m^3; Taharoa – 197 ha, 439.4 ha and 25.18 million m^3, Waikare – 26.5 ha, 149.5 ha and 2.97 million m^3.

Each lake thermally stratifies in warmer months. National Policy Statement for Freshwater Management (NPS) states for phytoplankton (chlorophyll-a) for each lake are - Kai Iwi rides the line between states A and B, weighted heavier towards B; Taharoa stays within state A, other than during periodic small events rising into state B and returning to A afterwards; and Waikare is more similar to Kai Iwi than Taharoa, yet even more pronounced, crossing over or verging into state C on occasion and recently favouring state B.

Nitrogen in Kai Iwi has pushed into state C on several occasions, but tends to clear back into state B. Nitrogen for Taharoa is generally a high state A. Nitrogen for Waikare is consistently in state B. Phosphorus and toxic ammonia for each lake is in state A.

Kai Iwi has had a long trend as low mesotrophic and has recently improved into the oligotrophic band. Taharoa is low oligotrophic (good water quality) and enters microtrophic (very good water quality). Lake Waikare is medium oligotrophic (good water quality), occasionally entering mesotrophic (average water quality). All three lakes have improved in water quality over the last year.

As with thermal stratification, each of the three lakes experience seasonal deoxygenation events at depth. Kai Iwi stratifies starting at around 7 m between October and April. Taharoa stratification is much deeper, with deoxygenation starting at 19 m from September to May and Waikare between 9-11 m from November to early June.

The pH for Kai Iwi and Waikare is stable and largely neutral at pH 7, whereas Taharoa is the exception with a consistently lower (acidic) pH of 6.5. Taharoa's extreme depth means that its aquatic plant community is relatively lower per unit volume, so the ecosystem services provided by plants in scrubbing carbon and nutrients from the water and its long holding time, keep its waters in a more acidic state (due to lack of carbon removal) than the other two smaller lakes.

Waikare sits at a higher altitude at 10 m above Taharoa and Kai Iwi. Kai Iwi is slightly higher than Taharoa and field observation confirms that the flow in their connecting channel moves from Kai Iwi to Taharoa during high water.

The localised influence of rainfall and evaporation can be seen in the co-varying height trends in all three lakes, which generally rise and fall together.

Kai Iwi has a relatively larger catchment size to lake volume and a higher influence of groundwater (30%) from the ranges compared to the other two lakes. This may suggest why Kai Iwi has the densest reed belt of all three lakes, with few periods of the littoral zone drying out.

Lake Taharoa is the lake most influenced by rainfall (74%) and the least influenced by surface run-off (9%). Groundwater influence is 18%. This may explain the sensitivity this lake has to the effects of heavy rain or drought conditions. Over its long timeline the trend is a slow decline in level, although lake levels are currently equal to the historic maximum.

Likewise, Lake Waikare is similar to Lake Taharoa in its seasonal variations in lake level and longer-term decline, although, once again, it is near to its historic maximum level. However, Waikare has an opposite relationship to Taharoa in its run-off versus groundwater influence with Waikare having 33% run-off and only 8% groundwater in comparison to Taharoa's 9% run-off and 18% groundwater. Therefore, Waikare is more subject to threats from land use.

The estimated lake water residence time of the lakes is: Kai Iwi - 0.558 years; Taharoa - 11.247 years and Waikare - 4.468 years. Kai Iwi and Waikare flush at 20 and 2.5 times faster than Lake Taharoa, respectively. This could account for lake level differences between the three lakes, with Taharoa having more marked variation, followed by Waikare and Kai Iwi.

Kai Iwi has the smallest volume (1,427,544 m³) of the three lakes and the smallest catchment area (120.9 ha) and has the lowest dilution factor. It is therefore more influenced by catchment land use than the other two lakes. Yet it has the lowest residence time so can flush a proportionally higher percentage of run-off the fastest.

Taharoa has the largest overall volume (25,182,936 m³) with the largest catchment (439.4 ha) and has the highest dilution factor. However, its long residence time of 11.247 years means that accumulated run-off takes 20 times longer to flush from the lake than it does from Kai Iwi which has a residence time of only 0.6 years. The dilution factor likely saves Taharoa from becoming nutrient enriched.

Lake Waikare (at a volume of 2,974,459 m³) has 8.4 times less volume than Taharoa and twice the volume of Kai Iwi, and it has the median catchment size, roughly the same catchment area as Kai Iwi and 2.9 times less than Taharoa. Yet the lake has the middle residence time of 4.5 years of the three lakes.

These two features, dilution factor and residence time, likely balance each other out, allowing each lake to be relatively equal in terms of catchment influence. Kai Iwi will have higher loads of run-off but recover quicker, a pattern of repeated and acute sediment and nutrient discharge. Taharoa will have substantial discharges and a longer holding time, but its significant volume will tolerate this. Waikare has relatively smaller discharges than the other two lakes and a medium-scale holding time.

In addition to these patterns, the land use of each catchment will be of influence. Both Kai Iwi and Taharoa have similar exotic grassland pasture and protective manuka/kanuka scrubland area in their catchments with Waikare just over half the pasture and half the scrubland in catchment cover. Waikare and Taharoa each have farm drains discharging into them, though they do not run continuously all year.

In summary, Kai Iwi is likely to be under greatest threat of nutrient enrichment stress in the long-term. The threat to Waikare from the farm drain can be remedied. Taharoa has the benefit of a highly assimilative capacity in terms of volume, but its extreme depth means that its aquatic plant community is relatively lower per volume so the ecosystem services provided by plants in scrubbing carbon and nutrients from the water and its long holding time keep its waters in a more acidic state (due to lack of carbon removal) than the other two smaller lakes, while native fauna prefers a more alkaline environment.

Both Kai Iwi and Waikare have experienced a rise in Invasive Impact Index with a corresponding fall in Submerged Plant Index (SPI) and Native Condition Index in 2011. Lake Taharoa retains a high and steady SPI and even a decline in invasive threat.

Between them, the lakes support 27 native plant species, including two rare natives in all three lakes; *Trithuria inconspicua* and *Myriophyllum votschii*. The tiny rare annual herb *Centrolepis strigosa* grows on the margins of all three lakes, occasionally in large numbers depending on seasonal climatic conditions. Because of its clear water, Lake Taharoa has deepest growing submerged vegetation of any North Island lake at 24m.

In addition to the native plants, there are two non-invasive exotic species present in each lake; Bulbous rush and bladderwort. Although these are exotic plants and contribute to overall ecological condition (Lake SPI score), neither plant has had a significant enough impact in the lakes to be considered a serious invasive species.

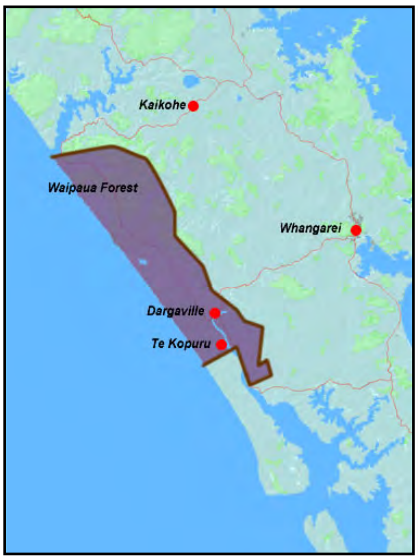
Gambusia and a rainbow trout fishery have a combined impact on the Dune Lakes Galaxias (DLG) which are found nowhere else than in these lakes. Koura/kewai are morphologically different to any other koura/kewai elsewhere. The relative old age of these lakes to all other Northland dune lakes has seen speciation in terms of DLG and progress towards speciation for koura/kewai.

The lakes have a low level of bird diversity and has no game birds present. New Zealand dabchicks occur widely in this sub-region.

5. SOCIAL AND CULTURAL DIMENSION

5.1. Mana whenua

Two Māori governance entities have rohe whenua Area of Interest in the area of Lake Kai Iwi - the hapū Te Roroa (purple) and the iwi Ngāti Whātua (orange). Both have reached Deed of Settlement with the Crown and there appears to have been no vesting of the lake bed. Kai Iwi Lakes are a specific Area of Interest for Te Roroa. The hapū Te Kuihi, based at Tangiterōria marae have ahi kaa status at the lakes.



5.2. Land Tenure

5.2.1. Catchment landowners and Lake bed owners

Lake Kai Iwi, along with neighbouring Lakes Taharoa and Waikare are managed by the Kaipara District Council under the Kai Iwi Lakes (Taharoa Domain) Reserve Management Plan 2016. The lake beds of Taharoa and Waikare are owned by Kaipara District Council and Kai Iwi has been returned to mana whenua.

Ten landowners own 11 land parcels within the Lake Kai Iwi catchment, nine landowners own 12 land parcels in the Lake Taharoa catchment and three landowners own three land parcels in Lake Waikare catchment.

5.3. Community Involvement

5.4. Public Use

5.4.1. Access

A locked gate bars vehicle access to Lake Kai Iwi. The lake is a short walk from adjacent Lake Taharoa and the perimeter of the lake has a walking track.

Lake Taharoa and Lake Waikare are accessible by public road and both lakes have walking tracks around them.

5.4.2. Boating

5.4.2.1. Boat access

There are no boat ramps at Lake Kai Iwi. Power boats are not permitted.

There are three approved boat launching areas in Lake Taharoa. Access is easy.

Boat access to Lake Waikare is easy although water-skiing was recently discontinued from this long-time water-skiing destination and confined to Lake Taharoa only.

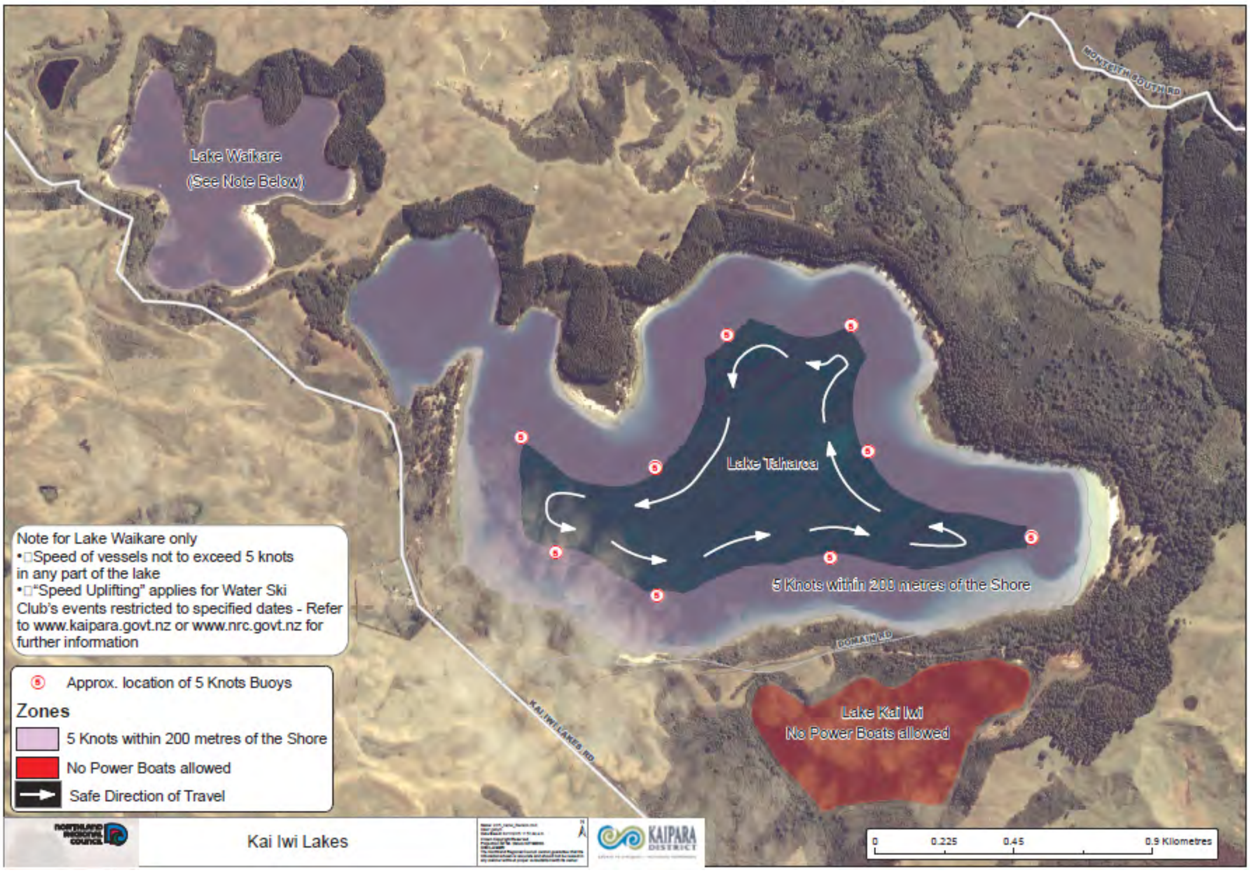
5.4.2.2. Water skiing

No power boating is permitted on Lake Kai Iwi.

Lake Taharoa is available for a range of mixed uses e.g. powerboats, swimming, fishing, waka ama, sailing, kayaking, etc.

Power-boat speed on Taharoa is restricted to 5 knots within 200 m of the shore. This boundary is marked by a series of buoys on Lake Taharoa, shown in the figure below. Water-skiing is permitted beyond this point, traveling in a counter-clockwise direction only.

Powerboats are not allowed on Lake Waikare, unless specifically authorised as safety vessels for events, for scientific and research purposes or for management operations.



5.4.2.3. Duck shooting

There is no duck shooting within the Taharoa Domain where the lakes are located.

5.4.2.4. NRC Monitoring boat

The lake is accessed quarterly by boat for NRC water quality monitoring.

5.4.2.5. Waka Ama

There is no waka ama on Lake Kai Iwi, but is a popular activity on Taharoa and Waikare.

5.4.2.6.Kayaking

Kayaking is permitted on Lake Kai Iwi but kayakers mostly use Lakes Taharoa and Waikare.

5.4.2.7. Trout fishing

Rainbow trout were first released into the Kai Iwi Lakes in 1968. Fingerlings were initially released into Lakes Taharoa and Waikare. The trout fishery is managed by the Northland Fish and Game Council (NF&GC). Each year the Northland Fish & Game Council releases ~2,000 trout fingerlings into Lake Taharoa and 300 into Lake Waikare. All persons fishing at the lakes are required to hold licenses, these can be obtained from licensed agents and sports shops in Dargaville.

The rules are:

- No more than three trout may be taken by any one person in a day.
- All trout taken are to exceed 300mm in length.

The Taharoa Domain Management Plan called for the stocking of trout to cease as of 1 January 2018 due to possible effects on the long-term survival of the endemic dune lakes galaxias. This decision is under review and monitoring and research is being planned to further examine the relationship between these two species and *Gambusia*. A working group has been established to guide the design and implementation of this work.

5.4.3. Campgrounds

There are two camping areas at Lake Taharoa.

Pine Beach - Campsites, wash and shower facilities, two flushing toilet blocks, and playground. In the summer, there are seasonal services including a mobile shop, and camp staff are on site. A limited number of powered sites, at an extra charge of $10 per night that must be booked as per the other sites at the camp ground.

Promenade Point - Camping areas, new toilet block. No shower facilities.

5.4. Events

Several annual events are held at the Taharoa Domain including:

- Avoca Kumura Kai Iwi Lakes Triathlon – February

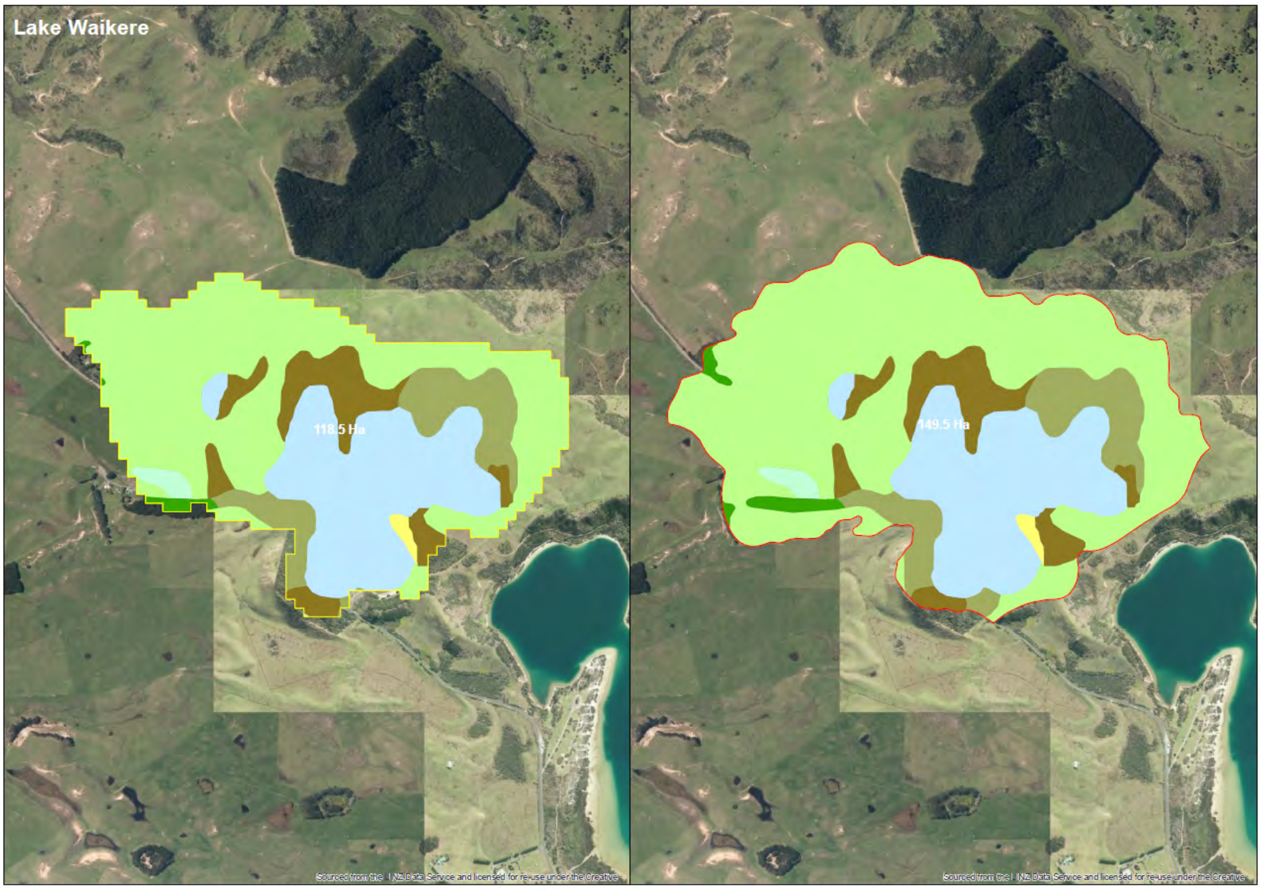
Through the Lake Waikare Event Centre (former Waterski Club):

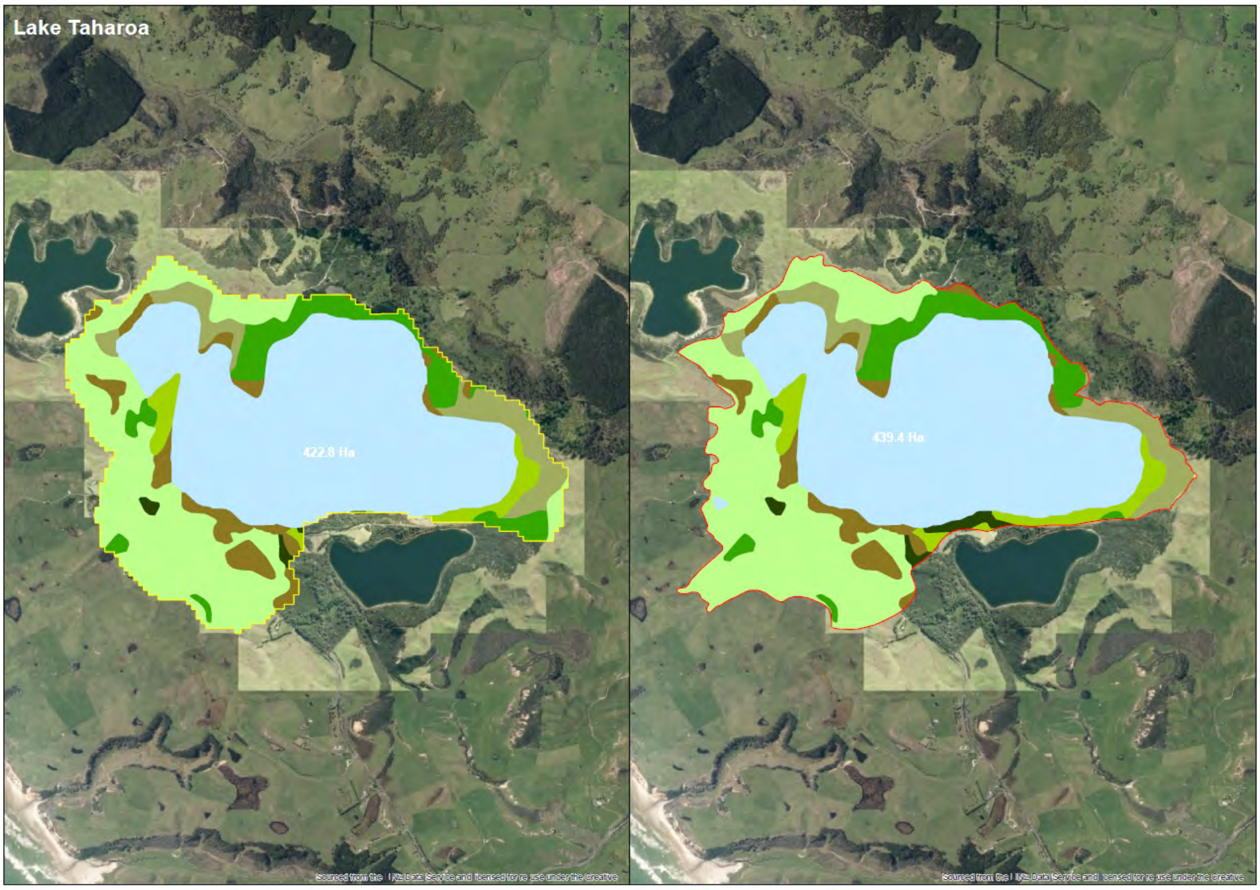
- Kai Iwi Lakes Big Day Out organized by Whitebait Connection - January/February - Activities provided to the public for free include:
  - Guided snorkeling
  - Waka ama Races
  - Guided walks
  - Pest workshops
  - Dune lakes displays
  - Check Clean Dry activities
  - Spot prizes and competitions
  - Dragon boat races
- School/Scout camps
- Hui/symposiums/meetings
- Training courses e.g. first aid courses, kaitiaki water monitoring toolkit courses
- Weddings or birthday parties

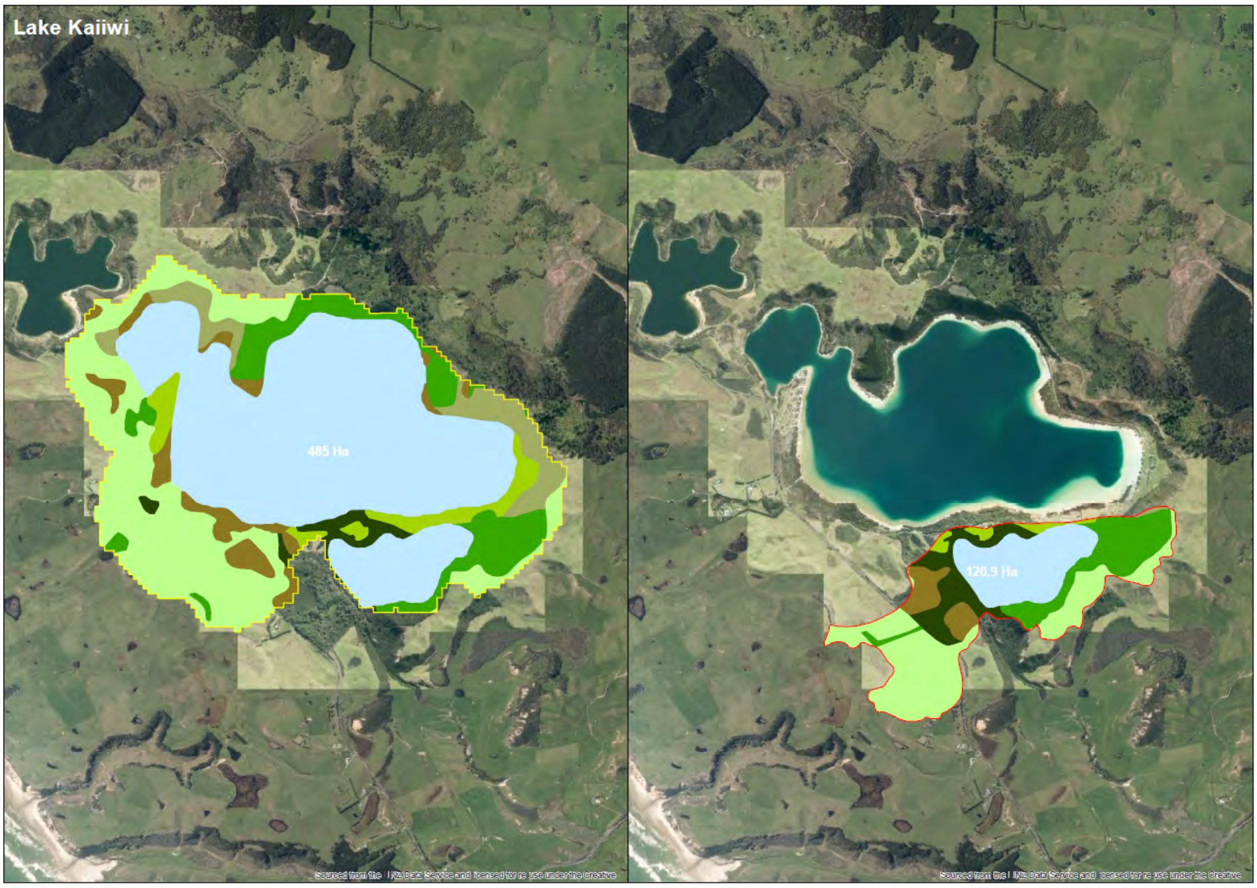
6. PHYSICAL CHARACTERISTICS

6.1. Catchment Area

The following maps show the extent of the lake catchments. On the left are the FENZ catchment boundaries. On the right are rationalised catchment boundaries based on altitude prepared by the NRC. By the end of 2018, highly accurate LiDAR boundaries will be available. The NRC-defined catchment areas, including the lakes themselves are 120.9 ha for Kai Iwi, 439.4 ha for Taharoa and 149.5 ha for Waikare.

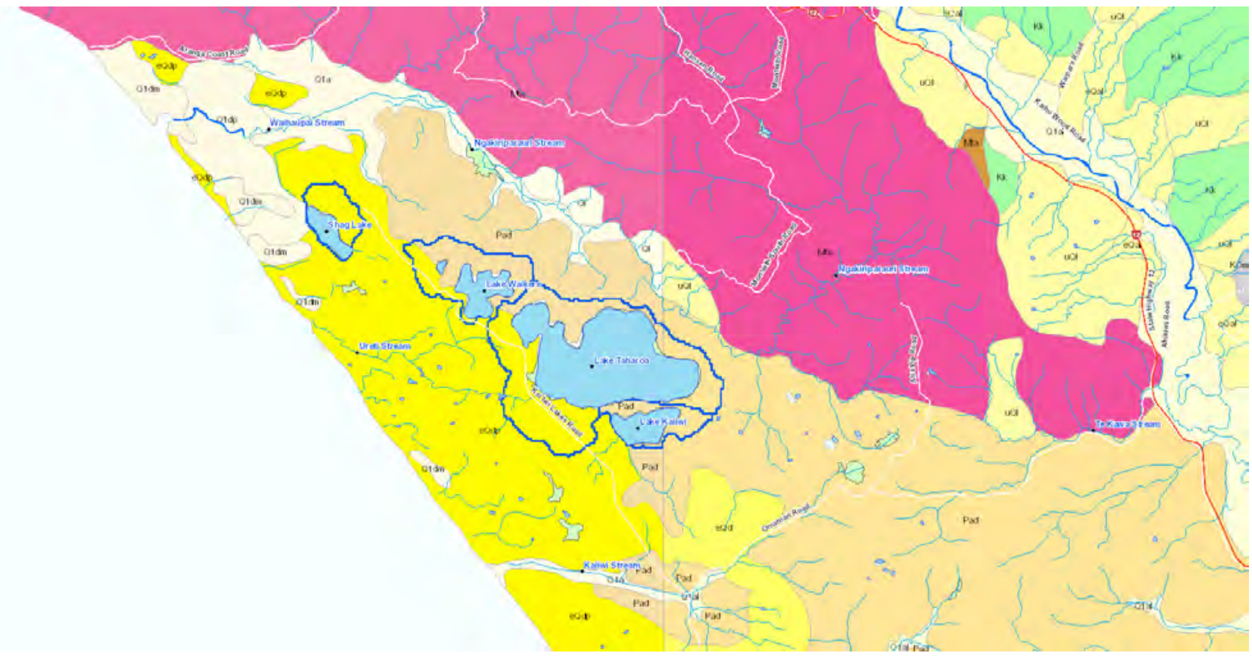

Lake Waikere
118.5 Ha
149.5 Ha


Lake Taharoa
422.8 Ha
439.4 Ha



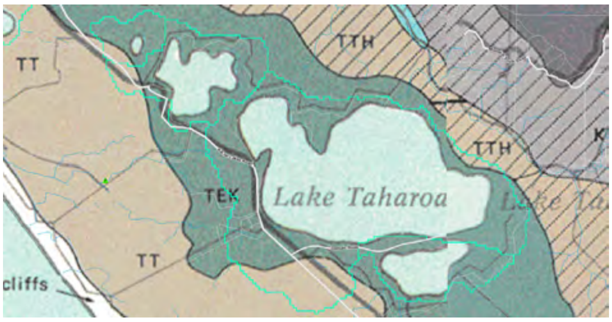
6.2. Catchment Geology and soil types

The following map ((C) GNS Science 2016) of the Kai Iwi Lakes area and table below it shows the geological history of the lake catchment. The lakes are sitting along and edge between Awhitu Group (IPad) cemented dune sand to the north-east and Early Quaternary dunes (eQd) to the south-west which formed during higher sea levels 12,000 years ago and earlier. These ancient dunes are now weakly cemented to uncemented. The Waipoua basalts in pink (Mtw) of the ranges to the east of the lakes flow down through the Awhitu cemented dunes, through the lakes and out through the poorly cemented Early Quaternary dune sands to the Tasman Sea. The Ureti and Kai Iwi Streams are important ecological connections to the Tasman Sea and it is likely that eels would have used these linkages to reach these lakes in the past.



Lake Name/Plot Symbol	eQd	IPlD (IPad)
Kai Iwi, Taharoa and Waikare	x	x
Name	Early Quatemary dunes	Awhitu Group
Description	Weakly cemented and uncemented dune sand and associated facies. Clay-rich sandy soil. These dunes arose during higher sea level 12,00 years ago and earlier.	Cemented dune sand and associated facies.
Geologic history	Early Quaternary	Late Pliocene to Early 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	0.78
Absolute maximum age (millions of years before present)	2.6	3.6
Supergroup equivalent stratigraphic name	Pakihi Supergroup	Pakihi Supergroup
Terrane equivalent name		
Lithology	sand	sand

Soil types in the catchment are portrayed in the soil map (adjacent) and table below. The majority of the three lake catchments are dominated by podzolised Te Kopuru sand (TEK) with minor parts of the catchments of Lakes Waikare and Taharoa in Tangitiki sandy loam to the west (TT), and east (TTH) of Taharoa.



Soil Symbol	Genetic soil group	Geological origin	Suite	Subgroup	Series	Soil name	Kai Iwi	Taharoa	Waikare	Description
TEK	Podzols	Soils of Lower Quaternary terraces and dunes	Pinaki		Te Kopuru	Te Kopuru sand (podzols)	x	x	x	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.
TT	Podzolised yellow-brown earths	Soils of Lower Quaternary terraces and dunes	Pinaki	Weakly to moderately podzolised	Tangitiki	Tangitiki sandy loam		x	x	Tangitiki series – usually rolling to steep with some very steep escarpments. Is usually a mosaic of more or less podzolised soils determined by slope and the presence or absence of kauri. Soils brownish with a relatively shallow topsoil. A typical profile of **Tangitiki sandy loam (TT & TTH)** may include: 90 to 150 mm of very dark grey to greyish brown loamy sand, on 100 to 200 mm of pale brown to yellowish brown sandy loam to loamy sand, on 300 to 350 mm of yellowish brown to light yellowish brown sandy loam, over a 250 to 350 mm cemented brownish yellow with grey veins and mottled sandy loam. This overlies brownish yellow, strongly consolidated weathered sands.
TTH	Podzolised yellow-brown earths	Soils of Lower Quaternary terraces and dunes	Pinaki	Weakly to moderately podzolised	Tangitiki	Tangitiki sandy loam		x		Tangitiki series – usually rolling to steep with some very steep escarpments. Is usually a mosaic of more or less podzolised soils determined by slope and the presence or absence of kauri. Soils brownish with a relatively shallow topsoil. A typical profile of **Tangitiki sandy loam (TT & TTH)** may include: 90 to 150 mm of very dark grey to greyish brown loamy sand, on 100 to 200 mm of pale brown to yellowish brown sandy loam to loamy sand, on 300 to 350 mm of yellowish brown to light yellowish brown sandy loam, over a 250 to 350 mm cemented brownish yellow with grey veins and mottled sandy loam. This overlies brownish yellow, strongly consolidated weathered sands.

6.3.Catchment Hydrogeology

The lakes sit to the north of the nearest major aquifer along the Wairoa River which empties into the Kaipara Harbour to the south. Being classed as Window Dune lakes, the Kai Iwi Lakes are influenced by the water table which partially feeds them through springs. Jacobs (2017) reports limited data on groundwater movement and aquifer parameters in the vicinity of these lakes. Geomorphology suggests flows from weathered basalts in the east to the west, through the lakes area.

6.4. Catchment drainage and sedimentation rates

The NRC-defined catchment area of Lake Kai Iwi, including the lake itself, is 120.9 hectares (the FENZ catchment area is 485.55 ha, substantially different). The FENZ catchment produces a mean annual flow, based on hydrological models, of 2,559,003.9 m³/year. For the NRC catchment size, the mean annual flow would be around 637,182 m³/year, based on a simple ratio. The lake has an estimated lake residence time of 0.558 years. The average particle size of surface rock in the catchment is 1.87 on a scale of 5, a value of 1 being sand (FENZ database).

The NRC-defined catchment area of Lake Taharoa, including the lake itself, is 439.4 ha, slightly larger than the FENZ catchment area of 423.27 hectares which produces a mean annual flow, based on hydrological models, of 2,239,077.4 m³/year. The lake has an estimated lake residence time of 11.247 years. The average particle size of surface rock in the catchment is 1.91 on a scale of 5, a value of 1 being sand (FENZ database).

The NRC-defined catchment area of Lake Waikare, including the lake itself, is 149.5, again only slightly larger than the FENZ catchment area of 118.62 hectares which produces a mean annual flow, based on hydrological models, of 665,799.2 m³/year. The lake has an estimated lake residence time of 4.468 years. The average particle size of surface rock in the catchment is 1.97 on a scale of 5, a value of 1 being sand (FENZ database).

The volume, NRC catchment area in square metres, the dilution factor produced from the prior two vales and the water residence time for each lake are shown in the following table:

Lake	Volume (m³)	NRC-defined catchment area (m²)	m³ water volume per 1 m² catchment (dilution factor)	Water residence time (years) or flushing rate
Kai Iwi	1,427,544	1,209,000	1.2	0.6
Taharoa	25,182,936	4,394,000	5.7	11.3
Waikare	2,974,459	1,495,000	2.0	4.5

Of interest in this data is the differential residence time of water in each lake. Lakes Kai Iwi and Waikare flush at 19 and 2.5 times as fast as Lake Taharoa, respectively.

Also, dilution factor shows the buffering power of Lake Taharoa, despite its residence time being longest at 11.3 years. For each m² catchment area, Kai Iwi has 1.2 m³ volume, Taharoa has 5.7 m³ volume and Waikare has 2.0 m³ volume.

Kai Iwi has the smallest volume (1,427,544 m³) of the three lakes and the smallest catchment area (120.9 ha) and has the lowest dilution factor. It is therefore more influenced by catchment land use than the other two lakes. Yet it has the lowest residence time so can flush this proportionally higher percentage of run-off the fastest.

Taharoa has the largest overall volume (25,182,936 m³) with the largest catchment (439.4 ha) and has the highest dilution factor. However, its long residence time of 11.247 years means that accumulated run-off takes 20 times longer to flush from the lake than it does from Kai Iwi which has a residence time of only 0.6 years. The dilution factor likely saves Taharoa from becoming more trophic.

Lake Waikare (at a volume of 2,974,459 m³) has 8.4 times less volume than Taharoa and twice the volume of Kai Iwi, and it has the median catchment size, roughly the same catchment area as Kai Iwi and 2.9 times less than Taharoa. Yet the lake has the middle residence time of 4.5 years of the three lakes.

These two features, dilution factor and residence time, likely balance each other out, allowing each lake to be relatively equal in terms of catchment influence. Kai Iwi will have higher loads of run-off but recover more quickly, a pattern of repeated and acute sediment and nutrient loads. Taharoa will have substantial loads and a long-term scale holding time, but the overall volume will tolerate this. Waikare has relatively lower loads than the other two lakes and a medium-scale holding time.

In addition to these patterns, the land use of each catchment will be of influence. Both Kai Iwi and Taharoa have similar exotic grassland pasture and protective manuka/kanuka scrubland area in their catchments with Waikare just over half the pasture and half the scrubland in catchment cover. Waikere and Taharoa each have farm drains emptying into them, though they do not run continuously all year.

In summary, Kai Iwi is likely to be under greatest threat of trophic stress in the long term. The threat to Waikare from the farm drain can be remedied. Taharoa has the benefit of a highly assimilative capacity in terms of volume, but its extreme depth means that its aquatic plant community is relatively lower per volume so the ecosystem services provided by plants in scrubbing carbon and nutrients from the water and its long holding time keep its waters in a more acidic state (due to lack of carbon removal) than the other two smaller lakes, while native fauna prefers a more alkaline environment.

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

The three Kai Iwi Lakes, along with Shag Lake, are the four Class 3 Window dune lakes in the Dargaville to Waipoua sub-region, originating as drownedvalleys or interdune basins. There is a possibility that Lake Kai Iwi is, instead, a Class 1 Perched dune lake, sitting above the water table.

Lake Kai Iwi has a maximum depth of 15.65 m with a mean overall depth of 8.15 m. The surface area of the lake is 22.6 hectares with a volume of 1,427,544.3 m³ (NIWA bathymetric survey). The catchment area, including the lake itself, is 485.55 hectares (FENZ database).

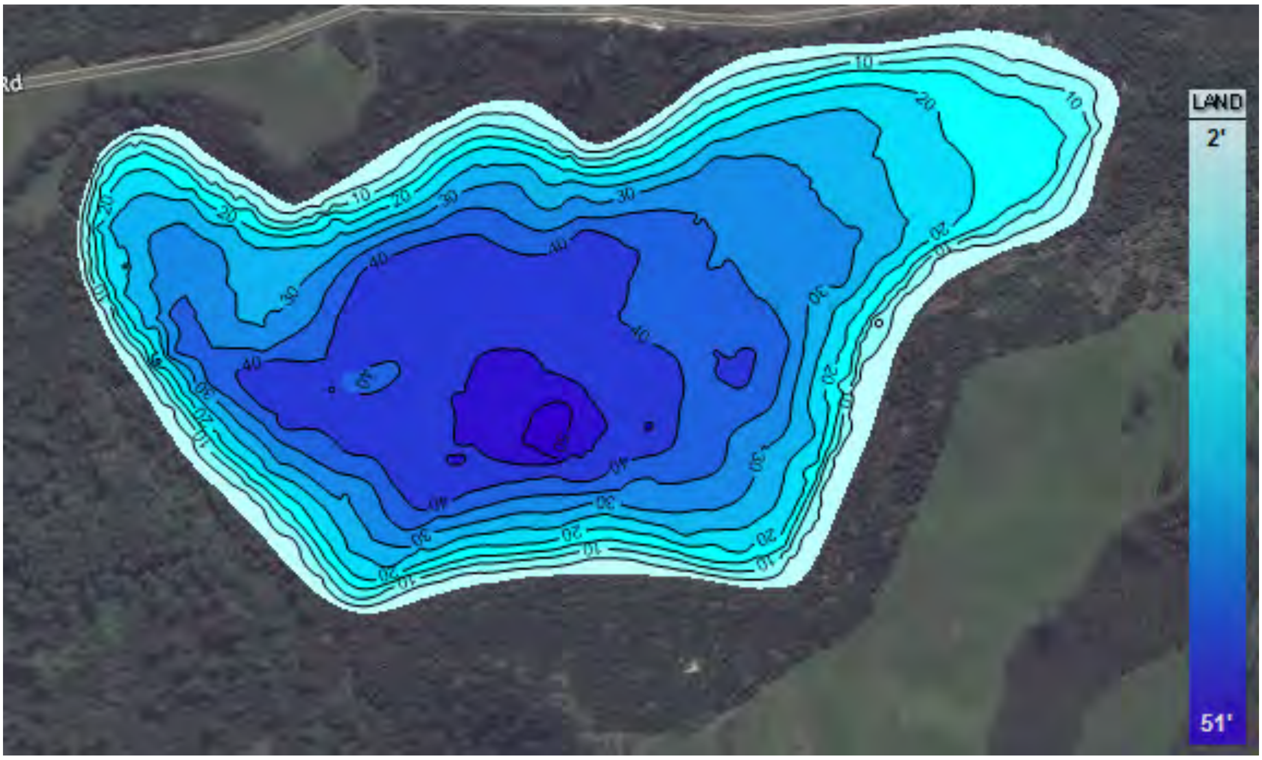
Lake Taharoa has a maximum depth of 38.81 m, the deepest dune lake in Northland, with a mean overall depth of 16.42 m. The surface area of the lake is 197 hectares with a volume of 25,182,936.9 m³ (NIWA bathymetric survey). The catchment area, including the lake itself, is 423.27 hectares (FENZ database).

Lake Waikare has a maximum depth of 29.48 m with a mean overall depth of 10.95 m. The surface area of the lake is 26.5 hectares with a volume of 2,974,459.4 m³ (NIWA bathymetric survey). The catchment area, including the lake itself, is 118.62 hectares (FENZ database).

6.6. Bathymetry maps

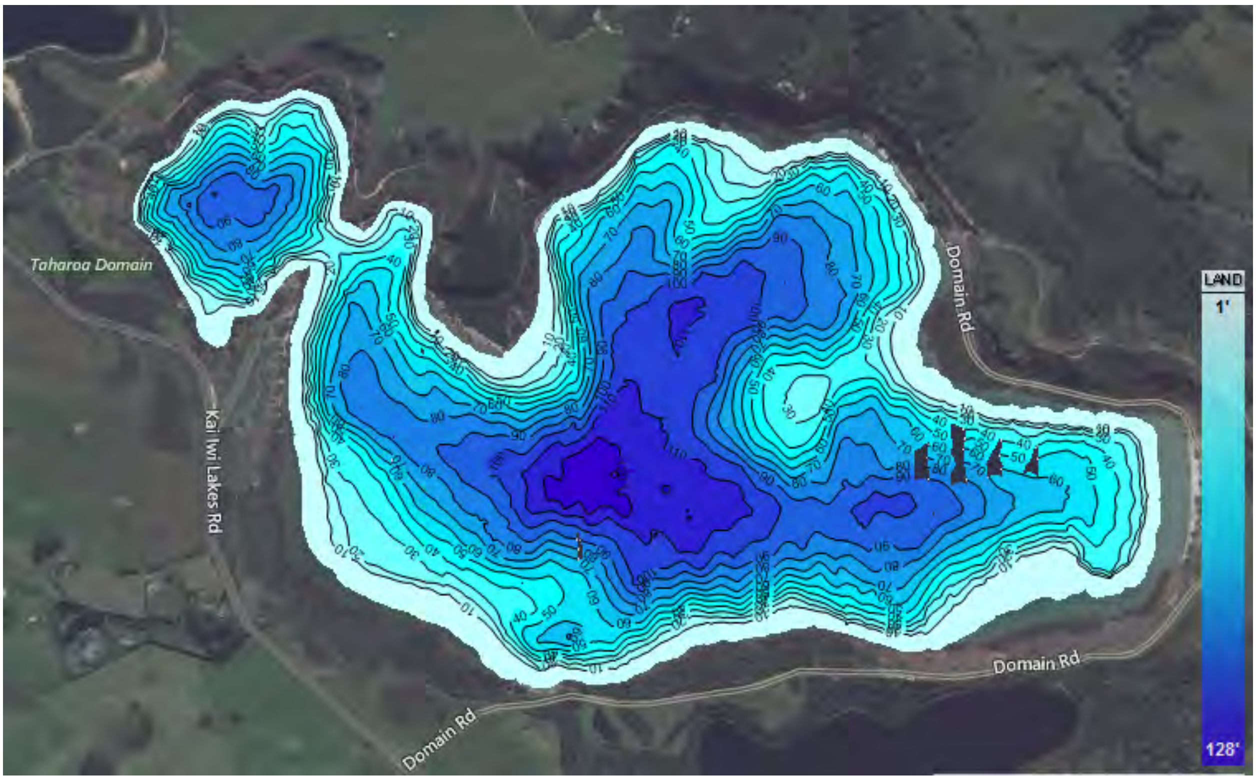
The bathymetric depth maps following comes from a survey done by NIWA for the NRC. Note that depth is expressed in feet, not meters, with gradients set at five-foot depths.

Lake Kai Iwi is formed as a single basin with maximum depth of 15.65 m and an overall mean lake depth of 8.15 m. The fringe of shallows to the north east allows this lake to host a belt of emergent plants, critical to catchment nutrient scrubbing.



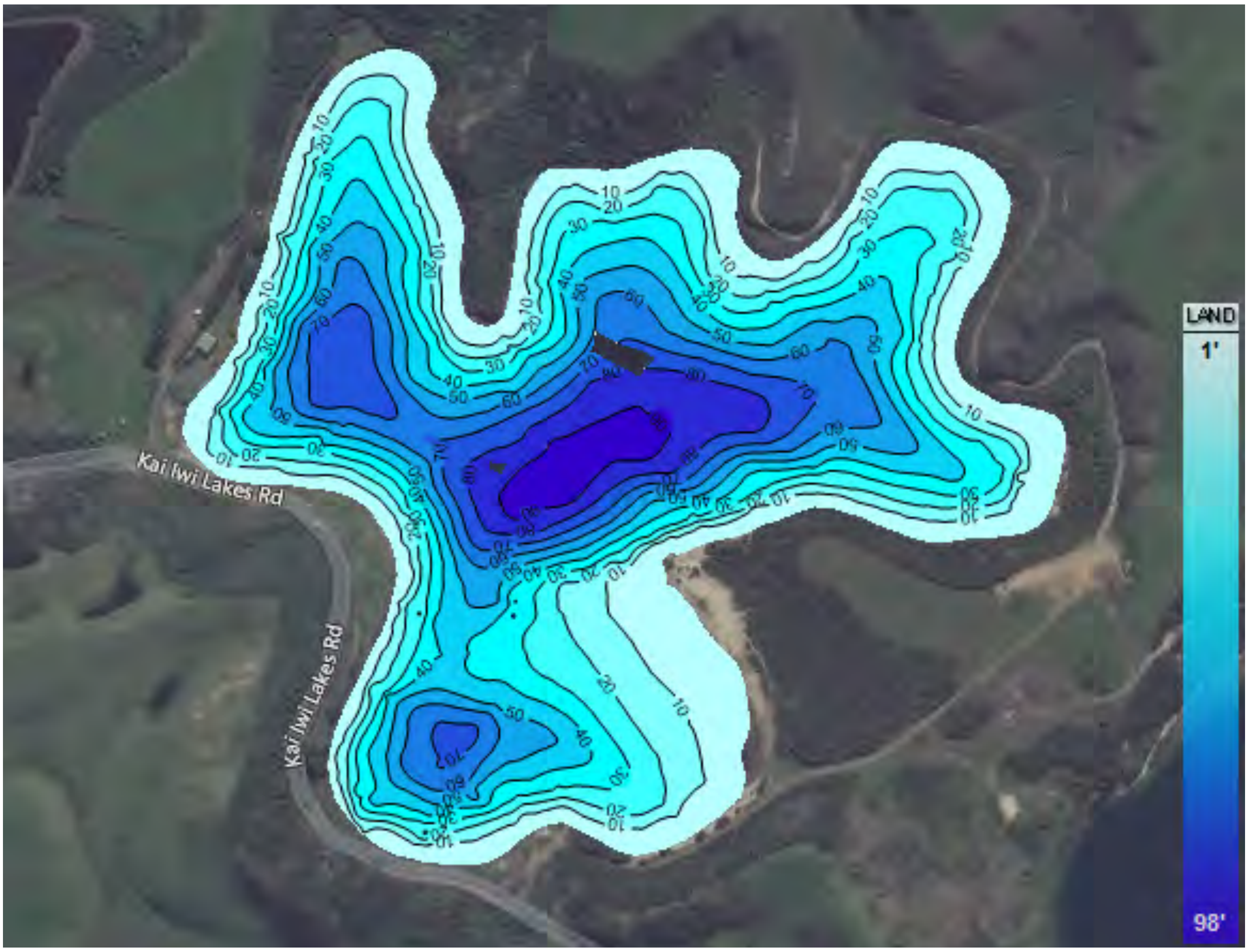
Lake Kai Iwi

The bathymetry of Lake Taharoa is complex with a deep central basin of 38.81 m linked to two shallower basins, as well as a discrete, nearly closed basin at its western end. The many steep drop-offs do not provide much habitat for a littoral fringe of emergent plants. Mean lake depth is 16.42 m.



Lake Taharoa

Lake Waikare has three basins with the central basin deepest at 29.48 m and a mean lake depth of 10.95 m. The undulating shoreline has steep drop-offs to the west and more gradual slopes to the east of each arm. Habitat favours the eastern edges for littoral emergent plant communities.



Lake Waikare

6.7. Natural inlets and outlets

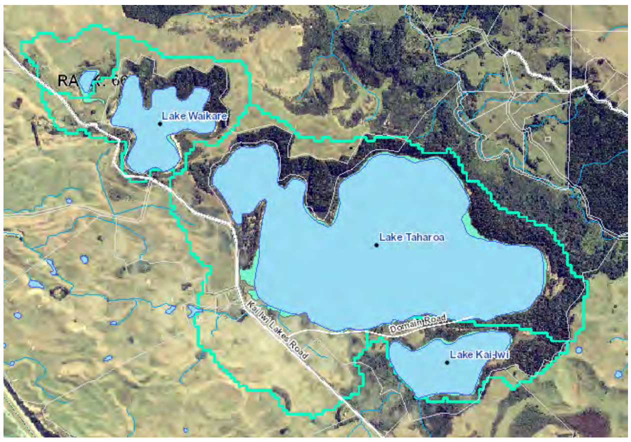
There are two inlets into Lake Kai Iwi; from Lake Taharoa and to the southern end of the lake. There are no outlets.

There are minor drains into Lake Waikare and no outlets.

As was mentioned in the geomorphology section, the Kai Iwi and Ureti Stream provide broken links to the Tasman Sea, so are of interest from an eel ecology perspective.

6.8. Wetland associations

The minor wetland fringes appearing in the image below in medium green are all of 'Top 150 Wetland' value.



6.9. Connectivity

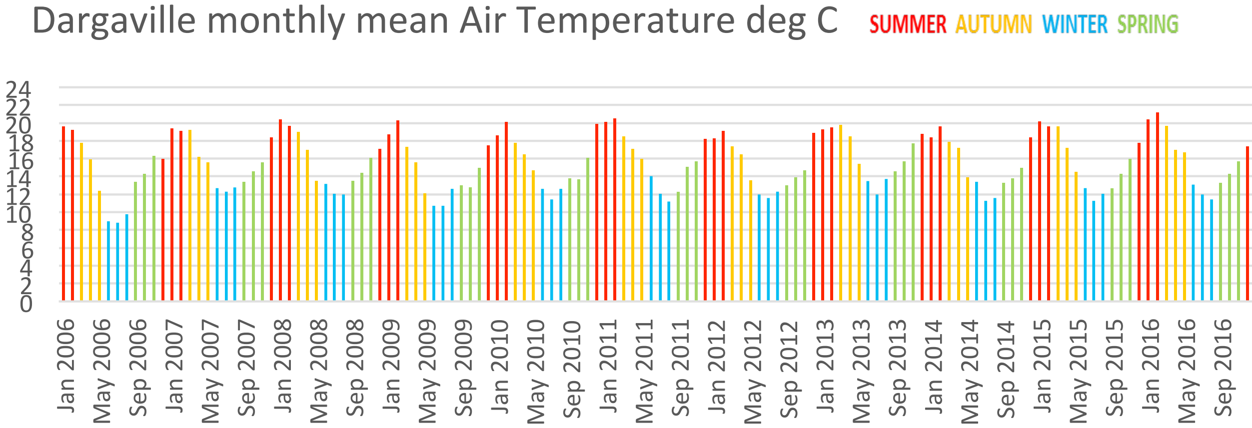
Lake Kai Iwi is connected to Lake Taharoa by a man-made channel, as shown in the adjacent image.

Lake Waikare is not connected to any other water body.

6.10. Air Temperature

Minor inter-annual seasonal peaks and troughs in air temperature, using Dargaville weather data as a proxy, see summer highs ranging from 19.1 – 21.2 degrees Celsius in summer and winter troughs between 8.8 – 12.3 degrees Celsius. Air temperature and sunshine affect water temperature which regulates the seasonal egg development activation of *Gambusia* starting when water temperature reaches 14 degrees C and pregnancy at 18 degrees C. These ranges are important for *Gambusia* control timing.

Dargaville monthly mean Air Temperature deg C

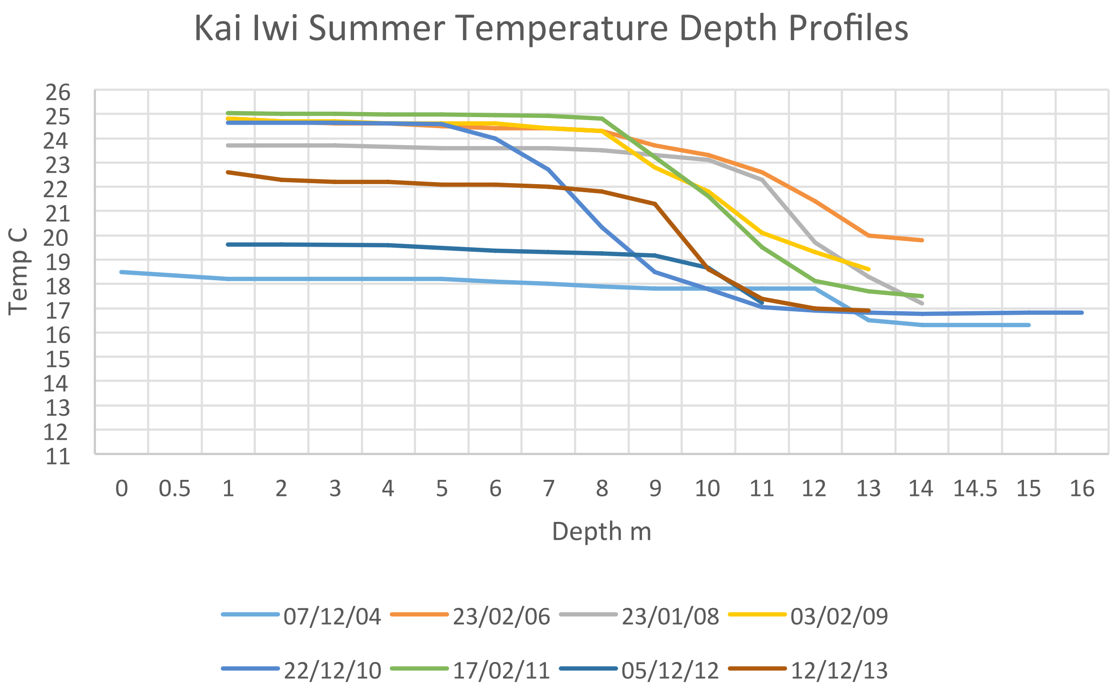


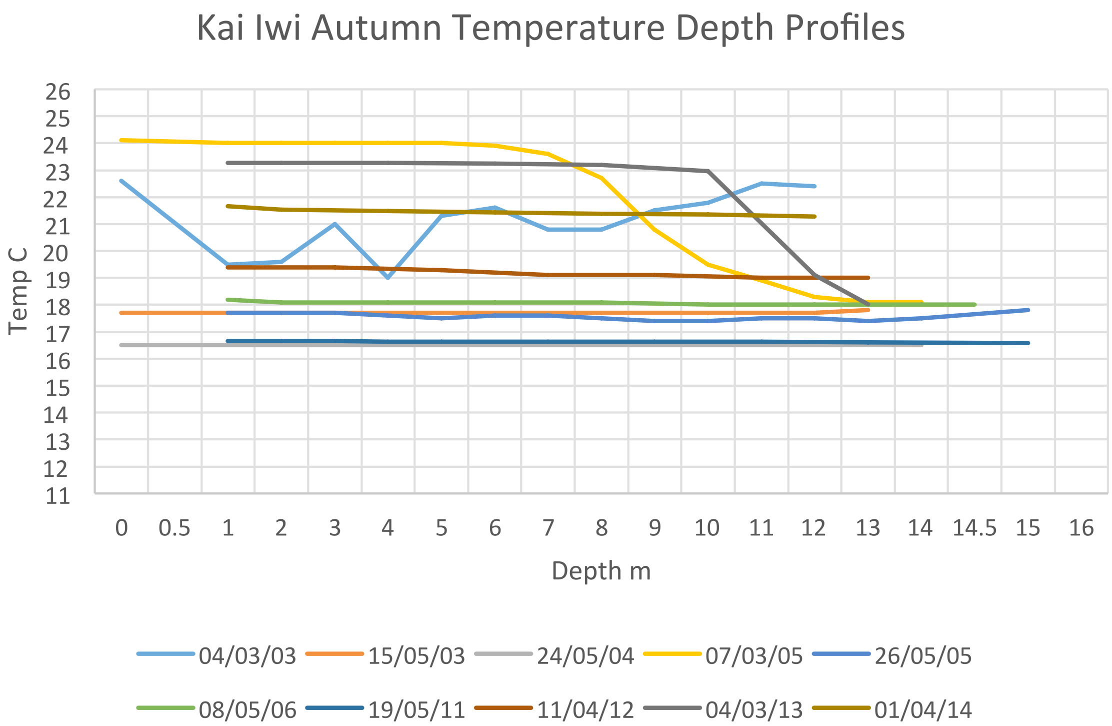
6.11. Thermal stratification

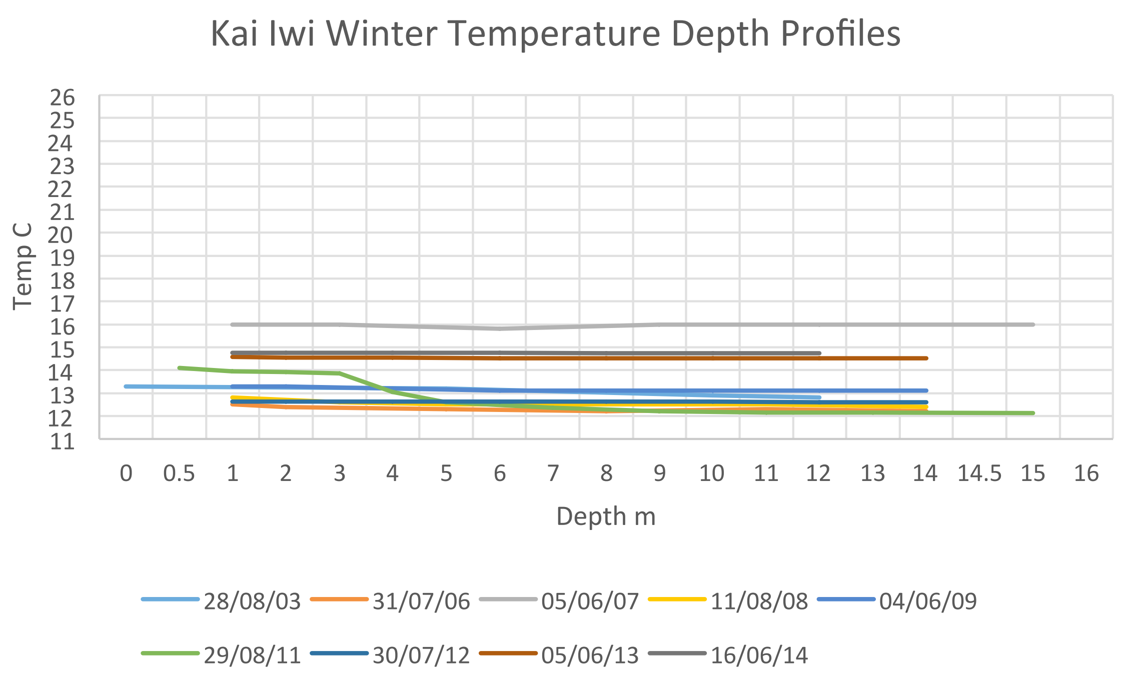
All three lakes meet the 10m-limit for thermal stratification to occur. The following graphs show a linear scatter-plots of days sampled for thermal profiling of the water column.

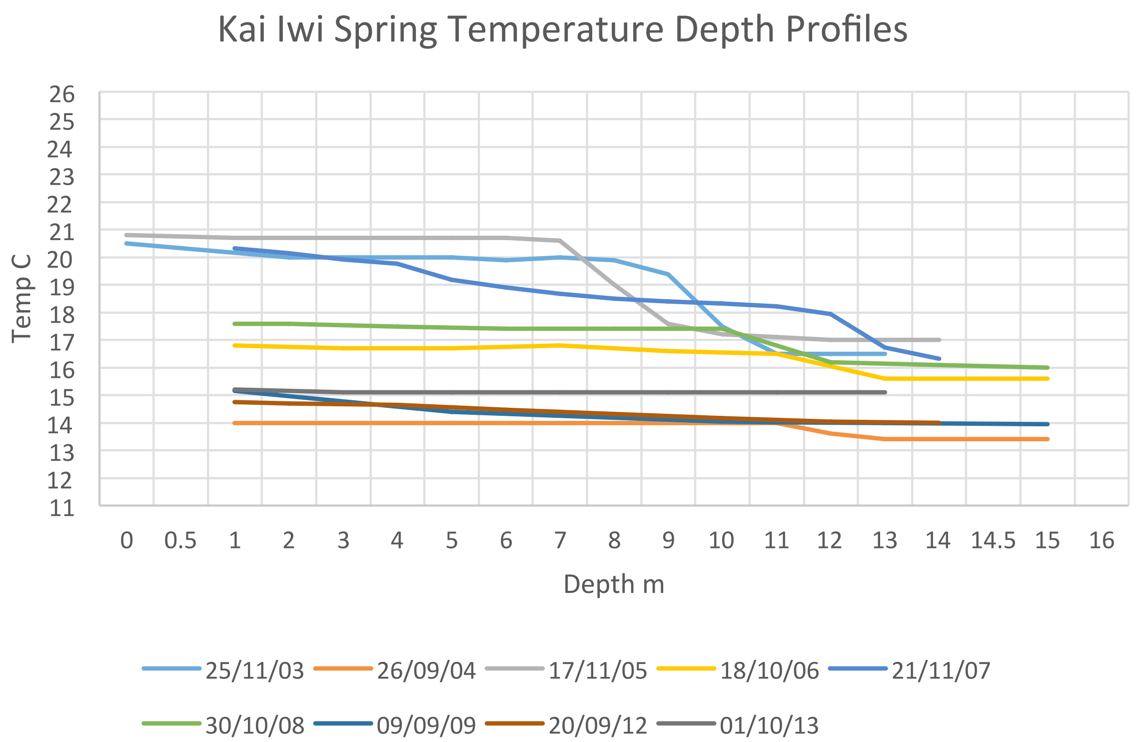
During stratification, nutrients are locked into the lower, colder strata, limiting availability for microplankton growth in the upper, warmer water column. When lines in the graphs appear solely horizontal, this indicates a more homogeneous temperature of the water column and therefore thorough mixing of nutrients in winter months June - August.

Lake Kai Iwi thermally stratifies with development of a thermocline between 5 m (late December) and 10m (early March) with maximum surface temperature at 25 degrees C and bottom temperatures as low as 15.6 degrees C during stratification. Minimum winter bottom temperature is 12.13 degrees C in late August.


Kai Iwi Summer Temperature Depth Profiles
Temp C
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 14.5 15 16
Depth m
07/12/04
23/02/06
23/01/08
03/02/09
22/12/10
17/02/11
05/12/12
12/12/13


Kai Iwi Autumn Temperature Depth Profiles
Temp C
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 14.5 15 16
Depth m
04/03/03
15/05/03
24/05/04
07/03/05
26/05/05
08/05/06
19/05/11
11/04/12
04/03/13
01/04/14


Kai Iwi Winter Temperature Depth Profiles
Temp C
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
0
0.5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
14.5
15
16
Depth m
28/08/03
31/07/06
05/06/07
11/08/08
04/06/09
29/08/11
30/07/12
05/06/13
16/06/14


Kai Iwi Spring Temperature Depth Profiles
Temp C
26
25
24
23
22
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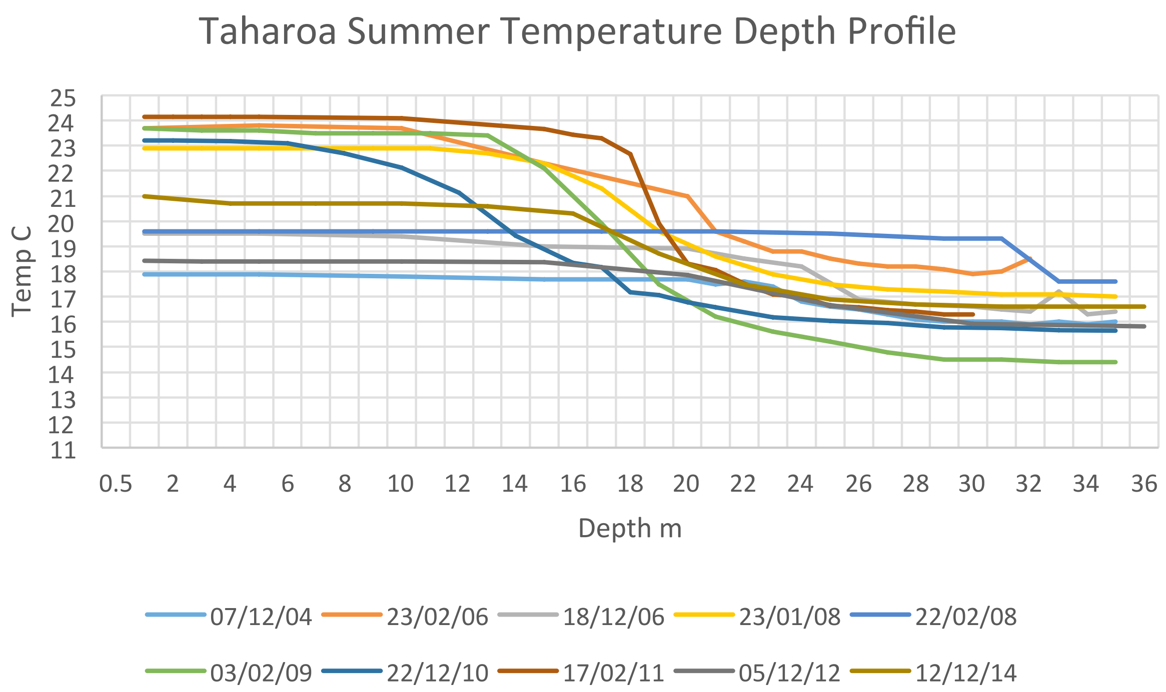
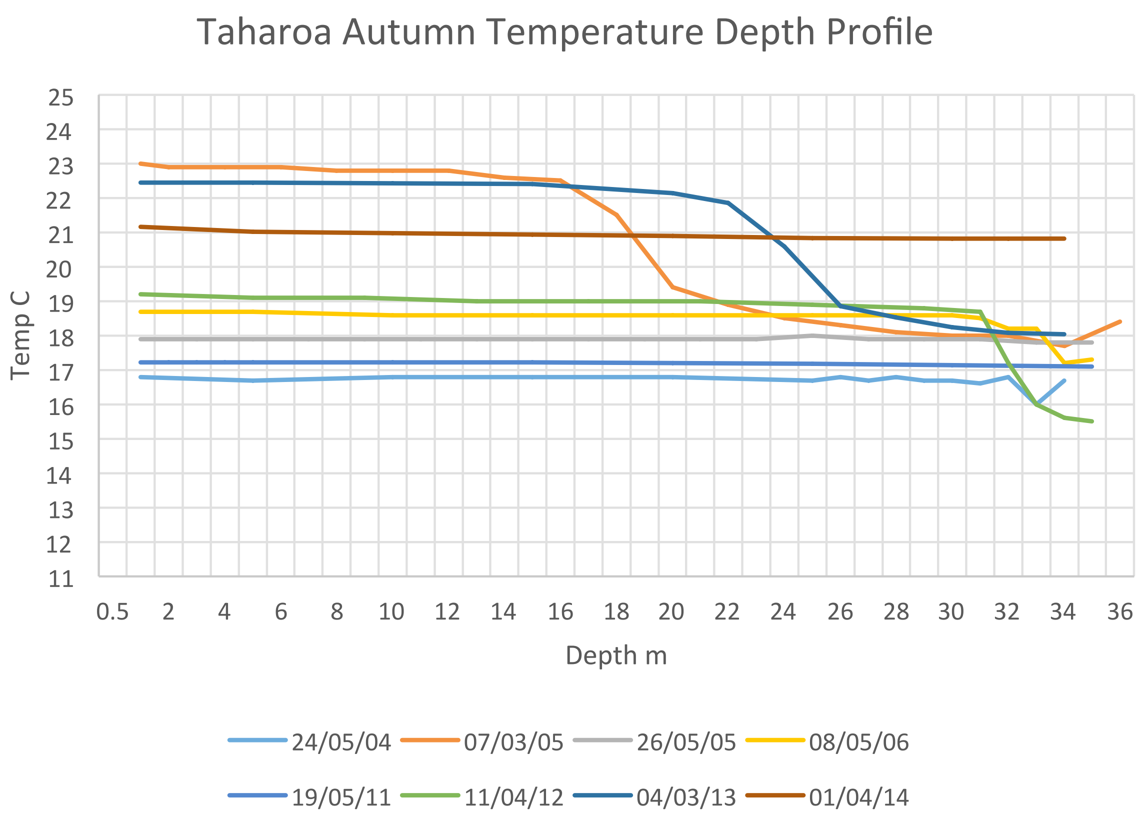
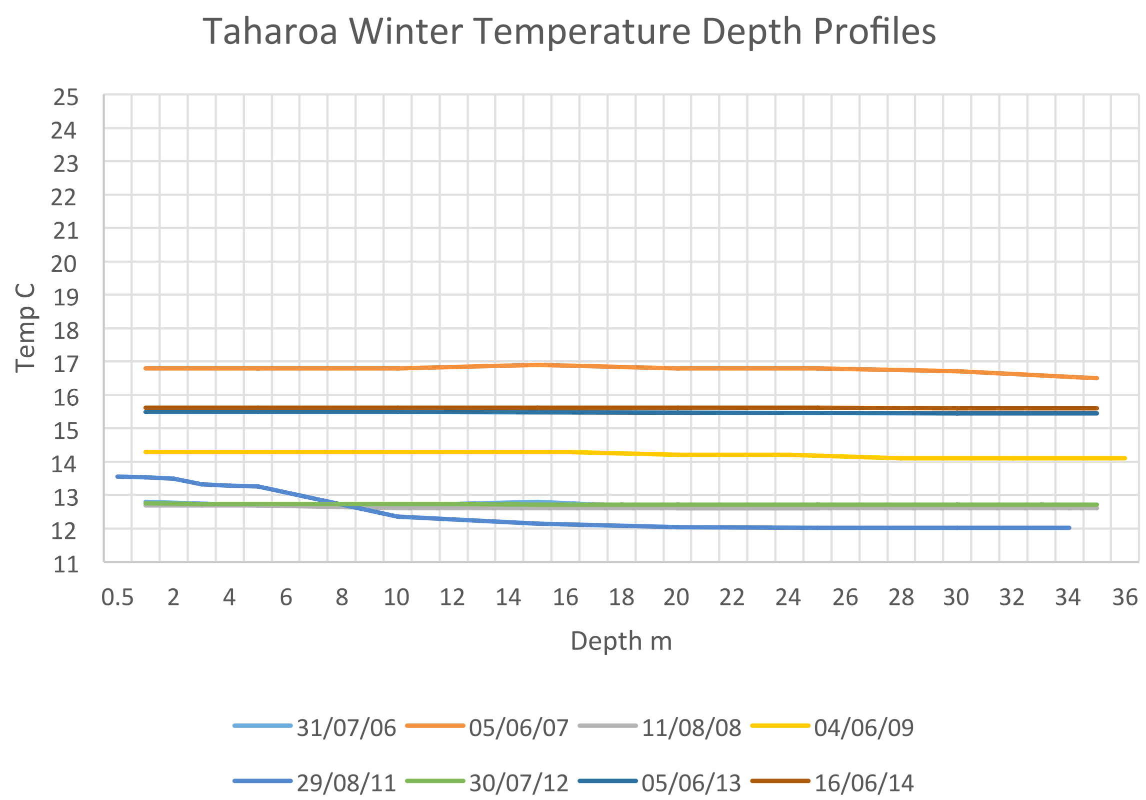
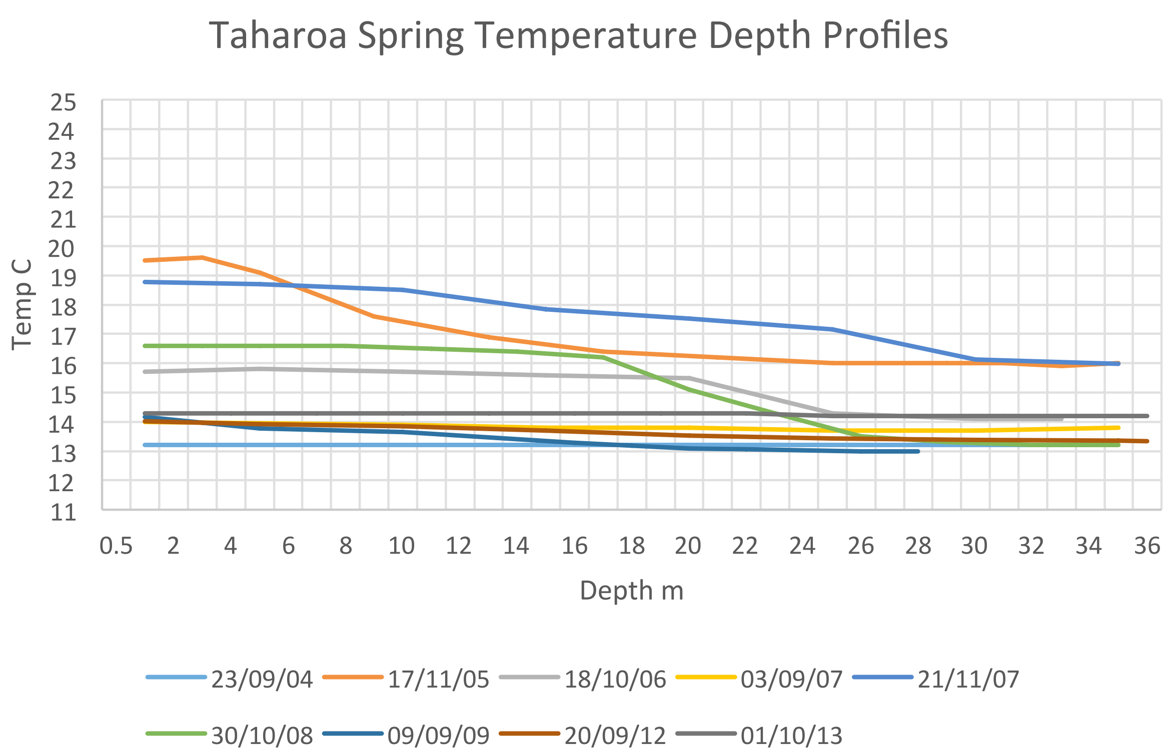
18
17
16
15
14
13
12
11
0
0.5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
14.5
15
16
Depth m
25/11/03
26/09/04
17/11/05
18/10/06
21/11/07
30/10/08
09/09/09
20/09/12
01/10/13

Lake Taharoa thermally stratifies at between 6 m (late December) and 22 m (early March) with maximum surface temperature around 25 degrees C and bottom temperatures of 16 degrees C during stratification. Minimum winter bottom temperature is 12.02 degrees C in late August.






Taharoa Winter Temperature Depth Profiles
Temp C
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Depth m
31/07/06
05/06/07
11/08/08
04/06/09
29/08/11
30/07/12
05/06/13
16/06/14


Taharoa Spring Temperature Depth Profiles
Temp C
25
24
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21
20
19
18
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16
15
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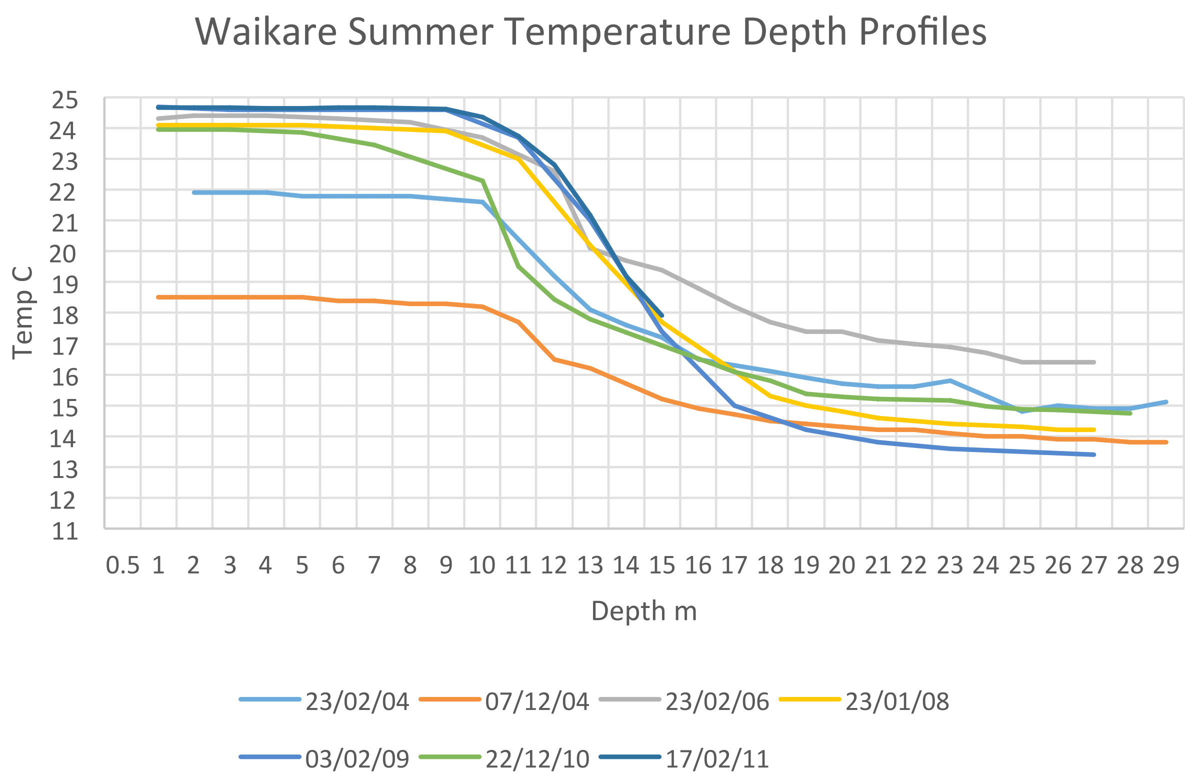
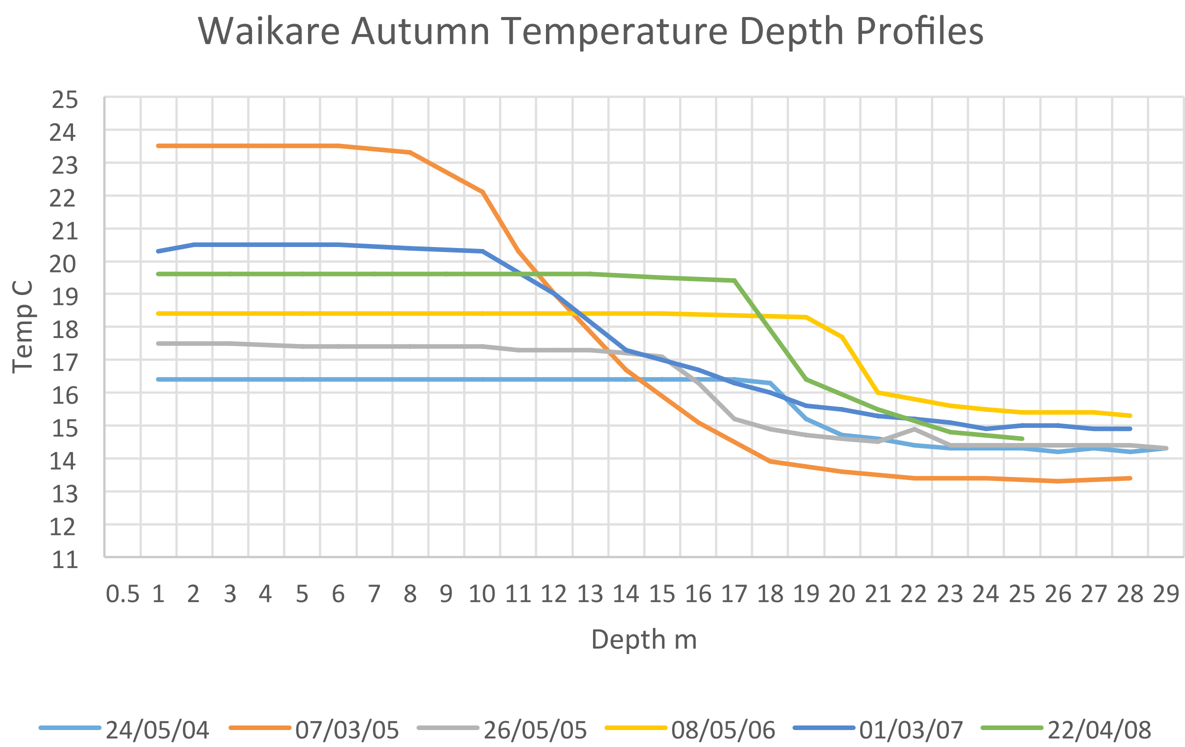
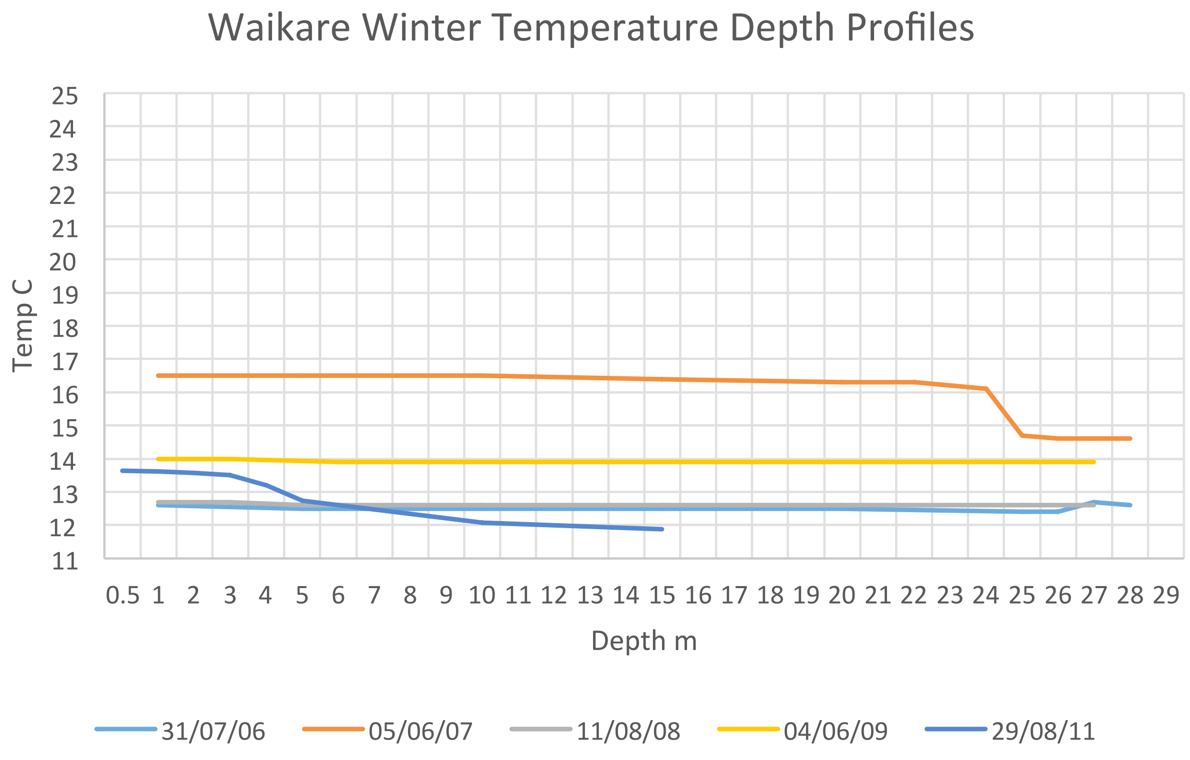
13
12
11
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Depth m
23/09/04
17/11/05
18/10/06
03/09/07
21/11/07
30/10/08
09/09/09
20/09/12
01/10/13

Lake Waikare has a marked thermal stratification at between 8 m (late December) and 17 m (late April) with maximum surface temperature around 25 degrees C and bottom temperatures as low as 14.3 degrees C during stratification. Minimum winter is 11.88 degrees C at 15 m in late August.






Waikare Winter Temperature Depth Profiles
Temp C
25
24
23
22
21
20
19
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15
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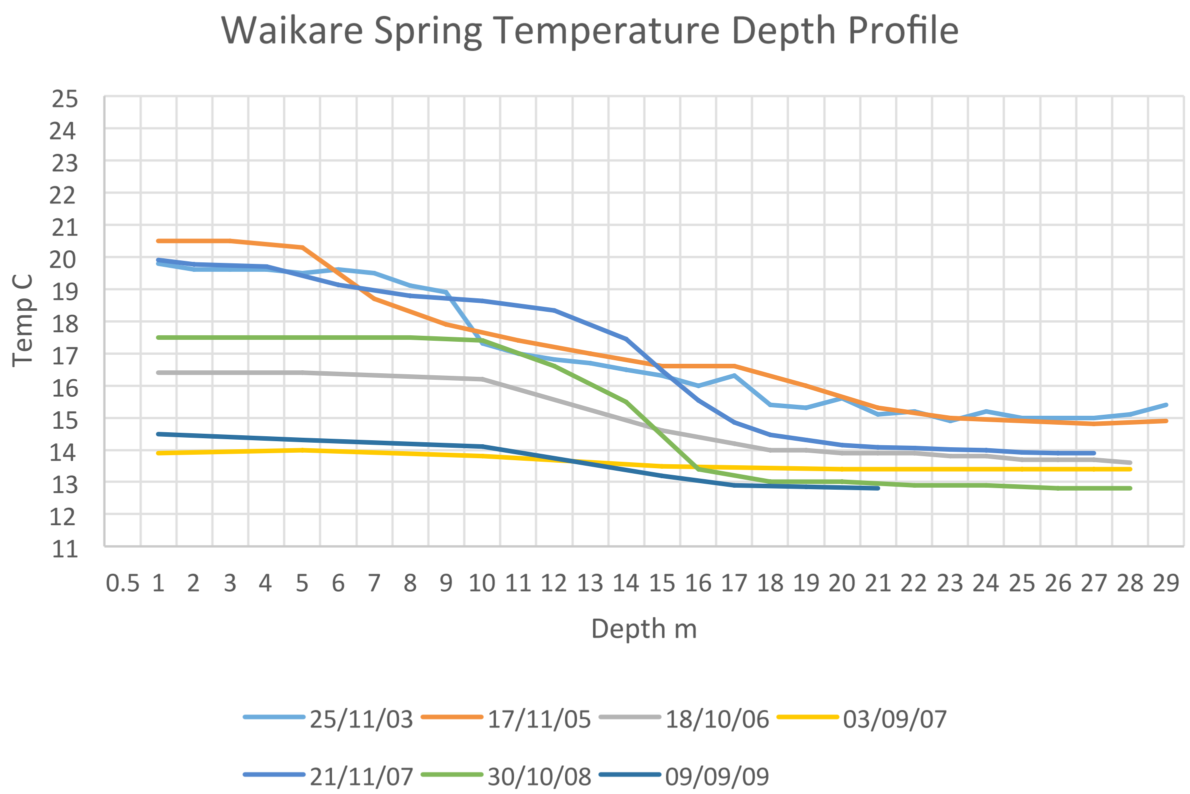
13
12
11
0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Depth m
31/07/06
05/06/07
11/08/08
04/06/09
29/08/11


Waikare Spring Temperature Depth Profile
Temp C
25
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21
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15
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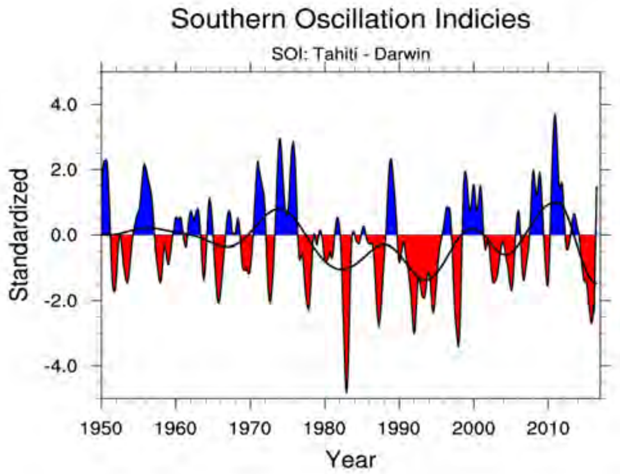
13
12
11
0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Depth m
25/11/03
17/11/05
18/10/06
03/09/07
21/11/07
30/10/08
09/09/09

6.12. Rainfall and drought

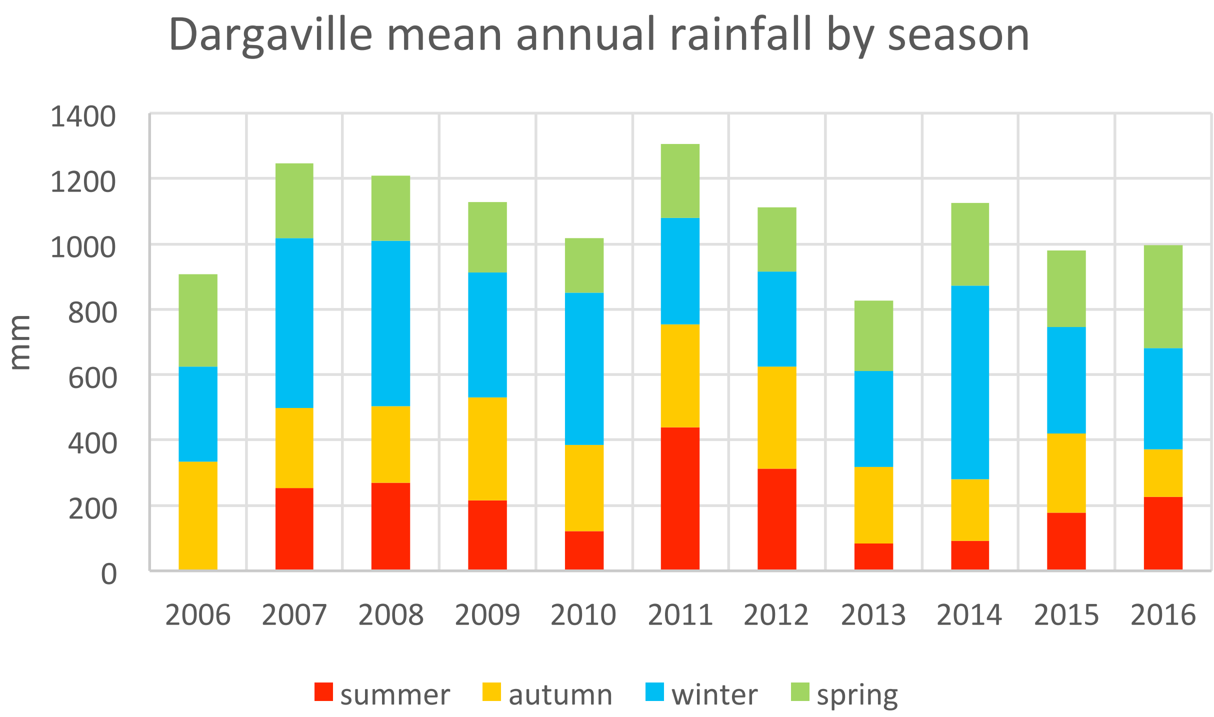
Extremes of flood and drought are marked on the west coast of Northland. Lake Taharoa receives 74% of its water from rainfall with 60% for both Kai Iwi and Waikare (table below).

Lake	% rainfall	% surface runoff	% rain + runoff	% ground-water
Kai Iwi	60	10	70	30
Taharoa	74	9	83	18
Waikare	60	33	93	8

Higher periods of rain are likely associated with the Southern Oscillation Index periods of El Nino conditions (blue peaks below).s



Dargaville is used as a proxy in the rainfall chart, following. Note that "summer" includes the December from the year before along with January and February of the calendar year shown. The 2006 summer data is not available since December 2005 data was not available. Lake Kai Iwi receives 30% of its water from groundwater sources so will experience a lag period between heavy rains in the ranges and associated lake level height.



6.13. Lake level

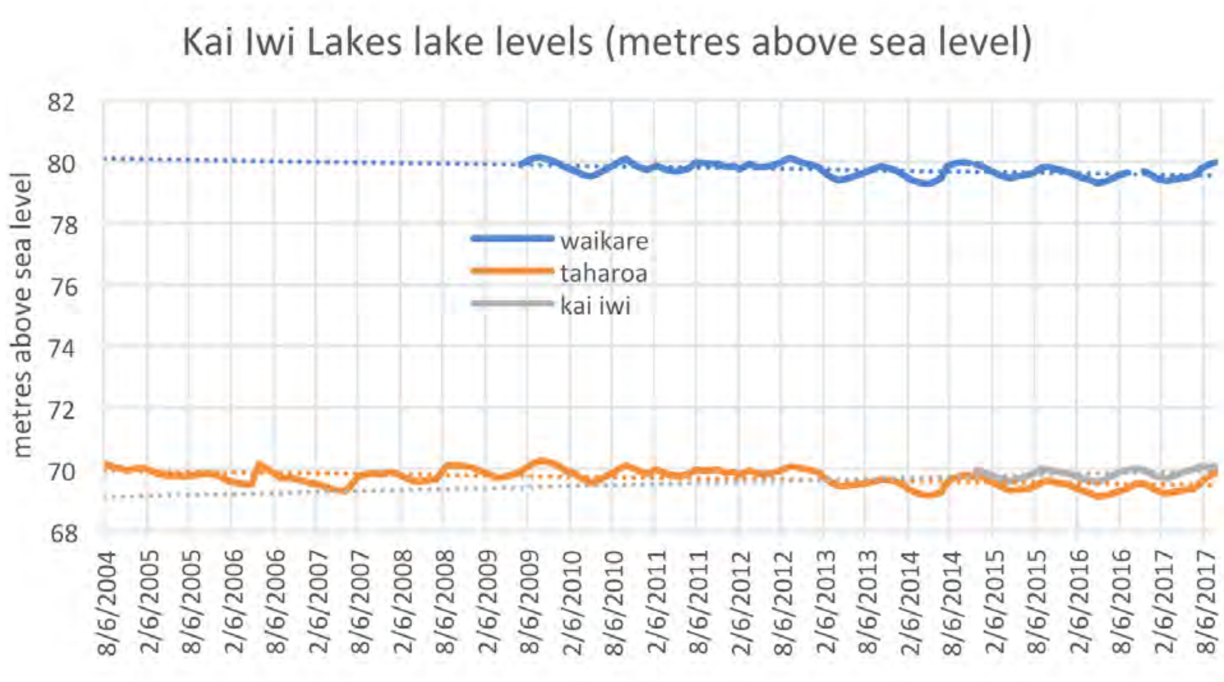
The graph below shows lake level for each lake, expressed in metres above sea level. The varying length to the three timelines is due to breakages in the staff gauges through time, so only the latest series for each lake has been used. Note that Waikare sits at a higher altitude at 10m above Taharoa and Kai Iwi. Kai Iwi is slightly higher than Taharoa and field observation confirms that the flow in their connecting channel moves from Kai Iwi to Taharoa.

The localised influence of rainfall and evaporation can be seen in the co-varying height trends in all three lakes, which generally rise and fall together.

Kai Iwi has a relatively larger FENZ catchment size to lake volume and the higher influence of groundwater (30%) from the ranges compared to the other two lakes. This may suggest why Kai Iwi has the densest reed belt of all three lakes, with few periods of the littoral zone drying out. It's overall trend, though short, shows a steady rise in lake level.

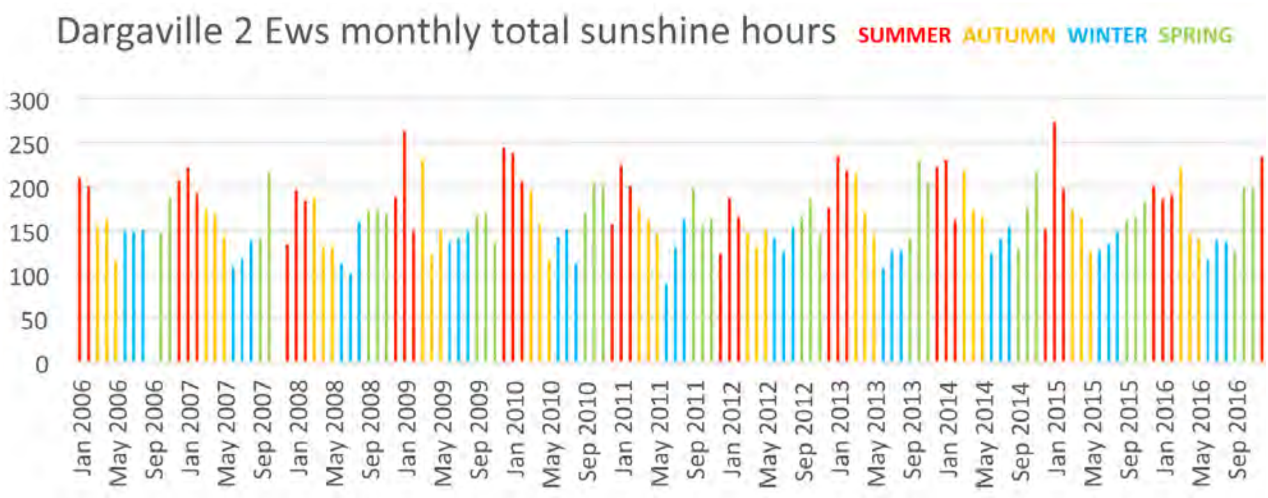
Lake Taharoa is the lake most influenced by rainfall (74%) and the least influenced by surface run-off (9%). Groundwater influence is 18%. This explains the sensitivity this lake has to the effects of heavy rain or drought conditions. Over its long timeline the trend is a slow decline in level, although lake levels are currently equal to the historic maximum.

Likewise, Lake Waikare is similar to Lake Taharoa in its seasonal variations in lake level and longer-term decline, although, once again, it is near to its historic maximum level. However, Waikare has and opposite relationship to Taharoa in its run-off verses groundwater influence with Waikare having 33% run-off and only 8% groundwater in comparison to Taharoa's 9% run-off and 18% groundwater. Therefore, Waikare is more subject to threats from land use.



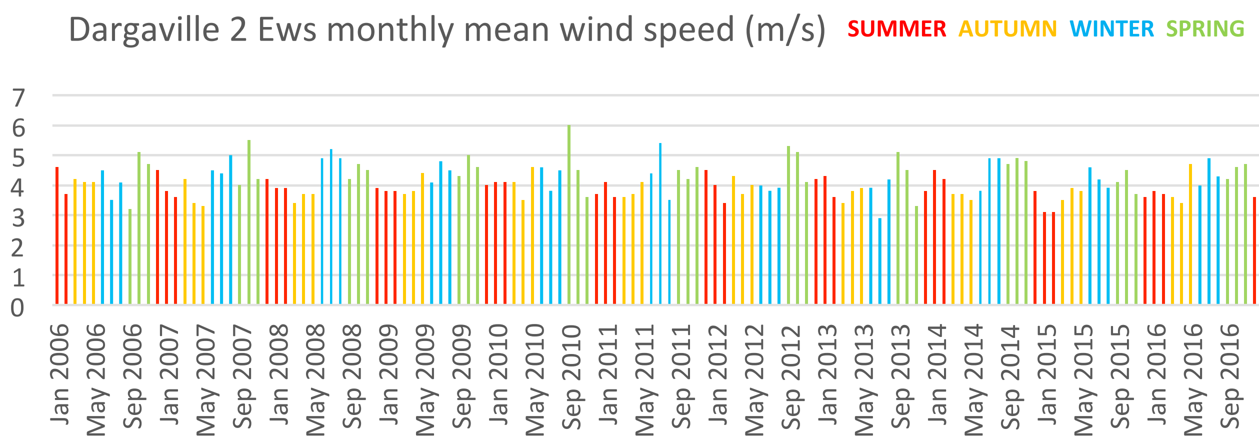
6.14. Sunshine

As was previously mentioned, sunshine hours affect temperature and evaporation rates just as rainfall affects a lake positively. Dargaville data is used as a proxy. Sunshine also affects the health of the macrophyte community by increasing plant growth in these low nutrient, high visibility lakes.



6.15. Wind Speed

Wind-speed has several effects on the lakes. One is mixing of the water column where displaced surface water if replaced by deeper water from the windward side of the lake. Nutrients from deeper water will have more influence on the western shores as a result. The fetch of the wind also creates wave action which erodes eastern shores, affecting both littoral plant growth there and some fish activity negatively. This is an indication that habitat in the west will likely be preferable to littoral fish, both due to plant habitat structure, low disturbance and possibly larval distribution into the central limnetic zone advantages. Wind in this region is usually steady with spring and winter peaks.



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

It is very useful to observe patterns in these three lakes together. Their differing trends are influenced by independent catchment boundaries, land use in those catchments and differing water retention time. To interpret the water clarity indicators, Total Suspended Solids and Chlorophyll-a are read as the lower the blue and green lines, the better the clarity and Secchi depth read as the higher the red line the better the clarity.

Firstly, the Secchi disk depth for all three lakes are exceptional and the best in Northland. Depths of 10.7, 18 and 13 m maximum for each lake mean a black and white quadrant metal disk is visible from the surface at those depths.

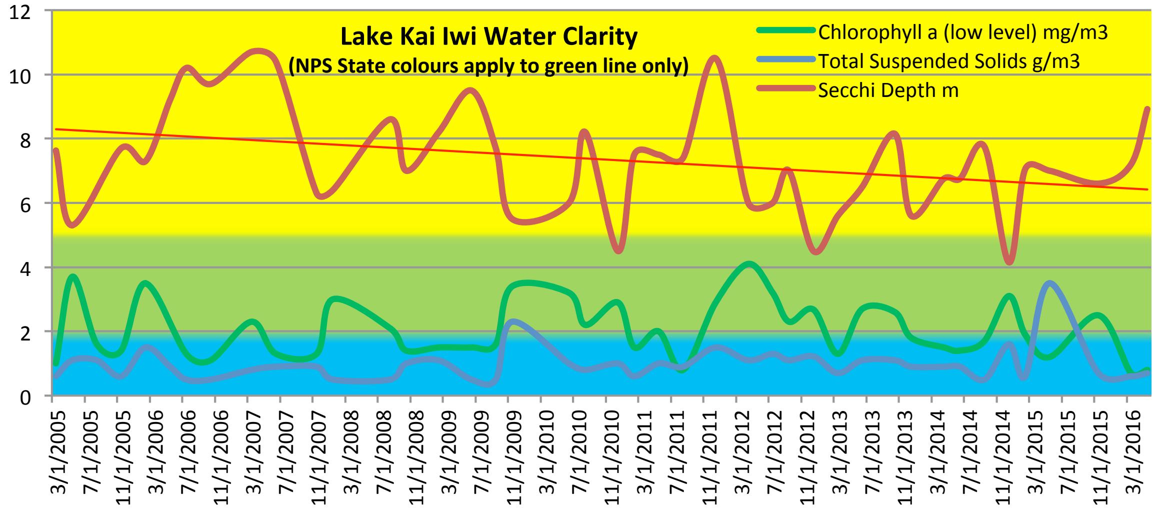
When the Chlorophyll-a and Total Suspended Solids peak, Secchi drops. This is due to poorer visibility due to either micro-algal growth (green line) or the Total Suspended Solids, an influence of a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage associated with run-off (blue line).

Kai Iwi experiences a long-term Secchi decline and the other two lakes, only slight improvement. However, Kai Iwi has seen improvement in 2017 (not shown). Also, the Chlorophyll-a trends show many small algal events in both Kai Iwi and Waikare with relatively fewer in Taharoa. Remembering that Kai Iwi has the largest catchment and the greatest influence from pasture and that Waikare has a direct drain from pastureland, these trends are not surprising. Where a blue suspended solid peak is seen without an immediate corresponding algal event (green line), it is likely that a intense weather event had occurred during or just prior to that sampling period.

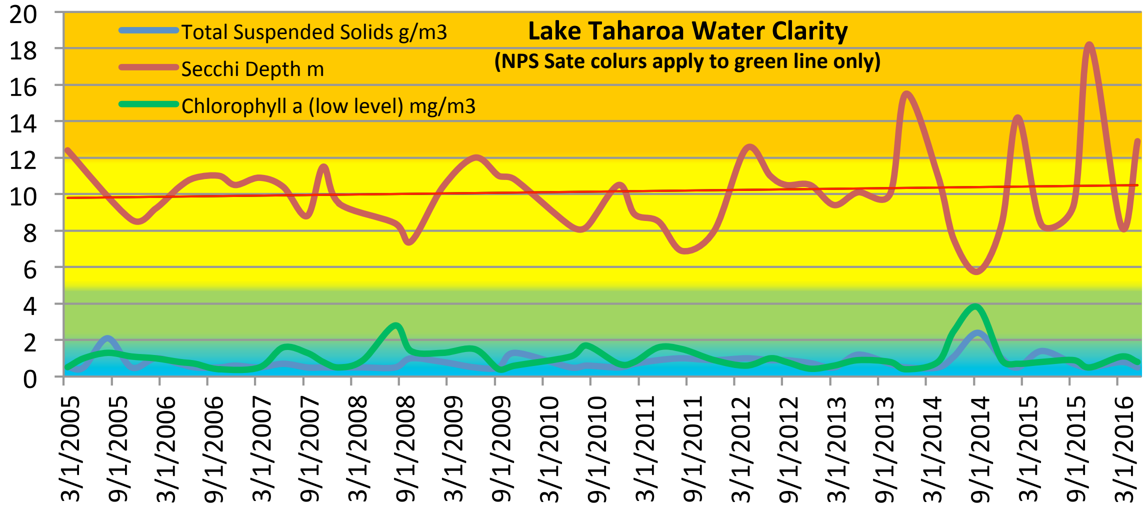
The table below shows the National Policy Statement for Freshwater Management states for phytoplankton (chlorophyll-a). These states are used as colours in the graphs for chlorophyll-a (green line) only.

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.

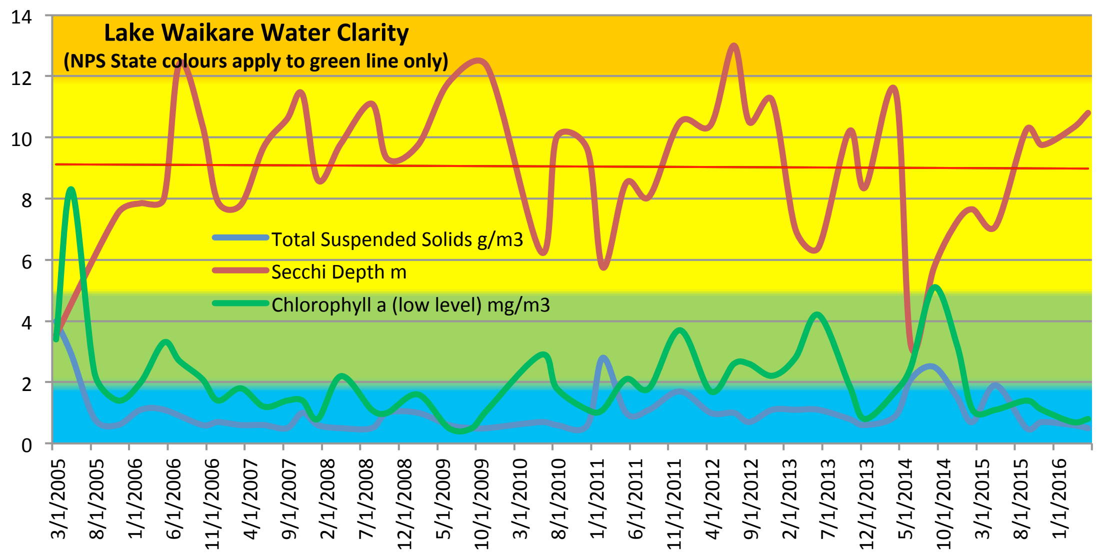
Kai Iwi Chlorophyll-a trend rides the line between States A and B, weighted heavier towards B. The NPS State colours apply to the green line only.



Taharoa Chlorophyll-a trend stays cleanly within State A, other than during periodic small events moding into State B and returning to A afterwards. The NPS State colours apply to the green line only.



Waikare Chlorophyll-a trend is more similar to Kai Iwi than Taharoa, yet is even more pronounced, crossing over or verging into State C on occasion and recently favouring State B. This could indicate degradation of the condition of this lake which would be of concern. The NPS State colours apply to the green line only.



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 the Kai Iwi Lakes. Significant results are highlighted. For the years and seasons assayed, each lake exhibits a different seasonal and limiting nutrient signature. Lake Kai Iwi is limited by phosphorus in Autumn, Lake Taharoa by nitrogen plus phosphorus in autumn and Waikare by nitrogen plus phosphorus in summer. No significant chlorophyll-a values were seen in any of the three lakes. This is confirmed by the trends in nitrogen and phosphorus following this section. Of the three lakes, Kai Iwi shows highest and increasing trend in nitrogen with both other lakes showing decline in nitrogen and all three lakes showing decline in phosphorus

	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
Kai Iwi	1.1	0.9	0.78	1.00	1.04	1.23	1.15	-0.08	1.00	1.00	1.00
	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
Taharoa	1.7	0.7	0.98	1.19	0.98	1.04	1.14	0.10	1.00	1.00	1.00
	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
Waikare	1.1	1.0	0.88	0.93	0.90	0.90	0.87	-0.03	0.89	1.00	1.11

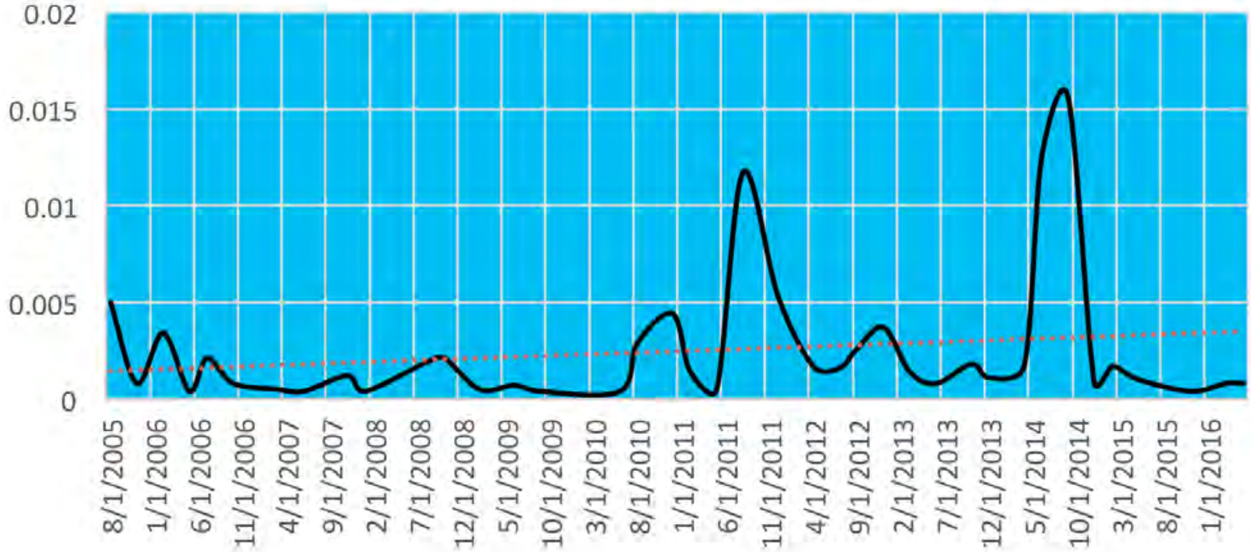
7.1.1.2. Ammoniacal Nitrogen (Toxicity)

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.

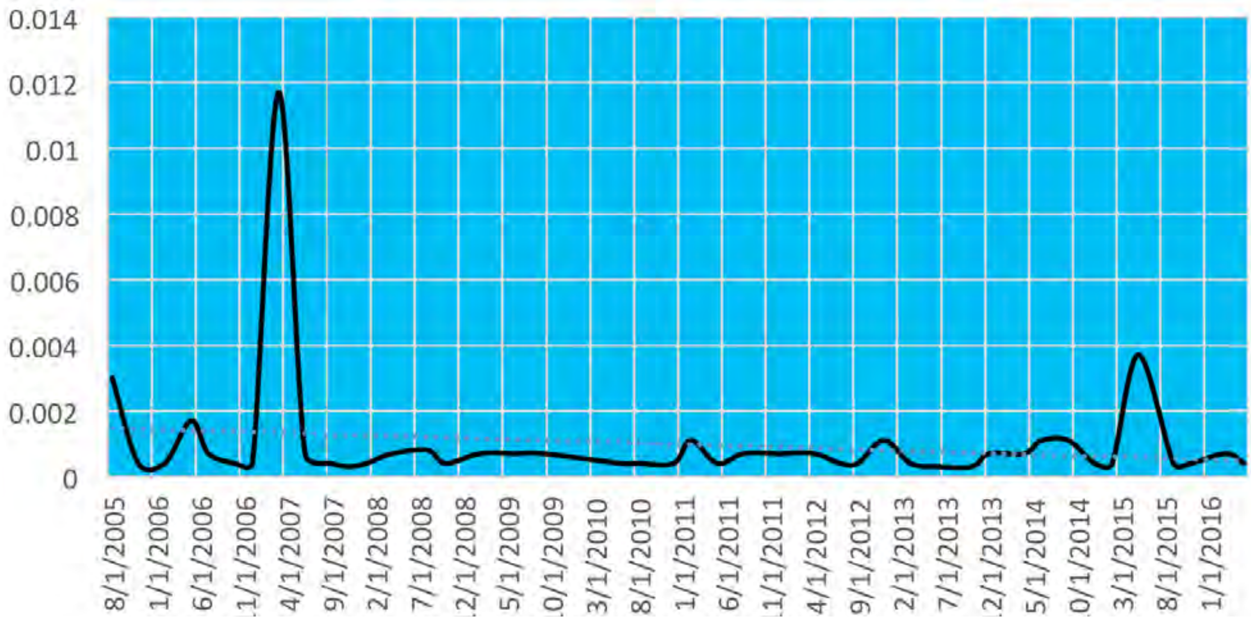
The table before the graphs shows the National Policy Statement Freshwater Management limits for lake state. has remained in State A or low ammonia toxicity levels. All three lakes are well within State A.

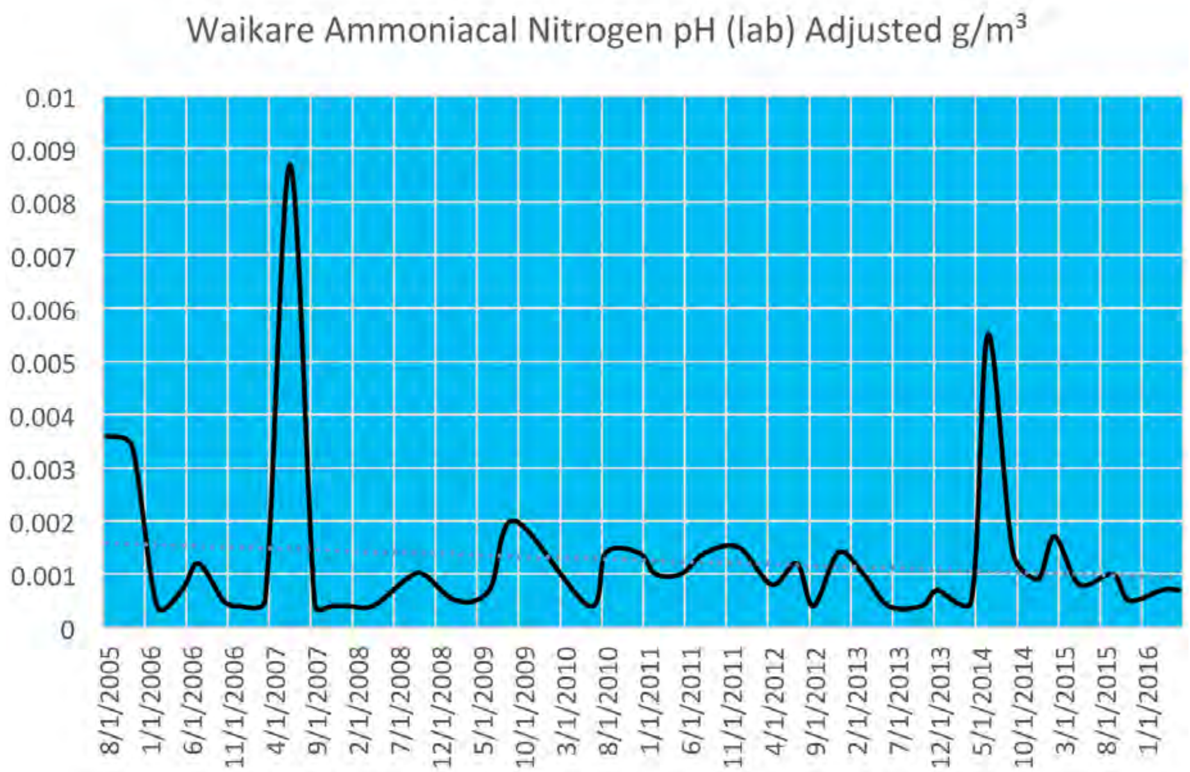
Attribute	Unit	Lake Type	State	Annual Median	Annual Maximum	Narrative State
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested
Ammonia (Toxicity)	mg NH4-N/L (mg ammoniacal-nitrogen per litre)	All	B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

Kai Iwi Ammoniacal Nitrogen pH (lab) Adjusted g/m³



Taharoa Ammoniacal Nitrogen pH (lab) Adjusted g/m³





7.1.1.3. Nitrogen

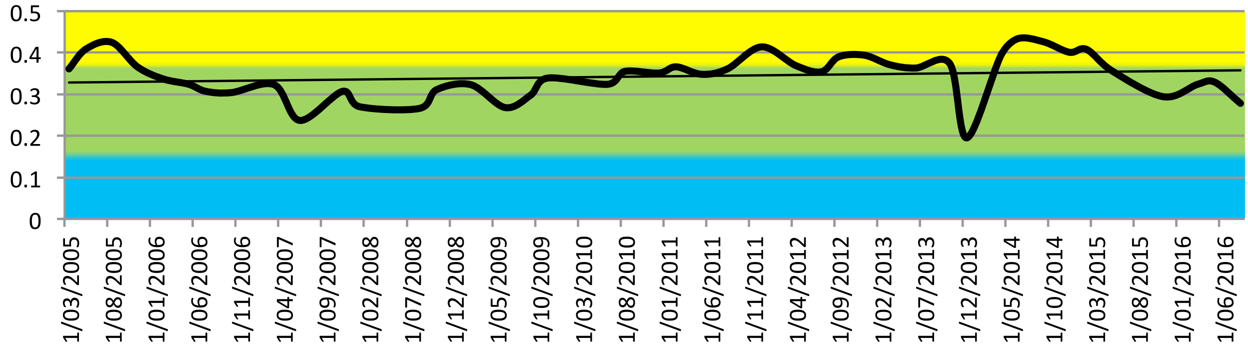
The following graphs show a total nitrogen timeline for each lake from 2005-2016. The trendline for lake Kai Iwi is the highest nitrogen levels and on a gradual rise, Taharoa is low and stable and Waikare is low to moderate and on a slow decline. Nitrogen sources are associated with farming practices and both Kai Iwi, with the largest catchment and the most influence from pastoral percentage catchment cover, as well as the farm drain into Waikare explains these trends.

The table following the chart shows the National Policy Statement for Freshwater Management limits for lake state.

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.

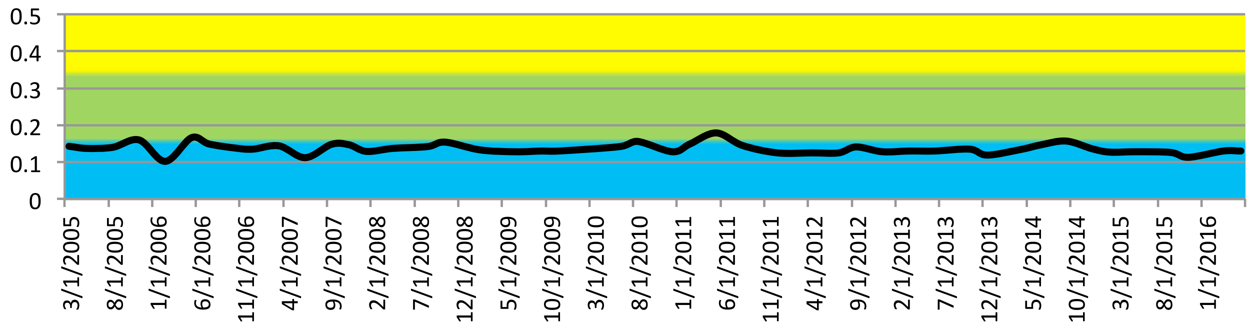
Nitrogen in Kai Iwi has pushed into State C on several occasions, but tends to clear back into State B.

Lake Kai Iwi
Total Nitrogen (TN) g/m3-N



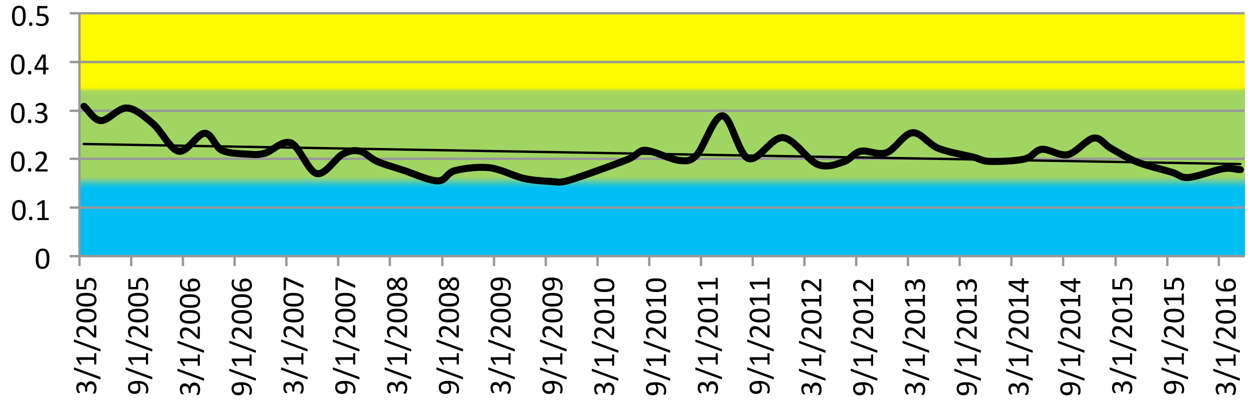
Nitrogen for Taharoa is generally a high State A.

Lake Taharoa
Total Nitrogen g/m3



Nitrogen for Waikare is consistently in State B.

Lake Waikare
Total Nitrogen g/m3



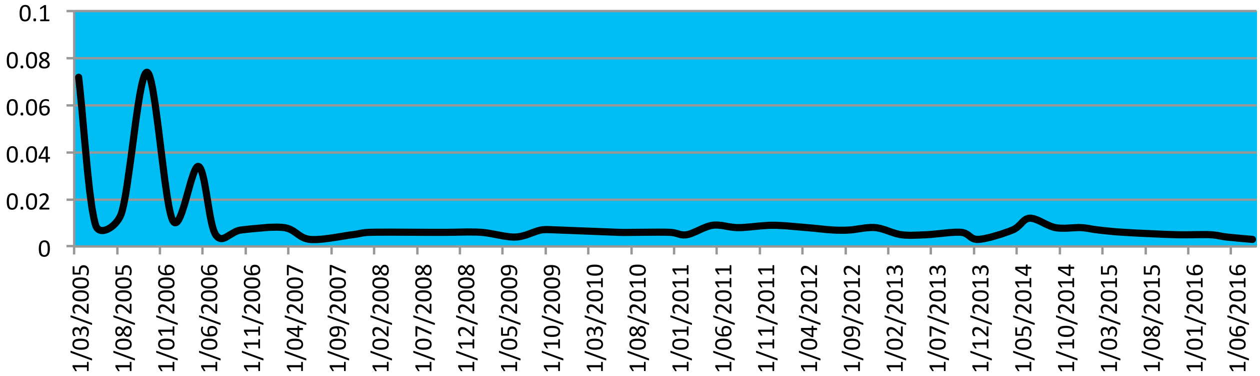
7.1.1.4. Phosphorus

Total phosphorus levels, as seen in the graphs below, are all very low and stable. The early high peaks could either be a sampling anomaly or, else, could indicate signals from forestry harvest in the catchments which occurred roughly the same time as these peaks.

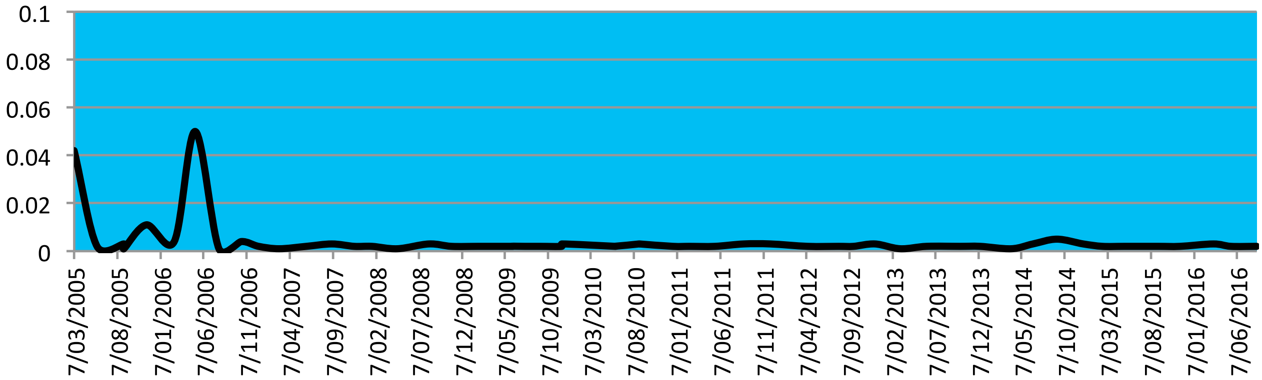
The following table shows the National Policy Statement for Freshwater Management limits for lake state for phosphorus. All three lakes are well within State A. Early rises, still within State A, may reflect forestry harvest but may also be early sampling error.

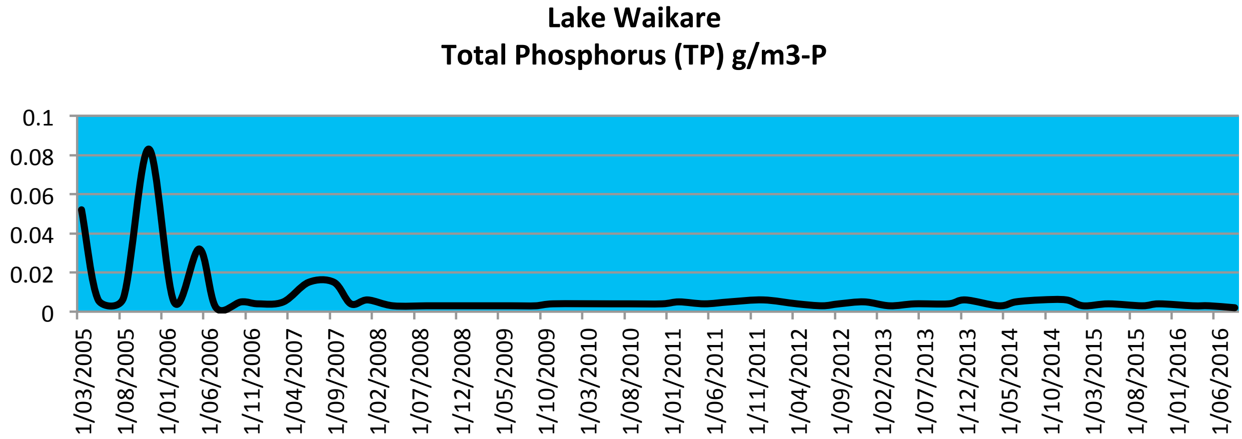
Attribute	Unit	Lake Type	State	Annual Median	Narrative State
Total Phosphorus (Trophic state)	g/m3	All	A	≤.01	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
Total Phosphorus (Trophic state)	g/m3	All	B	>.01 and ≤.02	Lake ecological communities are slightly 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.

Lake Kai Iwi
Total Phosphorus (TP) g/m3-P



Lake Taharoa
Total Phosphorus (TP) g/m3-P

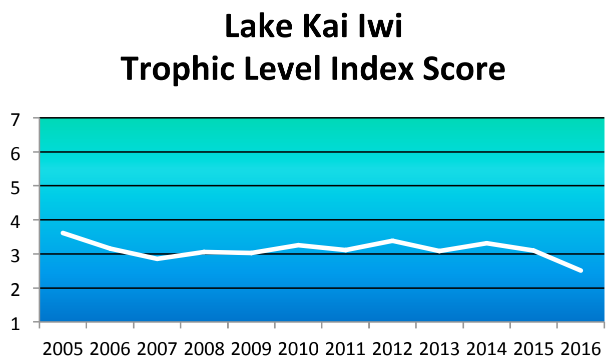


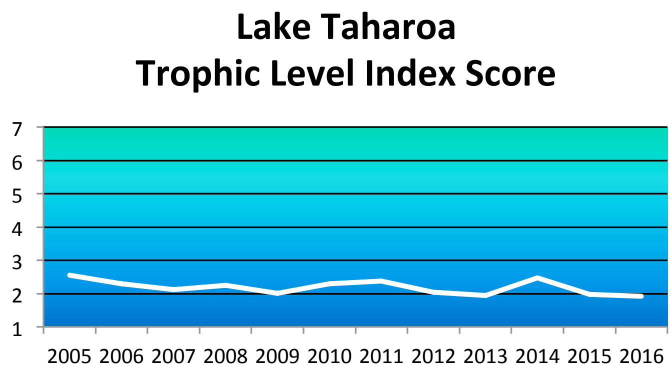


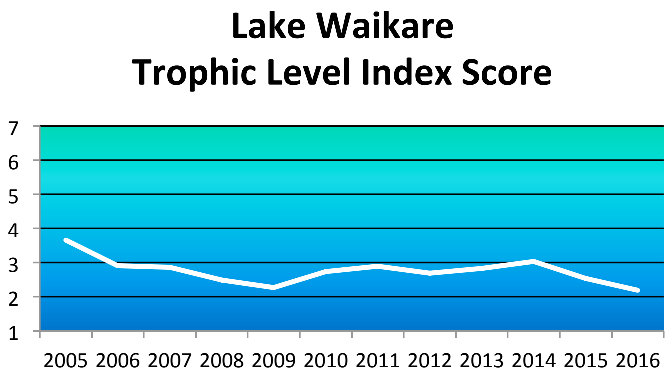
7.1.1.5. Trophic Level Index

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 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. Kai Iwi has had a long trend as low mesotrophic and has recently improved into the oligotrophic band. Taharoa is low oligotrophic (good water quality) and enters microtrophic (very good water quality). Lake Waikare is medium oligotrophic (good water quality), occasionally entering mesotrophic (average water quality). All three lakes have improved in water quality over the last year.

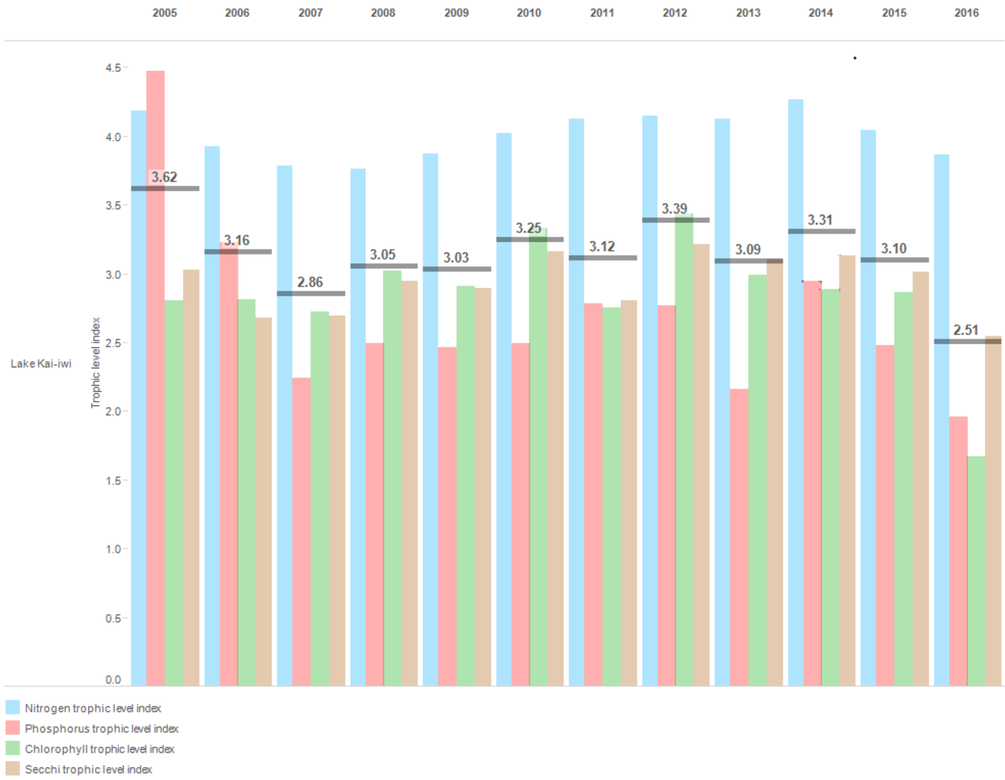




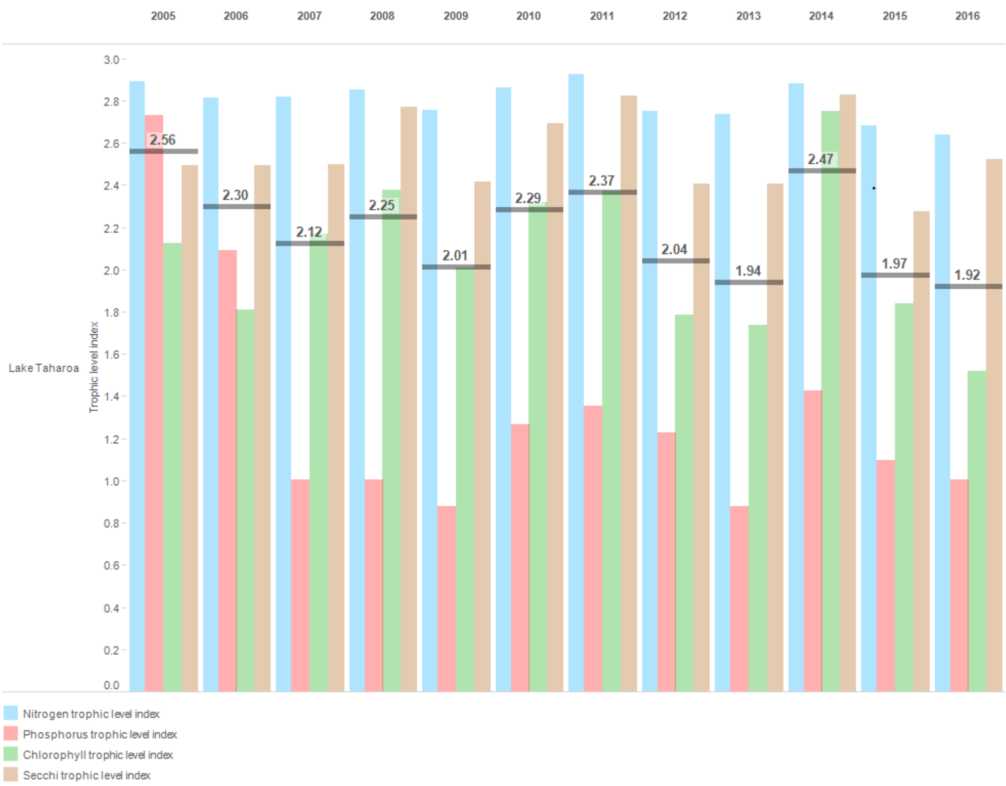


Water Quality	Trophic Level	TLI Score
Very Good	Microtrophic	<2
Good	Oligotrophic	2-3
Average	Mesotrophic	3-4
Poor	Eutrophic	4-5
Very Poor	Supertrophic	>5
No Data	No data available	

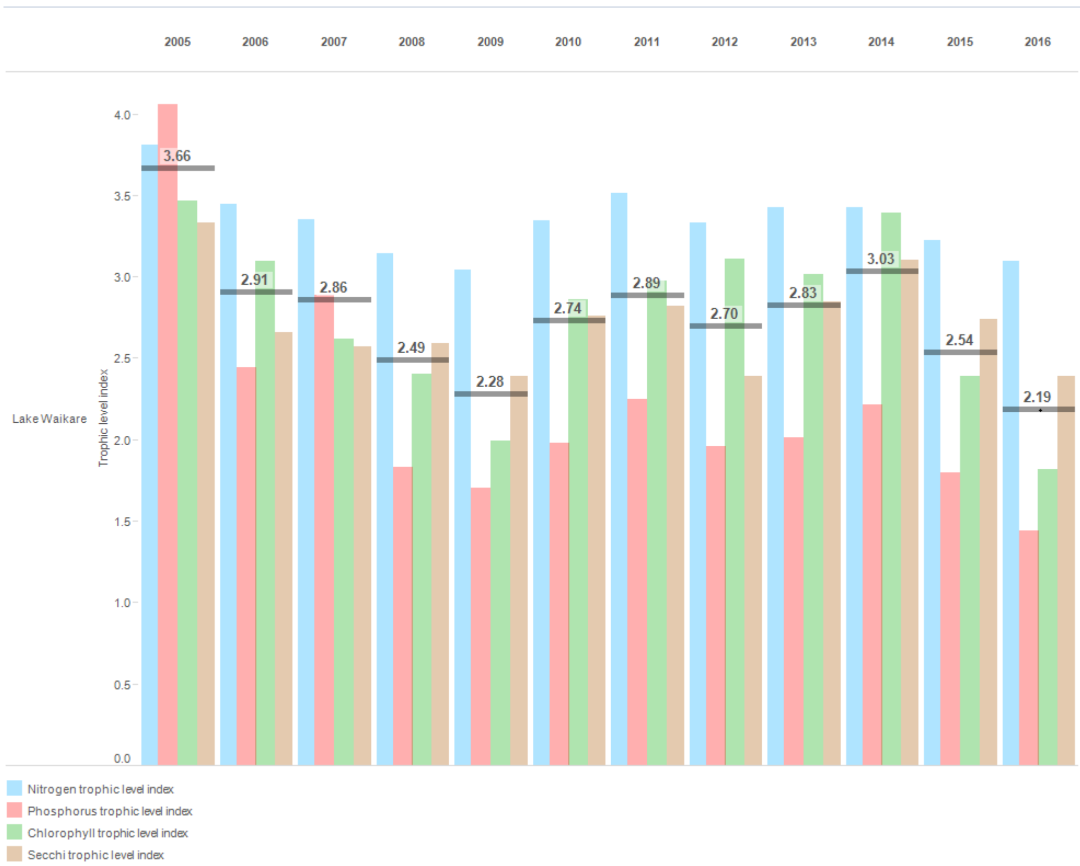
The contributing TLI variables for each lake are shown below. Nitrogen is the key component affecting Lake Kai Iwi apart from the 2005 peak in phosphorus.



Again, Lake Taharoa is much similar in terms of nitrogen being a key factor, but Secchi depth follows due to associated algal blooms and their effect on water clarity. This is likely due to the exposure of Taharoa to open sunshine. Taharoa sometimes appears white and cloudy, which reduces Secchi, but it also also appears aqua blue at other times.



Lake Waikare differs slightly, but is once again influenced by nitrogen, while algal blooms are the next influence. They affect visibility (Secchi depth) more than in Taharoa, as Waikare consistently has a dark green appearance. As with Kai Iwi, Waikare is more sheltered than Taharoa so the persistence of microalgae may be due to pulses of nitrogen coming from the farm drain, followed by blooms and their clearing between weather events. Another factor possibly affecting Secchi depth (water clarity) is suspended sediment, likely caused by decades of water-skiing boat wake eroding the banks of the lake.



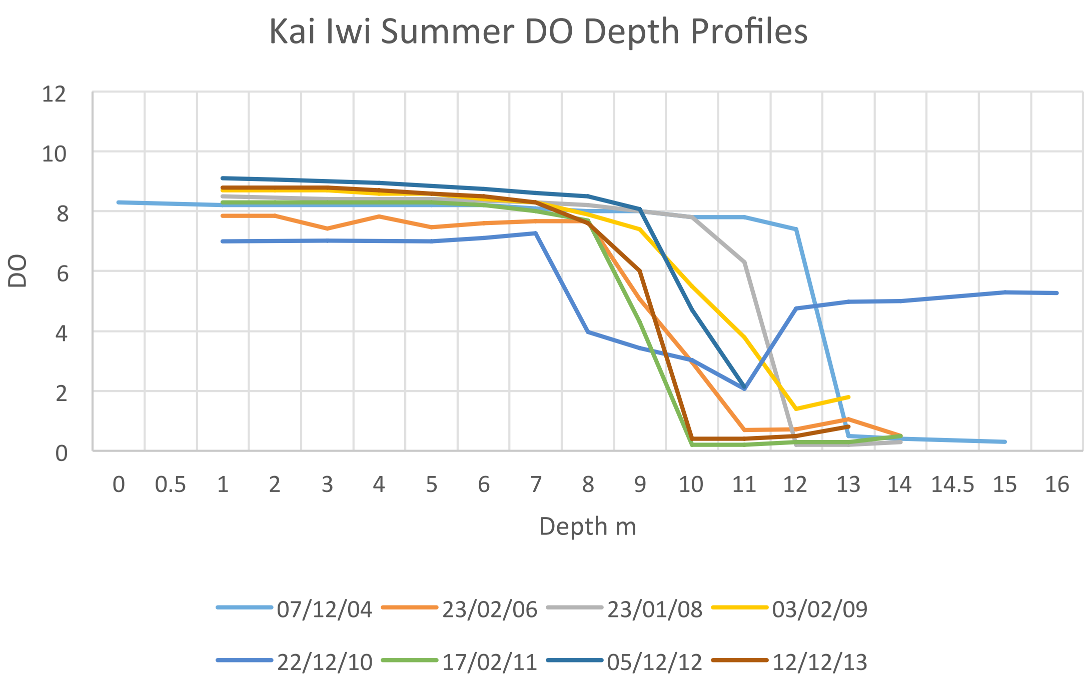
7.1.1.6. Dissolved Oxygen

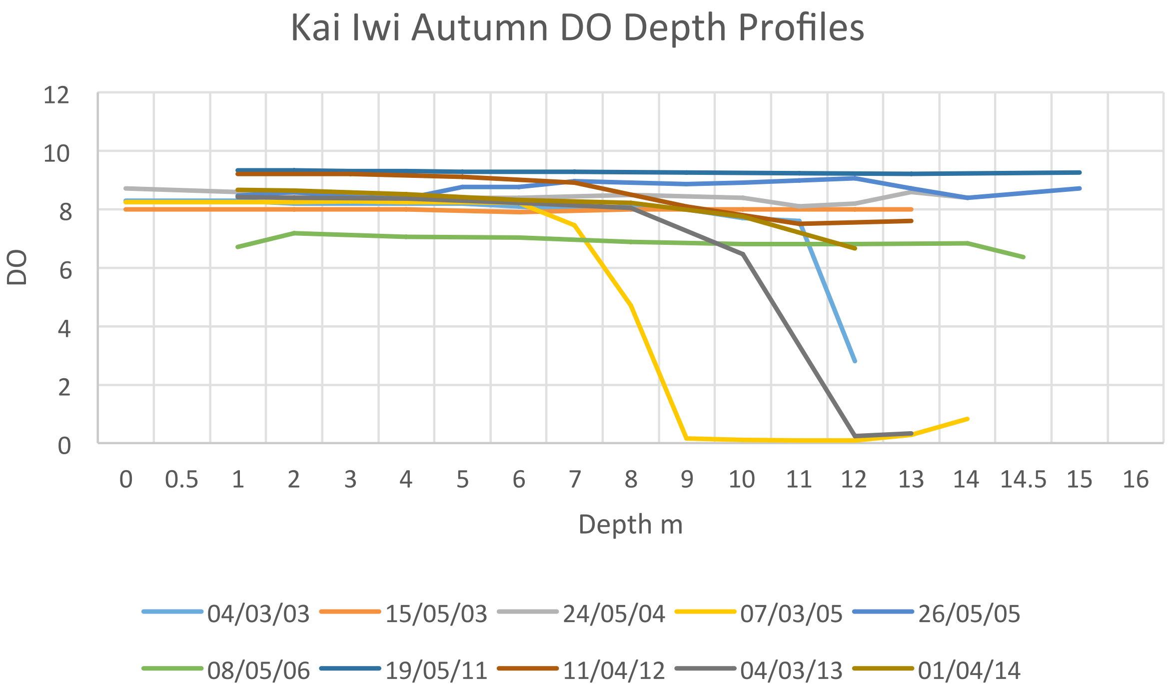
Each of the three lakes experience seasonal deoxygenation events at depth associated with thermal stratification. Kai Iwi stratifies starting at around 7 m between October and April. Taharoa is much deeper, with deoxygenation starting at 19 m and running from September to May and Waikare at between 9-11 m from November to early June.

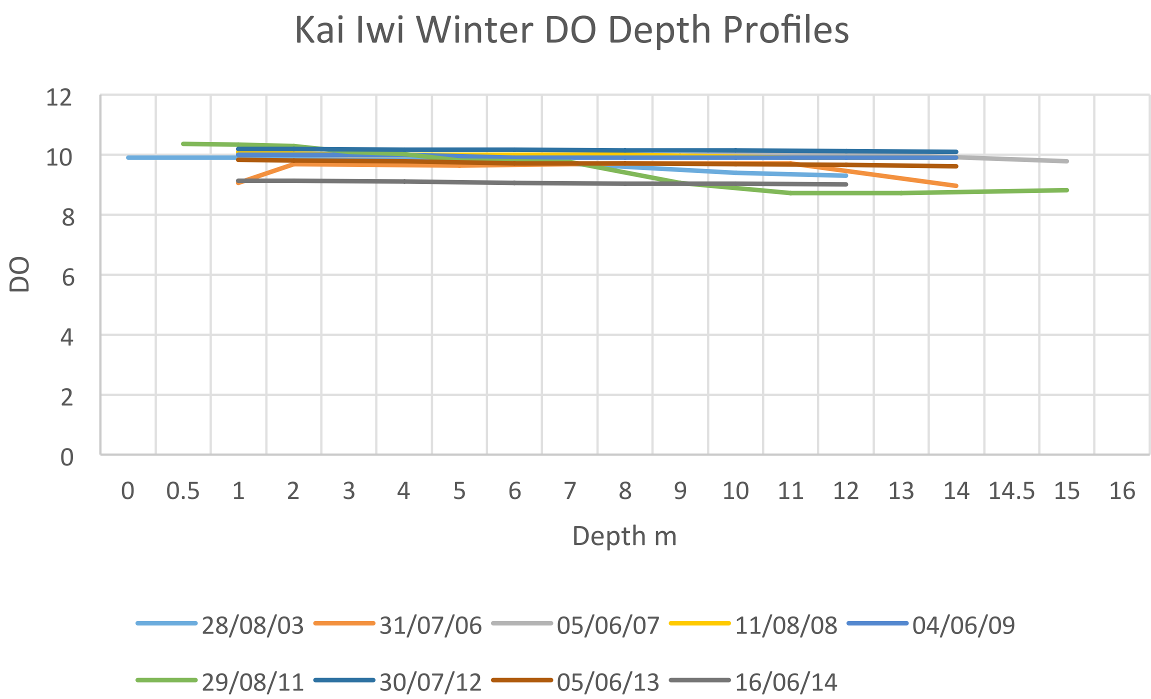
These events will cause redistribution of fish, including rainbow trout and dune lakes galaxias (DLG) adults in Lakes Taharoa and Waikare. This predator presence will likely cause Gambusia to seek littoral edges where sub-adult DLG and adult DLG (in the evening) are naturally found. This may be having an effect on DLG recovery from historically lower population levels.

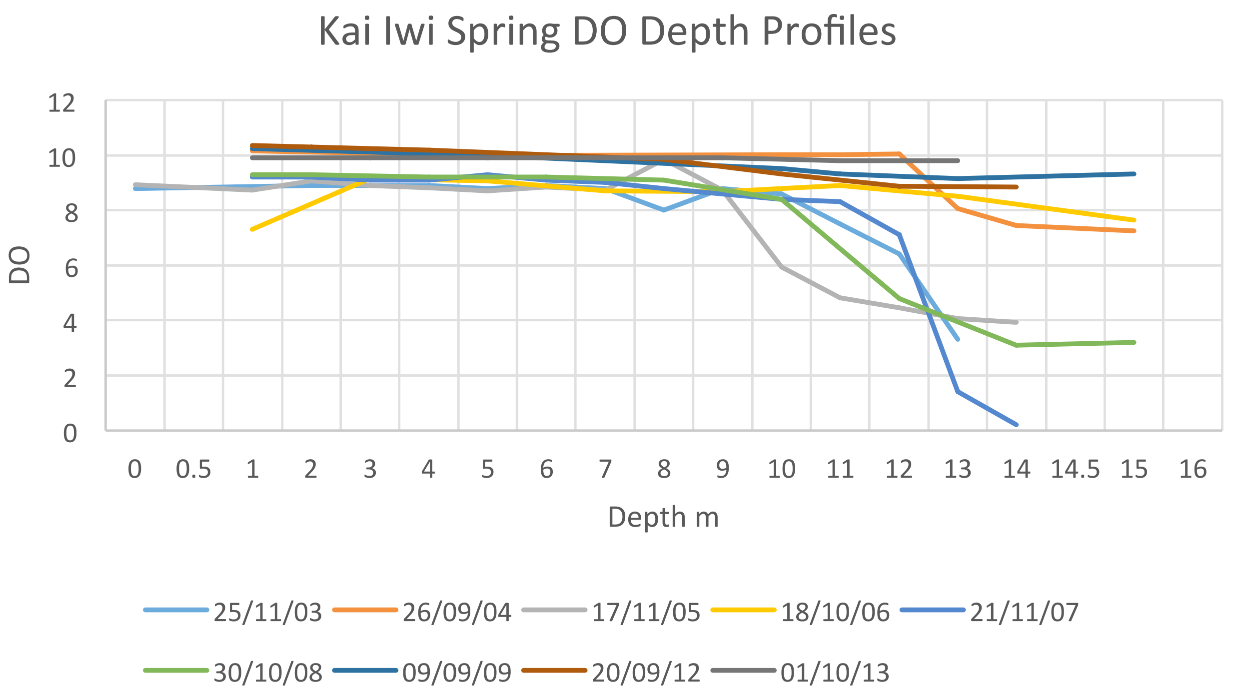
The table below shows the dissolved oxygen (at 15 degrees C) limits for New Zealand freshwater fish from https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/dissolved-oxygen-criteria-for-fish. These guidelines help interpret the depth profiles as to the depth of the water column usable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

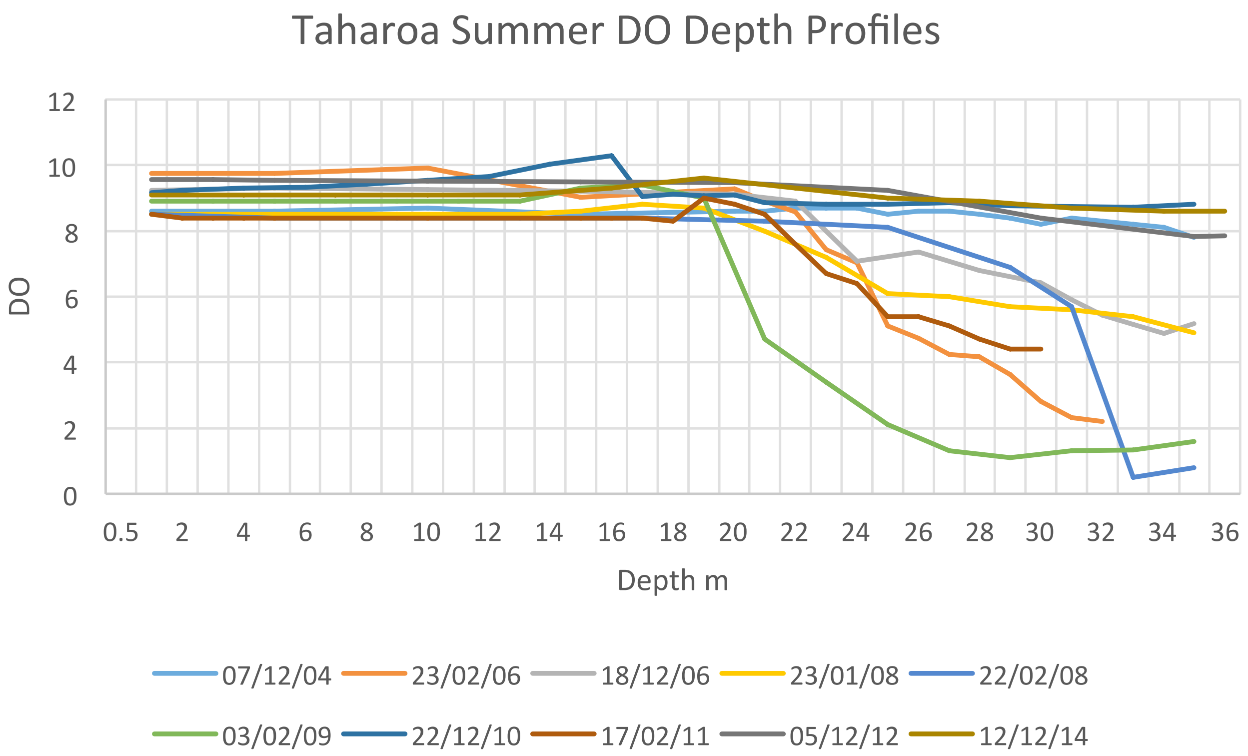
Dissolved Oxygen		Early life stages	Adults
30-day mean (mg L^{-1})	Guideline	9.0	8.0
	Imperative	6.5	6.0
7-day mean (mg L^{-1})	Guideline	7.5	6.5
	Imperative	5.5	5.0
7-day mean minimum (mg L^{-1})	Guideline	6.0	5.0
	Imperative	5.0	4.0
1-day minimum (mg L^{-1})	Guideline	6.0	4.0
	Imperative	4.0	3.0




Kai Iwi Autumn DO Depth Profiles
12
10
8
6
4
2
0
DO
0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 14.5 15 16
Depth m
04/03/03
15/05/03
24/05/04
07/03/05
26/05/05
08/05/06
19/05/11
11/04/12
04/03/13
01/04/14


Kai Iwi Winter DO Depth Profiles
12
10
8
6
4
2
0
DO
0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 14.5 15 16
Depth m
28/08/03
31/07/06
05/06/07
11/08/08
04/06/09
29/08/11
30/07/12
05/06/13
16/06/14


Kai Iwi Spring DO Depth Profiles
DO
12
10
8
6
4
2
0
0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 14.5 15 16
Depth m
25/11/03
26/09/04
17/11/05
18/10/06
21/11/07
30/10/08
09/09/09
20/09/12
01/10/13


Taharoa Summer DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Depth m
07/12/04
23/02/06
18/12/06
23/01/08
22/02/08
03/02/09
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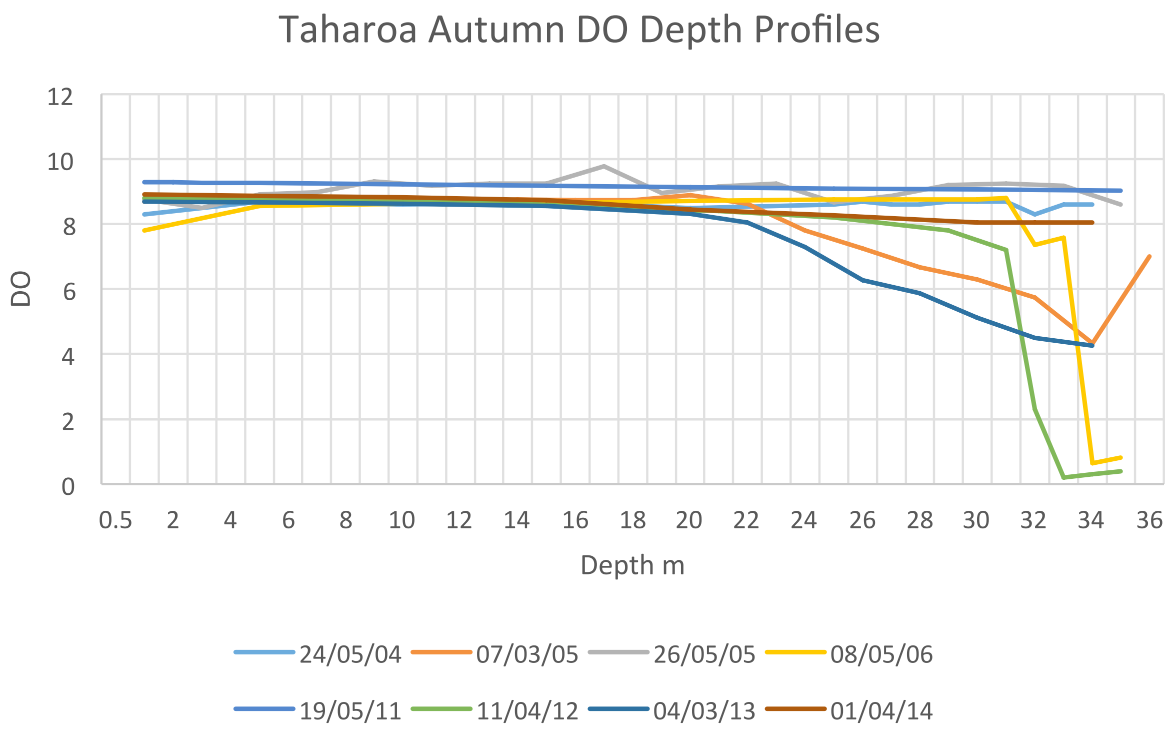
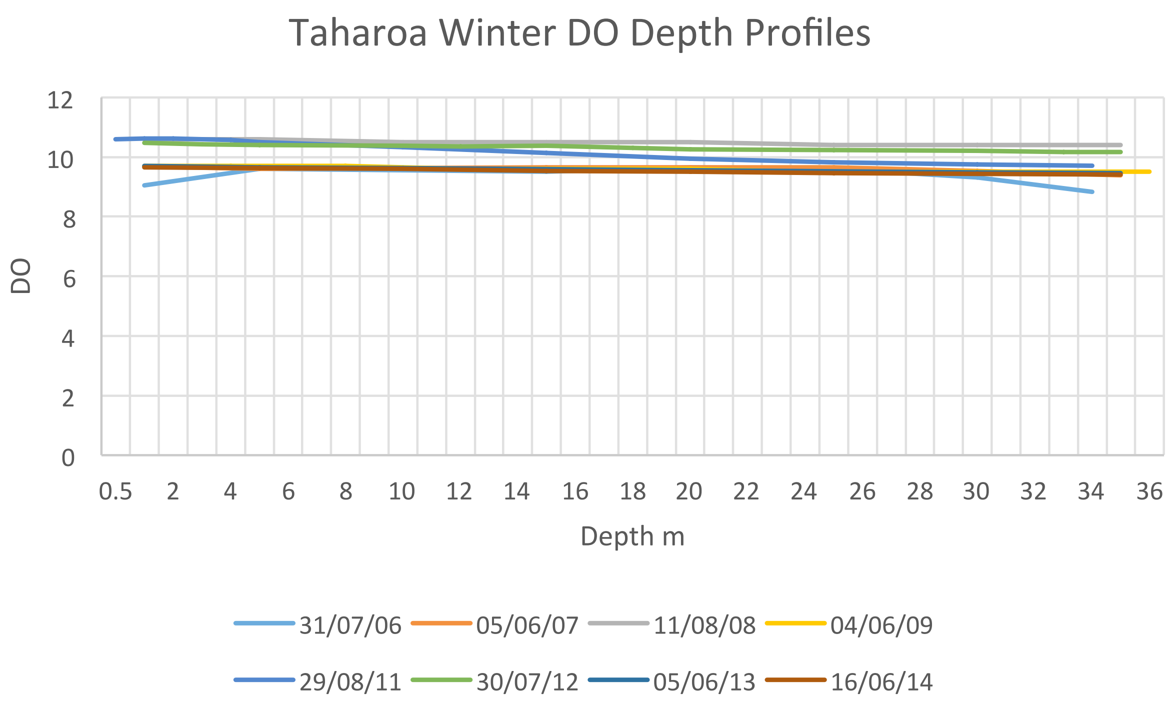
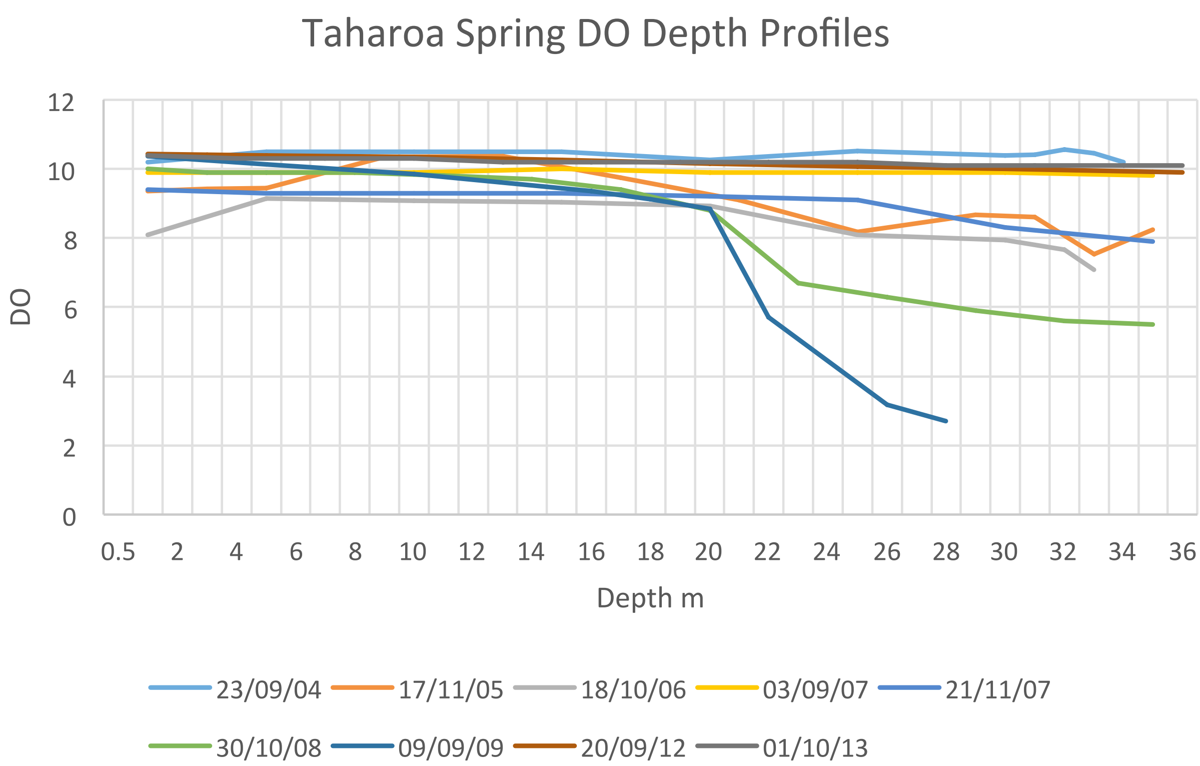
17/02/11
05/12/12
12/12/14

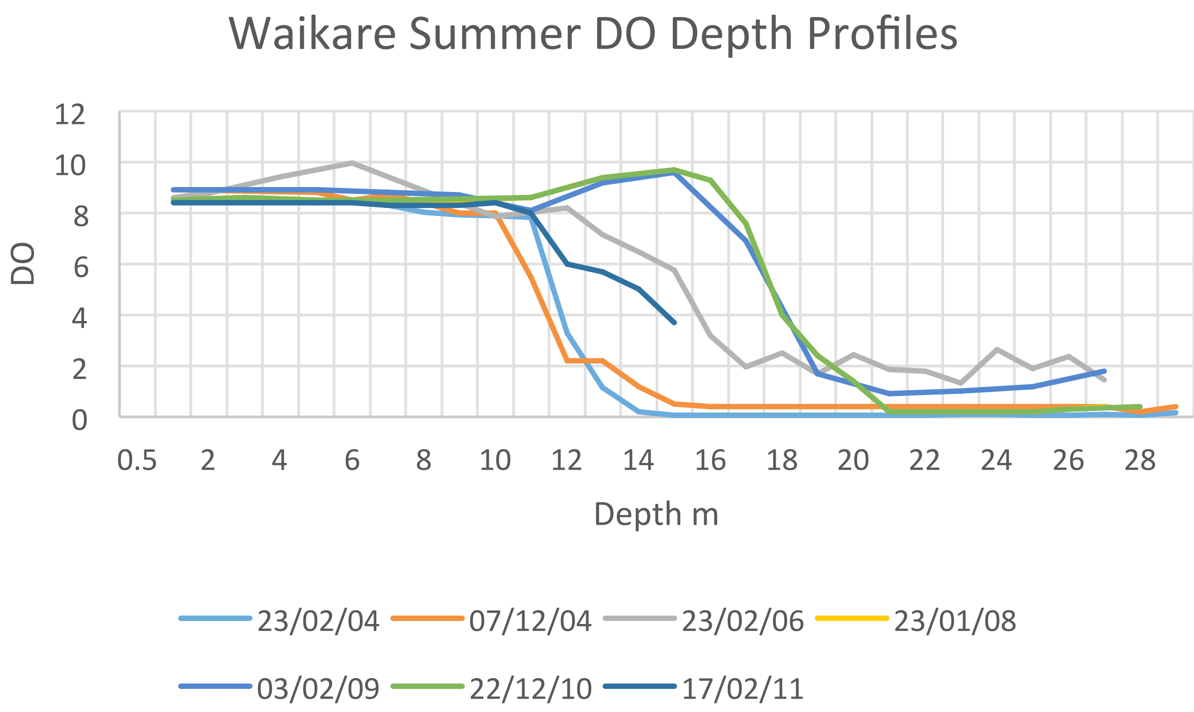


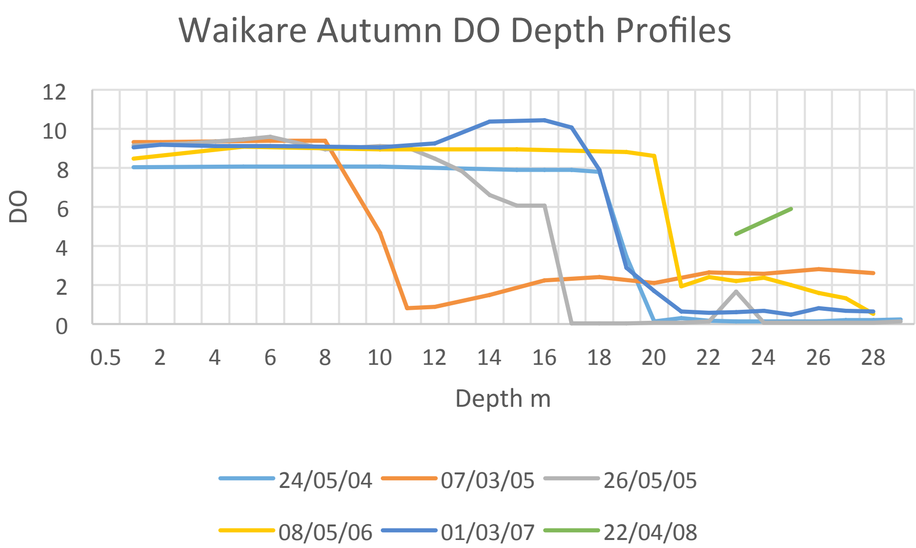
Taharoa Autumn DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Depth m
24/05/04
07/03/05
26/05/05
08/05/06
19/05/11
11/04/12
04/03/13
01/04/14

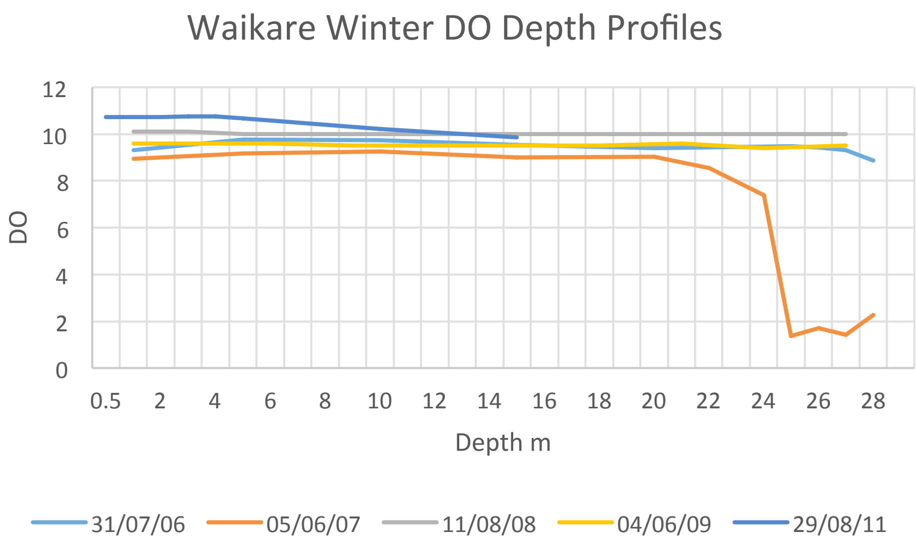


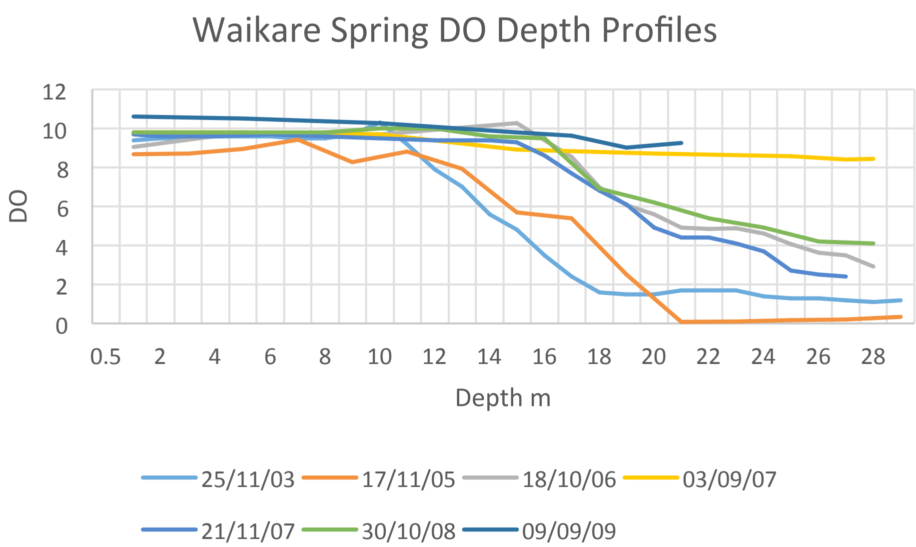
Taharoa Winter DO Depth Profiles
12
10
8
6
4
2
0
DO
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Depth m
31/07/06
05/06/07
11/08/08
04/06/09
29/08/11
30/07/12
05/06/13
16/06/14


Taharoa Spring DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Depth m
23/09/04
17/11/05
18/10/06
03/09/07
21/11/07
30/10/08
09/09/09
20/09/12
01/10/13


Waikare Summer DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Depth m
23/02/04
07/12/04
23/02/06
23/01/08
03/02/09
22/12/10
17/02/11

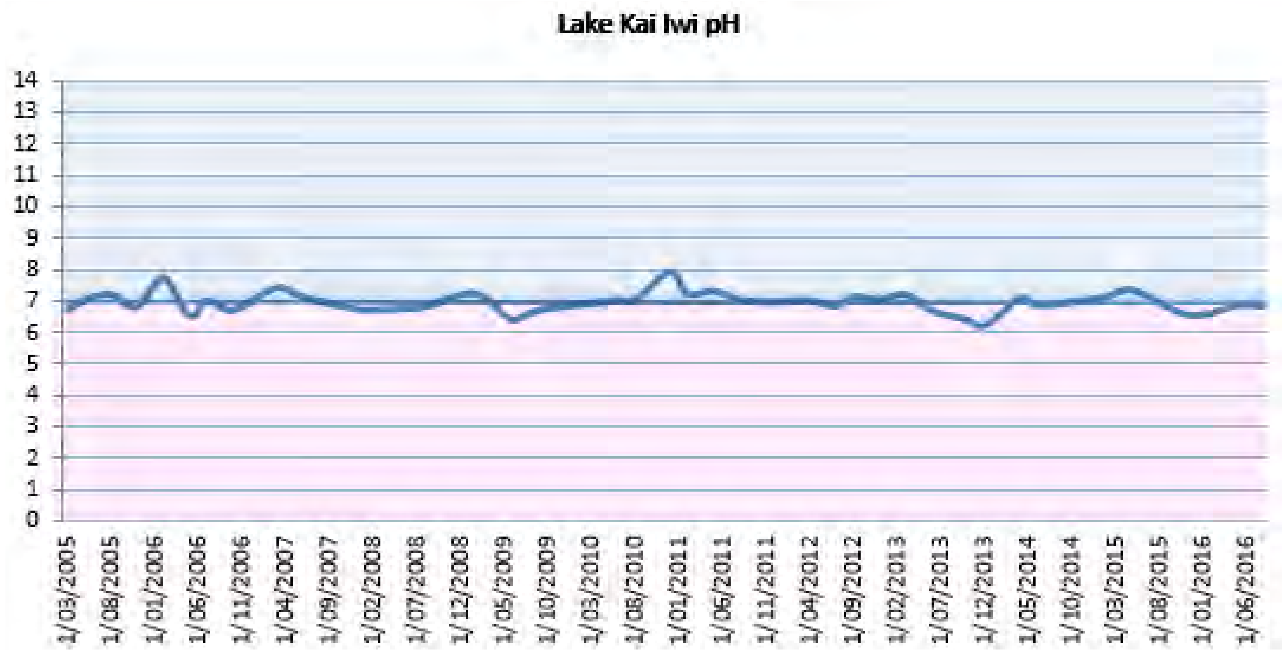

Waikare Autumn DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Depth m
24/05/04
07/03/05
26/05/05
08/05/06
01/03/07
22/04/08

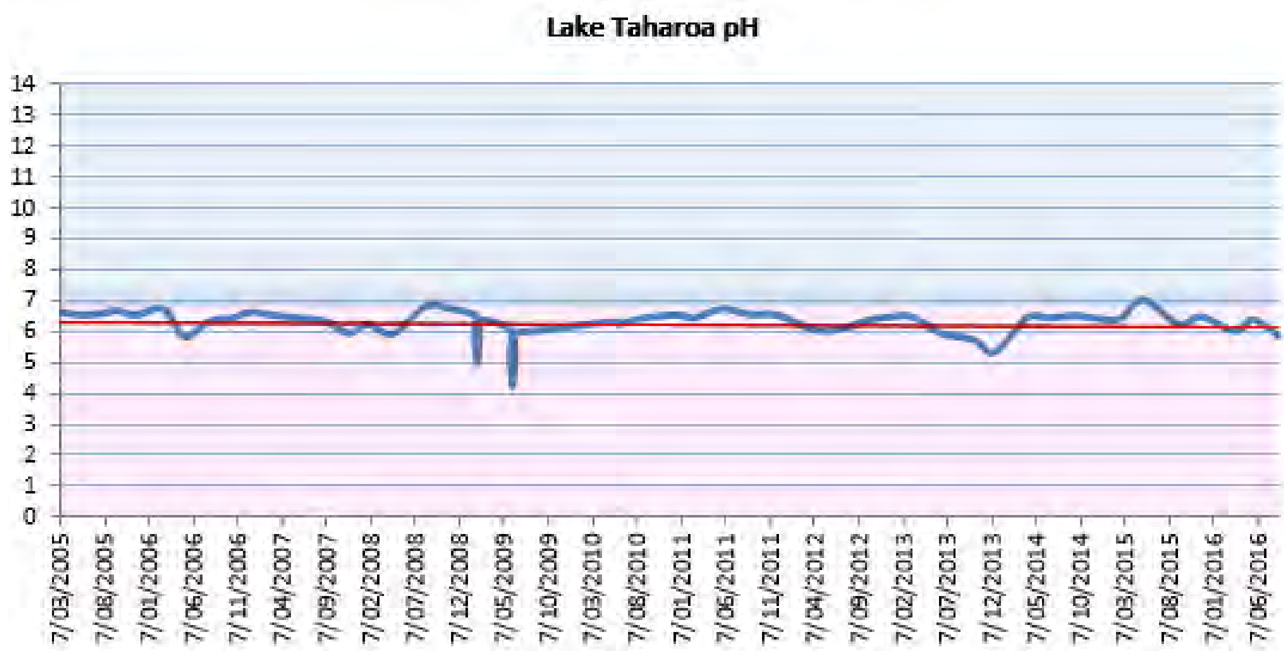

Waikare Winter DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Depth m
31/07/06
05/06/07
11/08/08
04/06/09
29/08/11

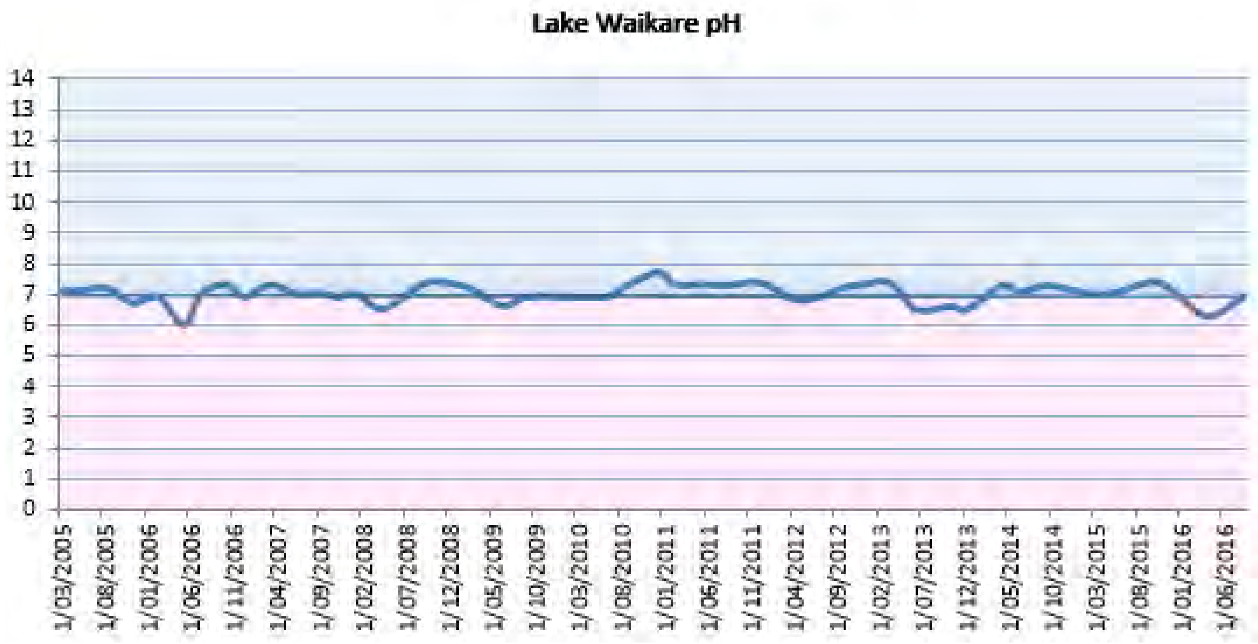

Waikare Spring DO Depth Profiles
DO
12
10
8
6
4
2
0
0.5 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Depth m
25/11/03
17/11/05
18/10/06
03/09/07
21/11/07
30/10/08
09/09/09

7.1.2. pH

The pH levels are fairly stable in each lake, but it is interesting that Lake Taharoa is relatively acidic (pink zone on graph) compared to the neutral pH in the other two lakes. Most native fish, including DLG, are basophilic, meaning they prefer alkalinity over acidic conditions. Possible reasons for Taharoa's acidic condition is its depth and low benthic plant cover as a result of lack of sunlight in the deeper waters. Plants use carbon dioxide and removing carbon from water in this way creates less acidic conditions. Another explanation is a possible connection to a deeper area of the water table.







7.2. Lake and catchment water and nutrient dynamic drivers

7.2.1.1. Influence of nutrient loading

As seen above, nitrogen appears to be having an impact on Lake Kai Iwi primarily with periodic influence on Lake Waikare. Phosphorus levels are low. Nitrogen does not tend to be a persistent legacy nutrient in lakes as the nitrogen cycle will remove it in time. However, given the pristine nature of these three lakes, remedial action is required to mitigate all nitrogen flows.

8. BIOLOGICAL CHARACTERISTICS

8.1. Lake Biodiversity and Biosecurity species

The Kai Iwi Lakes are the most ‘Outstanding value’ dune lakes in Northland. Apart from very good water quality, these lakes have low plant and animal pest diversity.

8.1.1. Plants

Between them, the lakes support 27 native plant species, including four rare natives, 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 invasives and natives.

In addition to the native plants, there are two non-invasive exotic species present in each lake; Bulbous rush and bladderwort. There are no invasive plant species present.

There are two rare natives in all three lakes; *Trithuria inconspicua* and *Myriophyllum votschii*. In addition, all three lakes have *Centrolepis strigosa.*

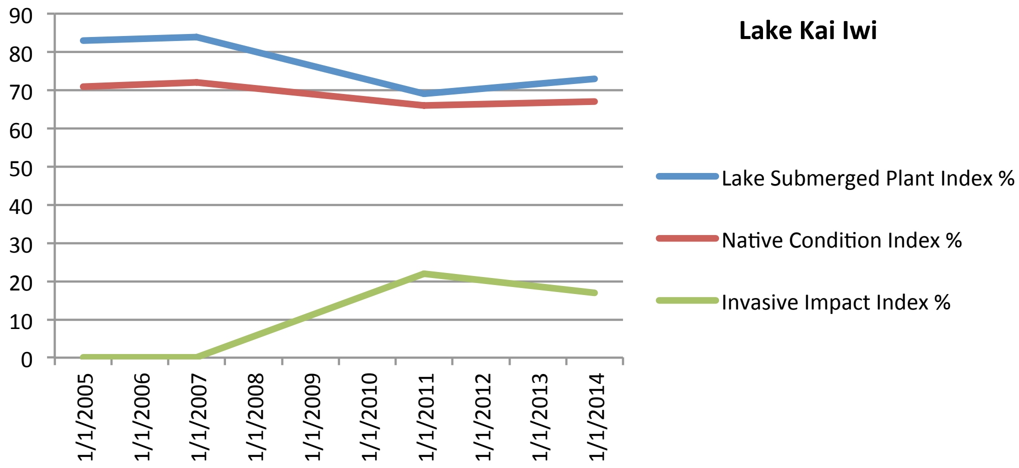
The table below presents plant communities in nearby dune lakes as a comparison and indication of biosecurity species of concern which should be contained wherever possible. Data is derived from annual NIWA ecological surveys. The nearest known waterbody with an invasive aquatic species is Lake Midgley, which has alligator weed as well as the less invasive exotic, water purslane. This lake had grass carp introduced as a tool by the landowner, to create a more open water environment. At last visit, most vegetation had been eaten by the carp (lake appears in green overleaf).

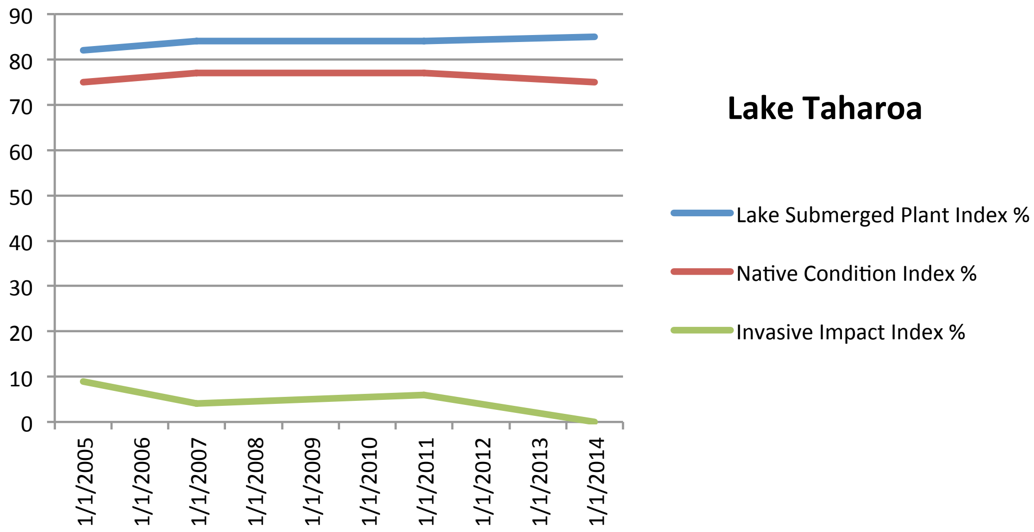
Depth and Plant Type Zone	Biogeography	Common Name	Species	Te Riu	Waingata (Waipoua)	Shag	Waikare	Taharoa	Kai Iwi	Midgley	McEvoy	Freidrich's	Frequency
Erect emergent	Non-invasive exotic	bulbous rush	Juncus bulbosus				x	x	x	x			4
Sprawling emergent	Invasive exotic	alligator weed	Alternanthera philoxeroides							x		x	2
Sprawling emergent	Non-invasive exotic	water purslane	Ludwigia palustris							x			1
Free floating	Non-invasive exotic	bladderwort, yellow bladderwort	Utricularia gibba	x			x	x	x			x	5
Erect emergent	Native	oioi, jointed wire rush	Apodasmia similis				x	x	x				3
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	x	x	x	x		8
Erect emergent	Native	knotted club-rush, knobby club-rush	Ficinia nodosa					x					1
Erect emergent	Native	leafless rush	Juncus pallidus					x	x				2
Erect emergent	Native	sedge	Machaerina arthrophylla (syn. Baumea arthrophylla)	x	x		x	x	x				5
Erect emergent	Native	jointed baumea, jointed twig rush	Machaerina articulata (syn. Baumea articulata)	x	x		x	x	x				5
Erect emergent	Native	sedge, tussock swamp twig rush	Machaerina juncea (syn. Baumea juncea)		x		x	x	x				4
Erect emergent	Native	baumea	Machaerina rubiginosa (syn. Baumea rubiginosa)				x		x				2
Erect emergent	Native	softstem bulrush, grey club-rush, great bulrush	Schoenoplectus tabernaemontani	x									1
Erect emergent	Native	bog Schoenus, the stabber	Schoenus brevifolius				x	x					2
Erect emergent	Native	raupo	Typha orientalis	x				x		x			3
Erect emergent	Rare native	centrolepis	Centrolepis strigosa					x					1
Sprawling emergent	Native	swamp millet	Isachne globosa		x			x					2
Low growing turf	Native	none known	Glossostigma elatinoides				x	x		x			3
Low growing turf	Native	none known	Glossostigma submersum			x							1
Low growing turf	Native	none known (sedge)	Isolepis prolifera					x					1
Low growing turf	Native	Zelandiae chain sword	Lilaeopsis novae-zelandiae			x	x	x	x				4
Low growing turf	Native	arrow grass	Triglochin striata					x	x				2
Low growing turf	Rare native	hydatella	Trithuria inconspicua (syn Hydatella inconspicua)				x	x	x				3
Floating leaved	Native	red pondweed	Potamogeton cheesemanii	x		x	x		x		x	x	6
Submerged milfoil	Native	common water milfoil	Myriophyllum propinquum				x		x	x	x		4
Submerged milfoil	Rare native	small water milfoil	Myriophyllum votschii				x	x	x				3
Submerged tall pondweed	Native	blunt pondweed	Potamogeton ochreatus		x	x	x			x		x	5
Submerged tall pondweed	Rare native	bladderwort, yellow bladderwort	Utricularia australis	x								x	2
Submerged charophyte	Native	stonewort	Chara australis	x	x	x	x		x	x		x	7
Submerged charophyte	Native	stonewort	Chara fibrosa	x	x		x	x	x				5
Submerged charophyte	Native	stonewort	Chara globularis	x									1
Submerged charophyte	Native	stonewort	Nitella leonhardii				x	x	x				3
Submerged charophyte	Native	stonewort	Nitella pseudoflabellata				x	x	x				3
Submerged charophyte	Native	stonewort	Nitella sp. aff. cristata				x	x					2
			Total Plant Diversity	**11**	**8**	**6**	**21**	**24**	**20**	**9**	**3**	**6**	
			Exotic Plant diversity	**1**	**0**	**0**	**2**	**2**	**2**	**3**	**0**	**2**	
			Native Plant Diversity	**10**	**8**	**6**	**19**	**22**	**18**	**6**	**3**	**4**	

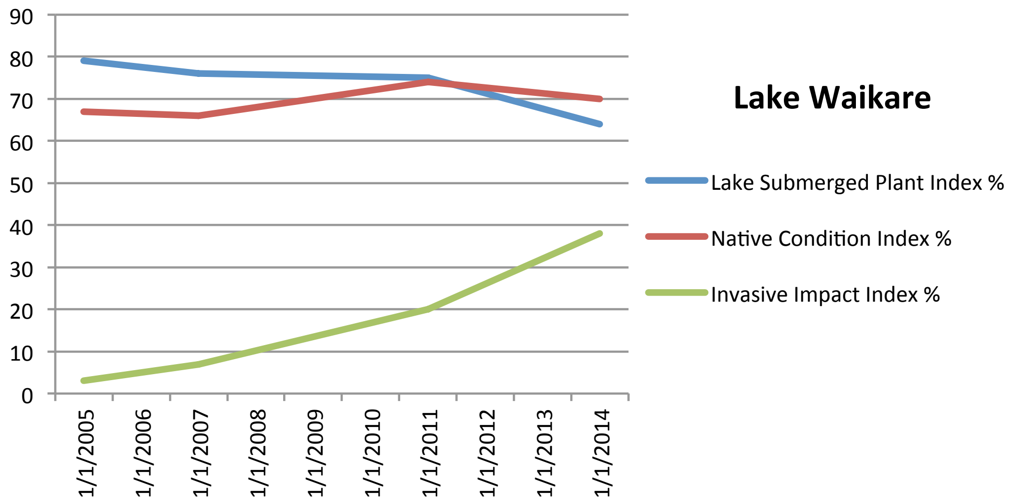
8.1.1.1.1. Lake Submerged Plant Index (LakeSPI), Native Condition Index and Invasive Impact Index

Three indices are valuable for considering the health of a lake's plant community; Lake Submerged Plant Index (SPI), Native Condition Index and Invasive Impact Index. From the 2004-2014 timeline below, both Lakes Kai Iwi and Waikare are experiencing a rise in invasive impact with a corresponding fall in SPI and Native Condition Index in 2011. Lake Taharoa retains a high and steady SPI and even a decline in invasive threat.

Being lakes with public recreational access, Kai Iwi lakes are at extreme risk from introductions of pest weeds and fish which can be accidentally transported from distant waterbodies on boats, trailers, fishing equipment and other gear. In order to be able to respond and eradicate an introduction early it is therefore important to maintain regular weed surveillance, especially at vessel launch points. The best way to prevent pest spread, however, is through an effective advocacy programme. This is best done through the Check, Clean, Dry biosecurity program which needs to be implemented more systematically at these lakes.







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 and Amphibians

The table below displays the fish of the area from Waipoua Forest, through to the Kai Iwi Lakes and southward to the north Dargaville lakes. Pest fish are shown in green and conservation species in pink. The Kai Iwi lakes appears in yellow. The lakes have a low level of fish diversity for both native species and pest fish.

The pest fish Gambusia is present across all four Kai Iwi lakes (including Lake Shag).

Eels are absent from Lake Kai Iwi, while being present in adjacent lakes. Stream pathways from the Tasman Sea need to be surveyed to see if any earthworks have cut off access to this aquatic ecological corridor.

Common bully is the only native species and dwarf inanga may be either lost or nearing localised extinction.

Two thousand rainbow trout are released annually into Lake Taharoa and 300 to Lake Waikere and have been seen in Lake Kai Iwi, possibly self-introduced via the channel from Lake Taharoa. A desk-top study has been completed to assess the relationship between the predatory trout and Gambusia, dune lakes galaxias and common bully as prey and on the aggressive nature of Gambusia to native fish. A working party has been established to design a research, monitoring and experimentation plan to assess the relationships between these four species.

Dune lakes galaxias (DLG) is soon to be classified as a new species (Ling, pers. comm.). Previously, DLG were considered to be more similar to the dwarf inanga which is found in dune lakes on the Pōuto Peninsula to the south. The relative age of the Kai Iwi Lakes has allowed this species to diverge genetically and morphologically. Other species such as koura/kewai (freshwater crayfish) are distinct in their morphology for the same reason. DLG are now locally extinct in Lake Kai Iwi where they were present in the past.

The survival of common bully in the Kai Iwi Lakes suggests less of an impact from trout on this species.

common name	species	Conservation status	Degree of loss	Te Riu	Waingata (Waipoua)	Shag	Waikare	Taharoa	Kai Iwi	Midgeley	McEvoy	Freidrich's	frequency
grass carp	Ctenopharyngodon idella									x			1
rainbow trout	Oncorhynchus mykiss						x	x	x				3
Gambusia	Gambusia affinis					x	x	x	x		x		5
shortfinned eel	Anguilla australis			x	x	x	x	x				x	6
longfinned eel	Anguilla dieffenbachii	at risk	declining			x	x						2
dune lakes galaxias	Galaxias sp.						at risk	at risk	historic				2
common bully	Gobiomorphus cotidianus			x parasites		x	x	x	x				5
	diversity pest fish			0	0	1	1	1	1	0	1	0	
	diversity native			2	1	3	4	3	1	0	0	1	

8.1.3. Waterbirds

The table below displays the waterbirds of the Kai Iwi and North Dargaville lakes. Game birds are shown in green and non-game bird native species in pink. The Kai Iwi lakes appears in yellow. The lakes have a low level of bird diversity and has no game species present. Dabchicks occur widely in this sub-region.

common name	species	Conservation status (DOC: *Conservation status of NZ birds*, 2016)	Criteria / Degree of loss	Shag	Waikare	Taharoa	Kai Iwi	Midgeley	McEvoy	Freidrich's	frequency
black swan	Cygnus atratus (resident native (not introduced) on game bird list)	Not threatened		x				x		x	3
Australasian bittern	Botaurus poiciloptilus	threatened	nationally critical	x			x	x		x	4
white-faced heron	Egretta novaehollandiae	not threatened			x						1
little shag	Phalacrocorax melanoleucos brevirostris	not threatened			x						1
pied shag	Phalacrocorax v. varius	at risk	recovering				x				1
New Zealand dabchick	Poliocephalus rufopectus	at risk	recovering	x		x	x	x		x	5
Australasian little grebe	Tachybaptus n. novaehollandiae		coloniser	x							1
	diversity resident native (not introduced) on game bird list			1	0	0	0	1	0	1	
	diversity native			3	2	1	3	2	0	2	

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 these lakes, the presence of koura/kewai in Waikare and Taharoa is a sign of the excellent water quality of these lakes as koura/kewai cannot tolerate less than clean water. Likewise, the Diptera midge, *Ceratopogonidae* in Lake Kai Iwi. No more than mild pollution is tolerated by the two species of Acarna mites in Kai Iwi and no more than moderate pollution is tolerated by the Diptera midge, *Tanytarsini* or the waterboatman, both also found in Lake Kai Iwi. These are signs of good lake health and strong wairua (life force), from a cultural perspective.

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)	Te Riu	Shag	Waikare	Taharoa	Kai Iwi	Midgeley	frequency
Mollusc, snail	*Physa (Physella) acuta*	0.1	x					x	2
Mollusc, snail	*Physa (Physella) sp*	0.1					x		1
Acarna, mite	Hydrachnidae	5.2					x		1
Acarna, mite	Oribatida	5.2					x		1
Crustacea, Cladocera	sp	0.7					x		1
Crustacea, Copepoda	sp	2.4					x		1
Crustacea, Decapoda, freshwater crab	*Halicarcinus lacustris*					x			1
Crustacea, Ostracoda, koura	*Paranephrops planifrons*	8.4			x	x			2
Crusteacea, Ostracoda	*Herpetocypris*	*1.9*					x		1
Diptera, midge, biting	Ceratopogonidae type B	6.2					x		1
Diptera, midge, non-biting, Chironomid	Tanytarsini	4.5					x		1
Diptera, midge, non-biting, Chironomid	*Chironomas sp*	3.4					x		1
Diptera, midge, non-biting, Chironomid	Orthocladiinae	3.2					x		1
Hemiptera, bug, backswimmer	*Sigara arguta*	2.4		x					1
Hemiptera, bug, waterboatman	*Diaprepocoris sp*	4.7					x		1
Mollusca, bivalve	Sphaeridae						x		1
Mollusca, freshwater mussel	*Echyridella menziesi*						shells		1
Mollusca, pea mussel	*novaezelandiae*			x	x				2
Nematoda, roundworm	sp	1.8					x		1
Nemertea, proboscis worm	sp	1.8					x		1
Odonata, dragonfly	*Hemicordulia australiae*	0.4					x		1
Oligocheate worm	Oligochaeta sp	3.8					x		1
Trichoptera, caddisfly	*Paroxyethira hendersoni*	3.7					x		1
	diversity invasive		1	0	0	0	1	1	3
	diversity native		0	2	2	2	17	0	23

8.1.5. Catchment weeds

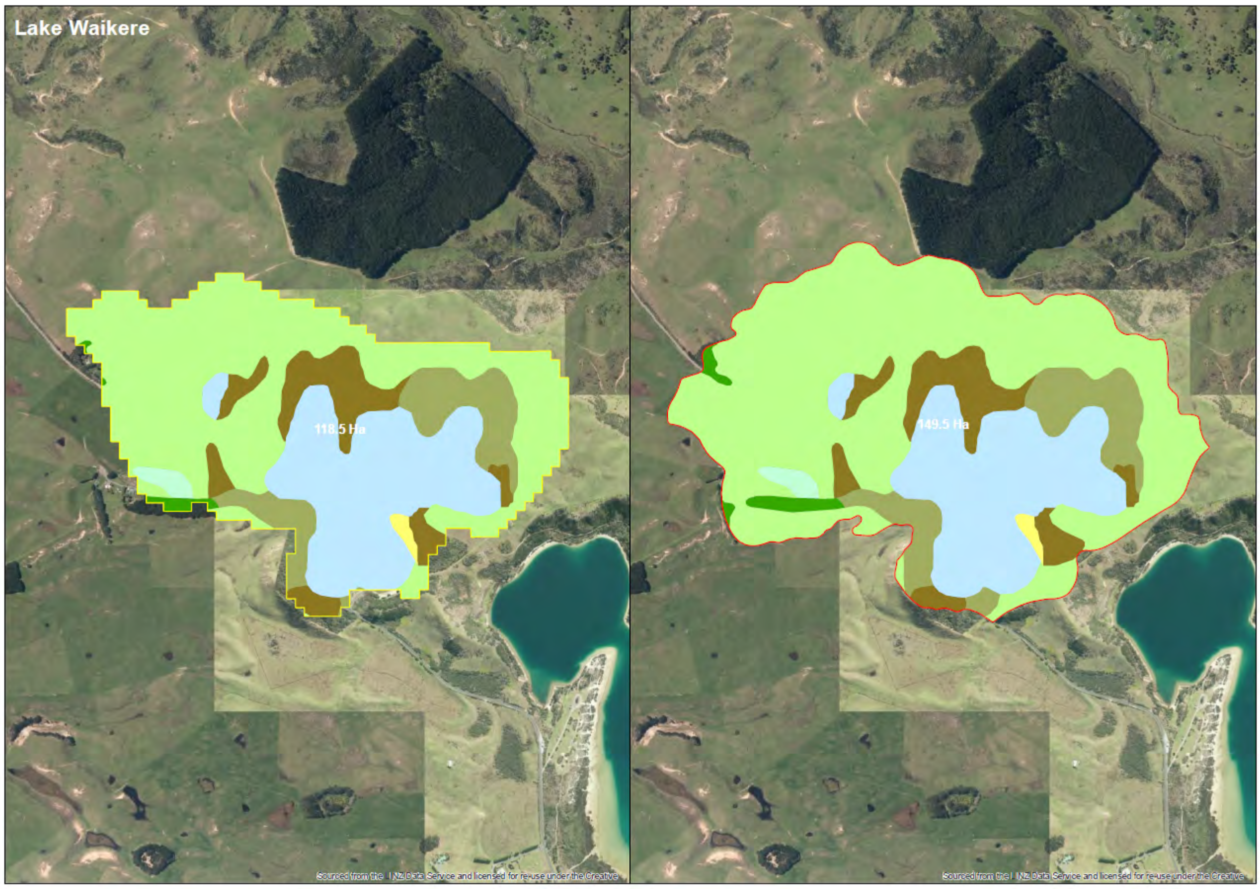
NRC are undertaking an aggressive programme of catchment weed management at the lakes, including wilding pine and nitrogen fixing weeds such as brush wattle and gorse.

9. LAND USE

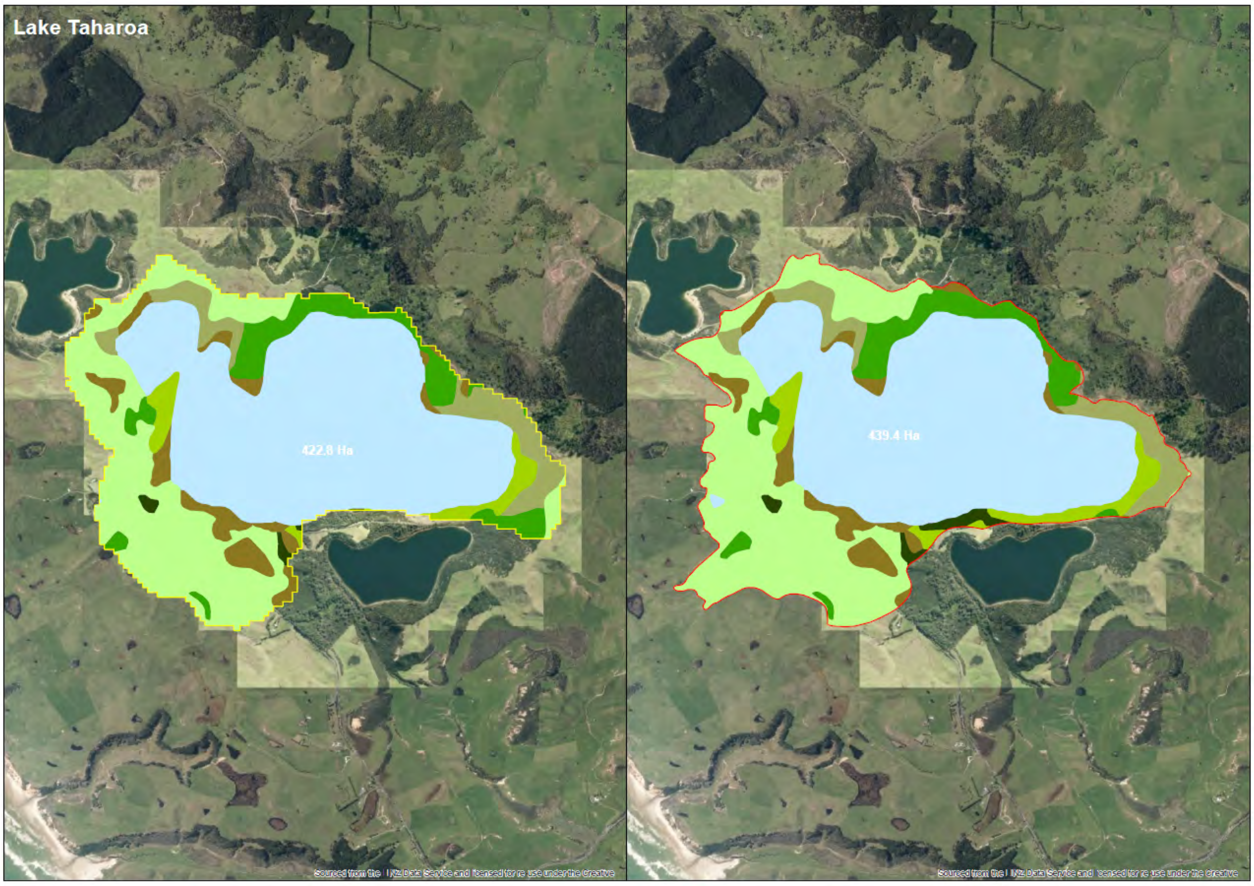
9.1. Catchment land use (ha) table and maps

The catchments of the lakes are primarily covered in high producing exotic grassland pasture (the light green areas on the map), exotic pine forest (dark green) and manuka/kanuka scrubland (brown). There are also a few other mixed covers.

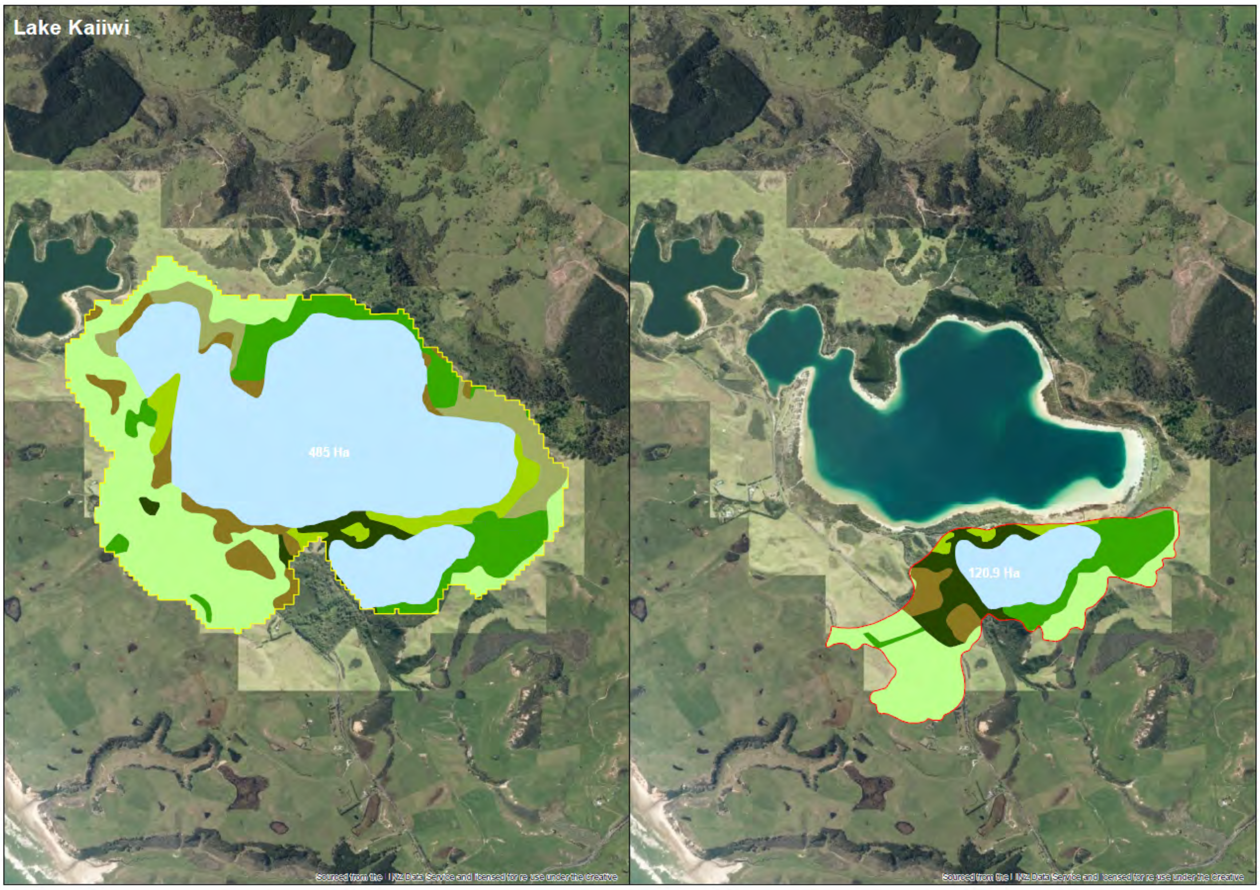
Lake	Cover Type	Total FENZ (ha)	Total Hand-drawn (ha)
Lake Waikare	Exotic Forest	0.76	2.18
Lake Waikare	Forest - Harvested	12.61	13.92
Lake Waikare	Herbaceous Freshwater Vegetation	1.32	1.32
Lake Waikare	High Producing Exotic Grassland	57.74	85.48
Lake Waikare	Lake or Pond	32.93	33.08
Lake Waikare	Manuka and/or Kanuka	12.43	12.80
Lake Waikare	Sand or Gravel	0.70	0.70
Lake Waikare Total		118.49	149.48



Lake	Cover Type	Total FENZ (ha)	Total Hand-drawn (ha)
Lake Taharoa	Exotic Forest	31.56	28.78
Lake Taharoa	Forest - Harvested	27.91	25.31
Lake Taharoa	High Producing Exotic Grassland	103.44	118.12
Lake Taharoa	Indigenous Forest	2.15	5.52
Lake Taharoa	Lake or Pond	218.32	220.12
Lake Taharoa	Low Producing Grassland	13.73	17.23
Lake Taharoa	Manuka and/or Kanuka	25.71	24.35
Lake Taharoa Total		422.80	439.42



Lake	Cover Type	Total FENZ (ha)	Total Hand-drawn (ha)
Lake Kai Iwi	Exotic Forest	46.07	22.47
Lake Kai Iwi	Forest - Harvested	27.91	0.39
Lake Kai Iwi	High Producing Exotic Grassland	107.53	41.00
Lake Kai Iwi	Indigenous Forest	9.43	15.51
Lake Kai Iwi	Lake or Pond	249.09	29.73
Lake Kai Iwi	Low Producing Grassland	19.25	2.95
Lake Kai Iwi	Manuka and/or Kanuka	25.74	8.81
Lake Kai Iwi Total		485.01	120.86



9.2. Septic systems

Several toilet systems are in place at the old water-skiing clubhouse, now a Kaipara District Council (KDC) Event Centre, and at the campgrounds, also run by KDC. Swimmers are encouraged to use the toilets before entering the lakes, but the distance of toilet blocks from the popular swimming beaches may be a barrier. At peak times of the year, when there are hundreds of people swimming, cumulative nitrogen impacts are likely.

9.3.1. Pasture drains

The influence of farming is most evident in the ephemeral farm drains which empties into Waikare and Taharoa.

9.4. Forestry

The standing forest, owned by KDC will not be replanted. When other forestry in the catchment has been harvested in the past, sediment was observed entering the lake after heavy rainfall. Prior to harvesting, planning for avoiding an event of this type should be undertaken.

9.5. Kauri Log extraction

The area has a strong historic kauri extraction tradition. It is likely that wetland was lost at this time.

9.5.1. Fire Service regarding biosecurity risks between lakes

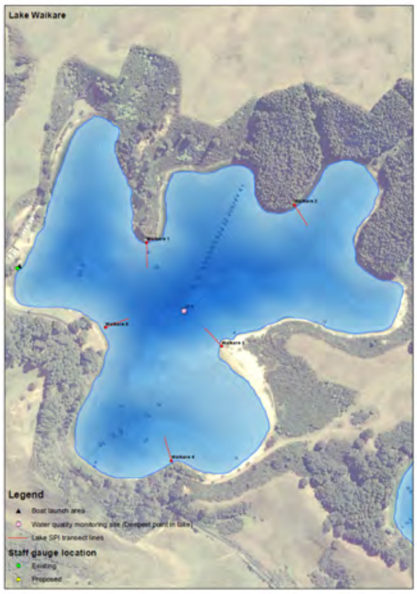
Due to the presence of *Gambusia* and bladderwort, it is inadvisable to use the Kai Iwi Lakes as a water source for fire-fighting if other water bodies are also to be sourced that do not already contain these two pests.

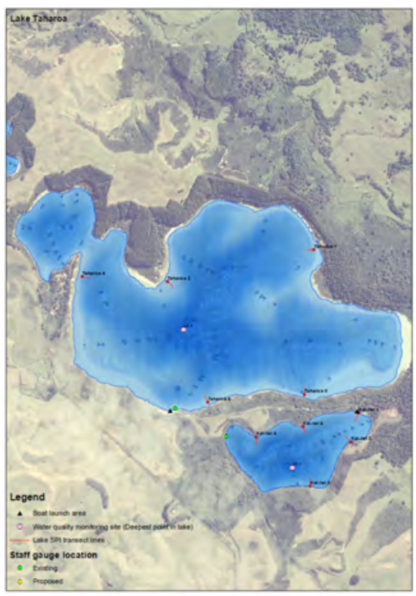
9.6. Recreational Boating

9.6.1. Water-skiing

Water-skiing has been a long-term activity at the lakes. The Taharoa Domain Management Plan reviewed the activity at Lake Waikare and found that water skiing does not comply with the Maritime Bylaw due to distance-from-shore rules. Powerboats are not permitted to exceed 5 knots anywhere in Lake Waikare. A water-skiing track has been now established in the middle of Lake Taharoa. NRC are currently monitoring the littoral reed beds of Lake Waikare in comparison to reed beds in Kai Iwi to see if there is any change in density due to past vessel wake effects on this habitat. Shoreline erosion is also being assessed and a baseline of nutrient levels in foliage samples is being established at the same sites.

10. MONITORING PLAN





The lakes are scheduled to be fully ecologically monitored every five years with weed surveillance annually. There have been eight full surveys since 1984 for Lake Kai Iwi, four for Taharoa and seven for Waikare with weed surveillance every year since 2005. The value class of each lake has held at Outstanding. The next full survey is scheduled for autumn 2018.

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
Te Riu	5															H					H				H						
Waingata (D)	10															H															
Freidrich's															L																
McEvoy's															L																
Midgeley	5-10														M-H		carp				deveg							?			
Kai-Iwi	5	1													O		O				O			O				?			
Shag															L					M								?			
Taharoa	5	1													O		O				O			O				?			
Waikare	5	1													O		O				O			O				?			

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 appear below.

10.2.1.1. Lake level

Lake Waikare requires installation of a staff gauge to measure water levels. The other two lakes currently have staff gauges in place.

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
Kai iwi lower							1		1				1	9			4	4	3	3	4	3	4	4	4	4	3	4	2	58
Kai iwi surface		1					3	1	1		1		1	9	5	2	4	4	3	3	4	3	4	4	4	4	3	4	2	70
Taharoa lower							1	1	1		1		1	9			3	5	4	4	4	3	4	4	4	4	4	4	2	63
Taharoa surface							3	1	1		1		1	9	5	2	4	5	4	4	4	3	4	4	4	4	4	4	2	73
Waikare lower							1	1	1		1			9			4	5	4	4	4	3	4	4	4	4	4	4	2	63
Waikare surface		1				3	3	1	1		1			9	5	2	4	5	4	4	4	3	4	4	4	4	4	4	2	76

11. WORK IMPLEMENTATION PLAN

Ongoing work includes:

- The NRC/NIWA ecological surveys will continue every five years with weed surveillance annually. The next full survey will be in 2018. Quarterly NRC water quality monitoring will continue.
- NRC are undertaking a programme of catchment weed management at the lakes, including wilding pine, a remnant of past pine forest in this area. This work also includes control of mammalian pests including possums and wild pigs.
- Impacts on shoreline erosion and on the emergent plant beds from past water-skiing vessel wake is being assessed by the NRC, along with nutrient uptake by the reeds.
- The slopes of the catchment are being replanted in natives by KDC.
- A research and monitoring plan has been developed by a working group of the Taharoa Domain Board to assess the interaction between Dune Lakes Galaxias (DLG), *Gambusia* and rainbow trout. The objective is the conservation of DLG.

The NRC's Freshwater Improvement Fund (FIF) Dune Lakes project includes several actions at the lakes, including:

- Remedy of the farm drain entering Lake Waikare and Taharoa
- Catchment nutrient assessment of all three lakes including recommendations for any further remedial actions.
- Assessment of the channel between Kai Iwi and Taharoa and closure if necessary.

Further opportunities for mitigation work include:

- Assessment of impact from the harvest of the remaining pine plantation in 15-20 years, owned by KDC.
- NRC Farm Water Quality Improvement Plans and the Environment Fund fencing subsidy for farms in the catchment.
- Due to the presence of *Gambusia* and bladderwort, it is inadvisable to use the Kai Iwi Lakes as a water source for fire-fighting if other water bodies are also to be sourced and do not already contain these two pests.
- Lake Waikare requires installation of a staff gauge to measure water levels. The other two lakes currently have staff gauges in place, but the gauge at Taharoa could be improved.
- Consideration of management of mahinga kai or customary food sources.
- Cultural monitoring, indicators and concepts of environmental health (mauri) as well as the resourcing of kaitiaki to participate in monitoring.
- More integrated monitoring and research by agencies and researchers.
- Increased biosecurity campaign to avoid water weeds and pest fish entering the lakes. Check Clean Dry may be the basis of this work.

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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)

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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