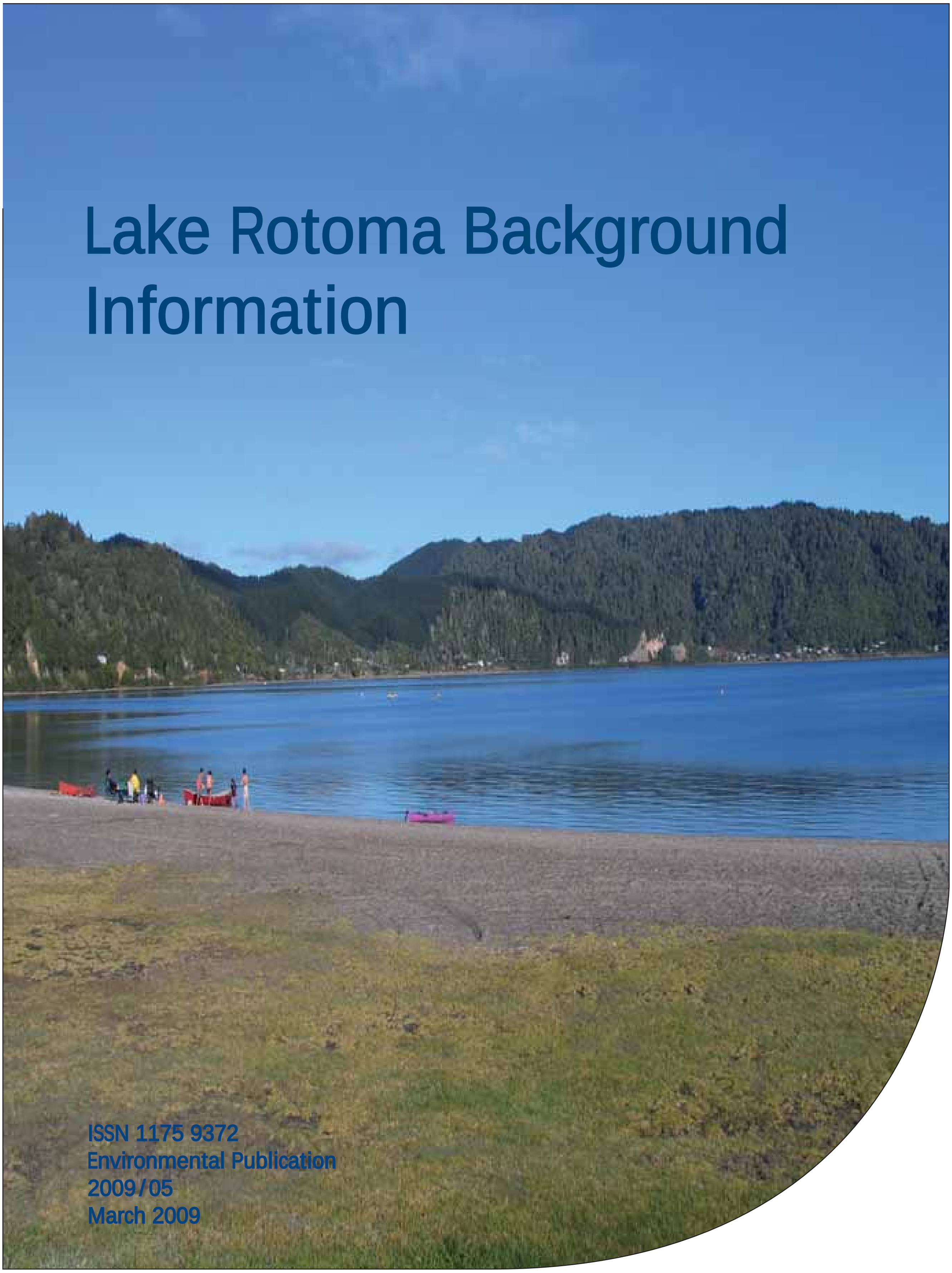
Lake Rotoma Background Information



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THE ROTORUA LAKES
Protection and Restoration Action Programme

An **Environment Bay of Plenty, Rotorua District Council** and **Te Arawa Lakes Trust** joint project

Contents

Chapter 1: Introduction

1.1 Lake Rotoma

Lake Rotoma means clear water – an apt description of the cleanest of the 12 Rotorua Lakes. Lake Rotoma was formed by volcanic eruptions approximately 8,500 years ago. Lake Rotoma is at the top of the northeast-trending Haroharo vent zone[1]. The lake has two basins. The northern basin is the deepest at 83 metres, and the southern basin has a maximum depth of 73.5 metres. The lake surface area is about 1,112 hectares.

1.2 Maori customary use of Lake Rotoma

Lake Rotoma and its surrounds have been used by Maori groups since descendants from the Arawa canoe entered the area.

Ngati Pikiao claims this lake as part of their tribal rohe extending from Mourea in the west. Ngati Awa from the Mataatua canoe also claims the lake and surrounds as their rohe; and Ngati Tuwharetoa (Bay of Plenty) claim association with this area through Rakeimarama, Tuwharetoa's matamua (eldest) son. These tribes have fought for occupation of this area from time to time.

Ngati Tuwharetoa were also associated with the area, now part of Lake Rotoma Scenic Reserve, through the iwi of Ngati Umutahi, and the Te Arawa hapu Ngati Tarawhai, Ngati Tiki, Ngati Rahikoia, and Ngati Hinewai. Umutahi's wife Rangipare was Tarawhai's grand-daughter, and their great grand-daughter Ngapopoa married Tiki. It has been stated that Ngati Tiki carried the mana of Ngati Umutahi at Lake Rotoma.

Traditionally, Ngati Tuwharetoa also lived at a kainga, Taraki, on the eastern shore of Lake Rotoma, and fished at a fishing ground called Purehurehu. Here they gathered whitebait and Koura. Koura in Lake Rotoma are still a significant customary fishery, renowned as succulent and sweet.

A common Ngati Pikiao and Ngati Tuwharetoa story about Lake Rotoma centres on Rakaimarama. As a highly respected tohunga, Rakeimarama could venture anywhere unchallenged because of his powerful incantations and sorcery. He lived on an island in Lake Rotoma with his iwi. One fateful day Rakeimarama arrived on the shore of Lake Rotoma at his pa called Ngohiorangi. Feeling tired and hungry, he called across the water for his people to fetch him, as was the custom. Angry at not receiving a response after some time he waded into the water and recited certain incantations. His karakia summoned a storm against the island. The island and the pa sank below the water.

[1] Johnston, D.M., Nairn, I.A. Volcanic Impacts Report. Institute of Geological and Nuclear Sciences, prepared for Bay of Plenty Regional Council Resource Planning Publication 93/6, October 1993.

The now-submerged island is a small rhyolitic dome that has been above water before European settlement.[2] It is only one to three metres below the lake surface in places and is marked with buoys on the lake. It is a popular diving spot as it is a shallow area that drops off sharply into the lake.

The Ngati Pikiao ancestral link to Lake Rotoma goes back to Rakeimarurmaru, who had whakapapa back to Waitaha-a-Heui and Uruika. He and his descendents settled around Lakes Rotoma and Rotoehu. Rakeimarurmaru's daughter Hinetamairu succeeded to his lands and married Tamateatutahi. They had Hinehopu, who married Pikiao II and produced the claimants to Waitangi, Tamateatutahi-Kawhiti, Te Rangiunuora and the Rotoma area[3].

Four tribal groups currently have customary interests in some form over Lake Rotoma:

- Ngati Awa's area of interest includes Lake Rotoma and its catchment, with a statutory acknowledgement and deed of recognition of the Lake Rotoma Scenic Reserve, a statutory acknowledgement and deed of recognition for Rotoma Forest Conservation Area and ownership of the Otitapu Lookout (pa site) in this Reserve.

- Ngati Tuwharetoa Bay of Plenty's area of interest[4] also includes Lake Rotoma and its catchment, with a statutory acknowledgement and deed of recognition of the Lake Rotoma Scenic Reserve, a statutory acknowledgement and deed of recognition for Rotoma Forest Conservation Area and ownership of the Otitapu Lookout (pa site) in this Reserve. The statutory acknowledgement area also includes the bed and waters of the lagoon near Otumarokura Point. Otitapu Pa was a lookout post on the Tihetihe range in the Lake Rotoma Scenic Reserve. It served several pa sites surrounding it, including Okoroiti and Okake to the south and Opeke and Waituhi to the east. It also served the Haupanapana Track to the south and joined the Tararaika and Tuwharetoa Trails which were used by the Ngati Tuwharetoa people to and from the coast at Pikowai and Otamarakau.

- Ngati Pikiao does not have a Treaty of Waitangi settlement with the Crown. However it owns a significant portion of the lake catchment through the Rotoma #1 Block and other land trusts. It is also the main Maori group living around the lake, and Lake Rotoma is widely acknowledged to be part of its rohe.

- Te Arawa Lakes Trust is the governance entity established under Te Arawa Lakes Settlement Act 2006. The settlement relates to 14 lakes[5], including Lake Rotoma[6]. Property title for 13 lakebeds (excluding Okaro which is vested in Rotorua District Council) has been returned to Te Arawa. This includes ownership of the lakebeds (including plants attached to the lakebeds) and subsoil. Te Arawa Lakes Trust manages these lake beds, along with co-

[2] Donald, R. Rotorua Lakes Summary Report. Environment Bay of Plenty Environmental Report 1997/21, November 1997.
[3] Waitangi #3 Trust. Restoration, Capacity and Commercial Opportunities Project. Waitangi #3 Trust Sustainable Development Working Paper, 2007 – 2012.
[4] Deed of Settlement of the Historical Claims of Ngati Tuwharetoa (BOP) - Schedules; Pages 60-61.
[5] Lakes Rotorua, Rotomā, Rotoehu, Rotoiti, Rotomahana, Tikitapu, Tarawera, Tutaeinanga, Ngāhewa, Ōkaro (also known as Ngākaro), Ōkareka, Rerewhakaaitu, Ōkataina, and Ngāpouri (also known as Ōpouri).
[6] Only the lakebed under (perceived) public ownership management was transferred to Te Arawa Lakes Trust. Portions of the lakebed adjacent to the shoreline are under Maori Trust or private ownership, due in part to lake level fluctuations.

managing the lakes themselves with Environment Bay of Plenty and Rotorua District Council under the Rotorua Lakes Strategy Group. The Group is a joint committee authorised by the Te Arawa Lakes Settlement Act. Its purpose is "to contribute to the promotion the sustainable management of the Rotorua Lakes and their catchments, for the use and enjoyment of present and future generations, while recognising and providing for the traditional relationship of Te Arawa with their ancestral lakes". Existing public access to the lakes is protected.

- Te Arawa also has statutory acknowledgements over the 13 lakebeds which includes the water column and air space above the lakes.

- The Te Arawa Lakes settlement recognises Te Arawa's association with their ancestral lakes, provides for Te Arawa's lakebed ownership, and involves Te Arawa in lake management decisions.

There are a number of significant sites to Maori around Lake Rotoma. Information about these can be found in:

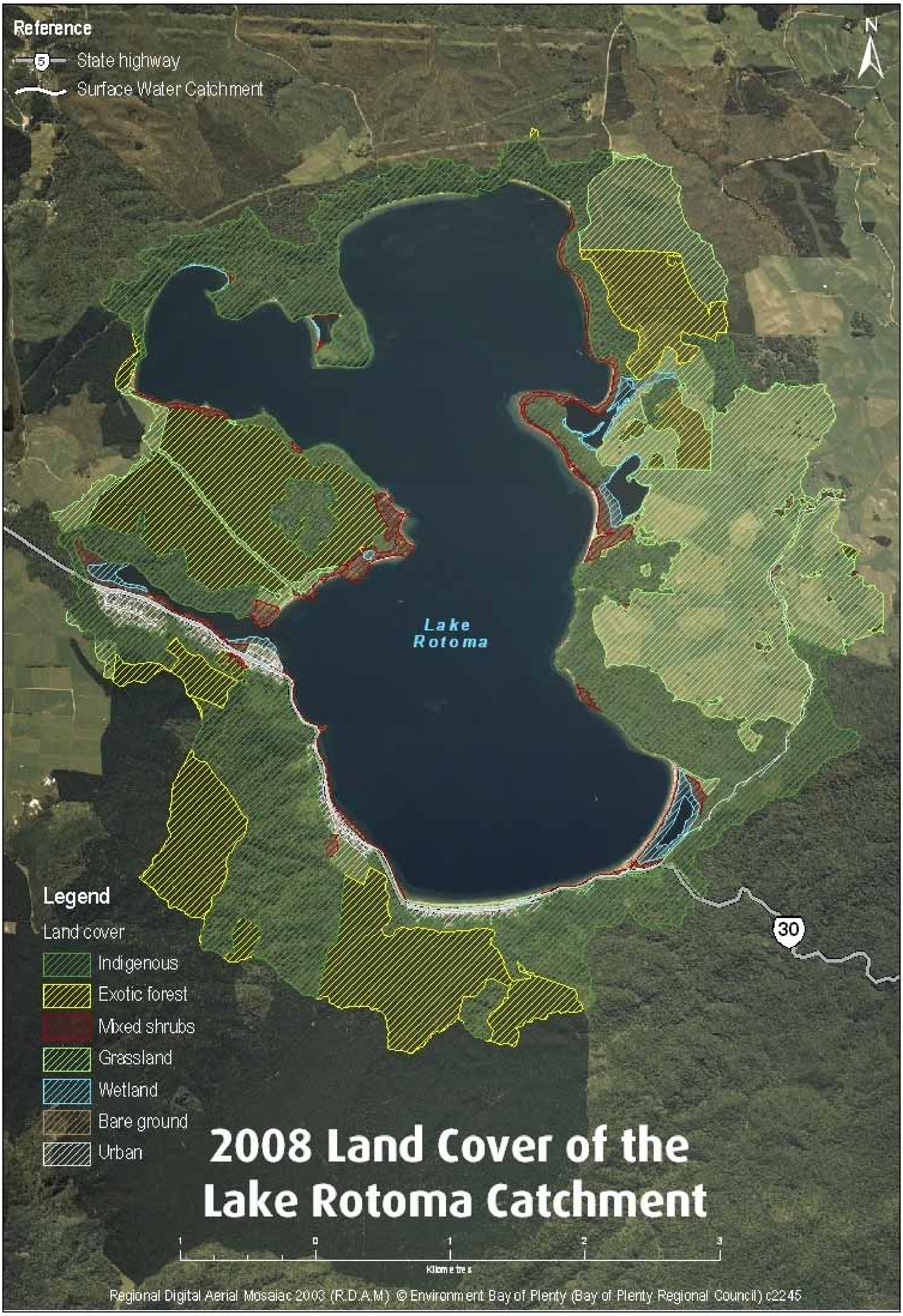
- Te Hu Repo Nuku Papa – Freshwater Wetlands Naming Project, Environment Bay of Plenty Resource Policy Publication 2001/01.

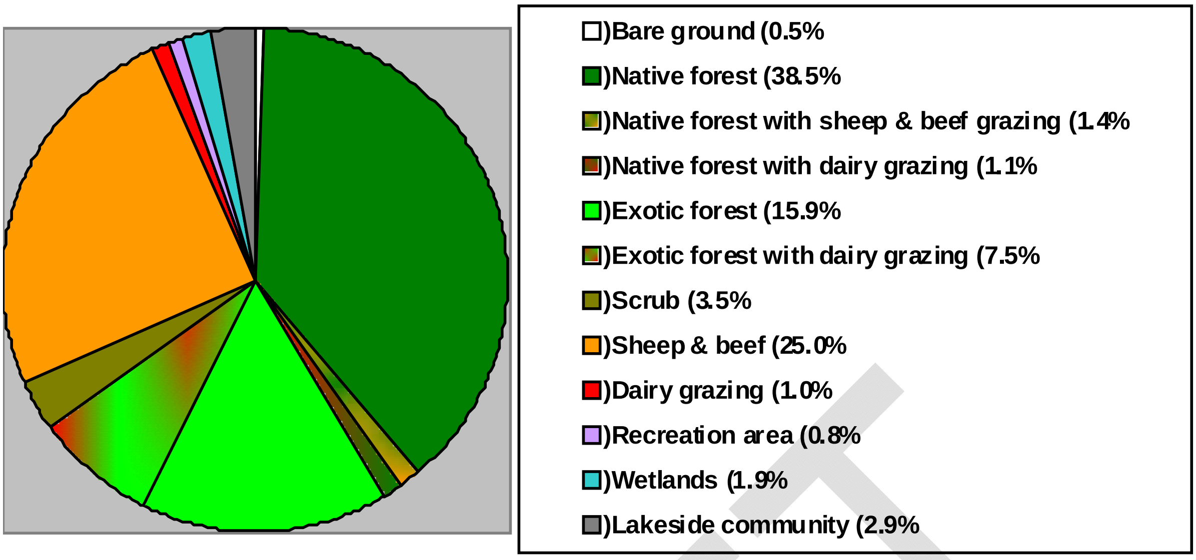
<u>Landmarks of Te Arawa – Volume 2: Rotoiti, Rotoehu, Rotoma.</u> Stafford (1996).

Chapter 2: Land use in the catchment

2.1 Land cover and land use

Land use in Lake Rotoma's catchment includes forestry, native bush, a lake edge community and livestock farming.


Reference
5 State highway
Surface Water Catchment
N
Lake
Rotoma
30
Legend
Land cover
Indigenous
Exotic forest
Mixed shrubs
Grassland
Wetland
Bare ground
Urban
2008 Land Cover of the
Lake Rotoma Catchment
1 0 1 2 3
Kilometres
Regional Digital Aerial Mosaic 2003 (R.D.A.M) © Environment Bay of Plenty (Bay of Plenty Regional Council) c2245



2.2 Lake ownership

The Te Arawa Lakes Settlement Act transferred ownership of the bed of Lake Rotoma to Te Arawa Lakes Trust along with the beds of other Rotorua Lakes. The Crown owns the water column and air space, which is administered by Land Information New Zealand. The Settlement Act means that:

(a) Public access on the lake is preserved.

(b) Existing commercial operations and lake structures can continue, subject to any resource consent requirements for consultation with Te Arawa Lakes Trust and Lake Information New Zealand.

(c) New lake structures and new commercial operations that use the lake need permission from Land Information New Zealand. If a proposed activity uses the lakebed, it also requires permission from Te Arawa Lakes Trust as owners. The resource consent process is separate to this.

(d) Te Arawa Lakes Trust has no responsibility for exotic weed management, nor the lake quality decline that has occurred during the Crown's management of the lakes.

Some areas of beach and lakebed are privately owned, for example the lakebed adjacent to the campground. Rotoma #1 Trust own on the south-eastern side of their land, as indicated below. The yellow lines are property boundaries.

2.3 Rainfall

The table below documents a rainfall summary in the Rotoma settlement from 1964 to 2003.

Rainfall Totals (mm) for the Lake Rotoma settlement adjacent to the Community Hall			
Mean Annual Rainfall	2131	Mean Summer Rainfall	460
		Summer Rainfall as % of Annual	22
		Mean Autumn Rainfall	515
		Autumn Rainfall as % of Annual	24
		Mean Winter Rainfall	637
Max 24 hr fall (on 02/02/1967)	248	Winter Rainfall as % of Annual	30
Max 48 hr fall (on 17/04/1974)	291	Mean Spring Rainfall	525
Max 72 hr fall (on 16/04/1974)	364	Spring Rainfall as % of Annual	25

2.4 Water balance

Water flows into the lake from rainfall, streams, springs, and groundwater. There are no surface water outflows; however, it is estimated that about 7% of the lake volume leaves via groundwater annually. Approximately half the groundwater flow drains to Lake Rotoehu[7]. Flow is westwards from the Matutu Basin through the porous pumice substrate, emerging at the groundwater-fed wetland area east of Lake Rotoehu. This drains to the Waitangi Soda Spring at the south-eastern corner of Lake Rotoehu. The remainder of the outflow drains southeast via subsurface flow to the Waikanapiti Stream[8].

2.5 Lake level fluctuations

The lake level fluctuates significantly. Records from 1955 to present day show the lake level fluctuating between 312.2 metres and 317.7 metres above sea level (Moturiki datum) – 5.5 metres. From 1911 to the lake level peak in late 1971, the lake fluctuated markedly about an overall rising trend of at least 6 metres. Former lake edge shelves as deep as 25 metres indicate that the lake level has been lower still[9].

Short term lake level fluctuations closely parallel annual rainfall. The lag period is about two – three months, as groundwater moves through to the lake[10]. However earthquakes also play a significant role. As part of the Haroharo vent zone in the Okataina Volcanic Area, a number of fault lines underpin Lake Rotoma[11]. Local residents have noticed changes in lake turbidity, lake level and lake movements in lakes along these fault lines (Lakes Okataina, Rotoehu, Rotoma). A sudden change in lake level was recorded after the 1931 Napier earthquake, when the submerged island was temporarily above water[12]. The earthquakes seem to affect the rate of groundwater recharge from Lake Rotoma, by changing the natural sub-surface outlets in the lake.

2.6 Maximum lake level

At about 318 metres above sea level, the lake may discharge over the saddle at the head of Whangaroa Bay and flow down to Lake Rotoehu. If the lake reached this height, in a high rainfall event a possible 'dam break' could happen at the highest point along this flow-path.

The Bay of Plenty Catchment Commission (superseded by Environment Bay of Plenty) obtained a water right (now a resource consent) in September 1972 to construct an open inlet channel, control weir, pipeline and outlet channel from the head of Whangaroa Bay in Lake Rotoma to Te Wairoa Bay in Lake Rotoehu. The purpose was to control high lake levels and flooding. The infrastructure was built, except for the open channel from Lake Rotoma to the control weir. Under the

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7 Donald, R. Rotorua Lakes Summary Report. Environment Bay of Plenty Environmental Report 1997/21, November 1997.

8 Taylor, C.B. et al. Preliminary measurements of tritium, deuterium and oxygen-18 in lakes and groundwater of volcanic Rotorua region, New Zealand. Institute of Nuclear Sciences report INSR-227.

9 Nelson, C.S. Bottom Sediments of Lake Rotoma. Vol. 11: 185-204, New Zealand Journal of Marine and Freshwater Research, 1983.

10 Clayton, J.S. The submerged vegetation of Lake Rotoma. Unpublished PhD thesis, University of Auckland, 1978. Also from local observations.

11 Johnston, D.M., Nairn, I.A. Volcanic Impacts Report. Institute of Geological and Nuclear Sciences, prepared for Bay of Plenty Regional Council Resource Planning Publication 93/6, October 1993.

12 Clayton, J.S. The submerged vegetation of Lake Rotoma. Unpublished PhD thesis, University of Auckland, 1978.

Resource Management Act, the resource consent exists until 2026. However the consent states that the lake level control cannot flow until the Lake Rotoehu level is also under control.

Policy 76 in the Regional Water and Land Plan states: "To discourage the artificial control of water levels in lakes that are not already controlled at the time this plan is notified, except in extreme circumstances where unusually high lake water levels are reached and buildings and important infrastructure are threatened and there are no practicable alternatives."

This Action Plan recommends that Environment Bay of Plenty investigates the cost and practical implications of a maximum lake level overflow structure for Lake Rotoehu as part of its hydrology work programme. Environment Bay of Plenty shall construct and operate the Lake Rotoehu and Lake Rotoma overflow structures if Lake Rotoma's lake level exceeds 317 metres above sea level (Moturiki Datum), in order to protect lakeside infrastructure, stock exclusion fencing and plants around both lakes.

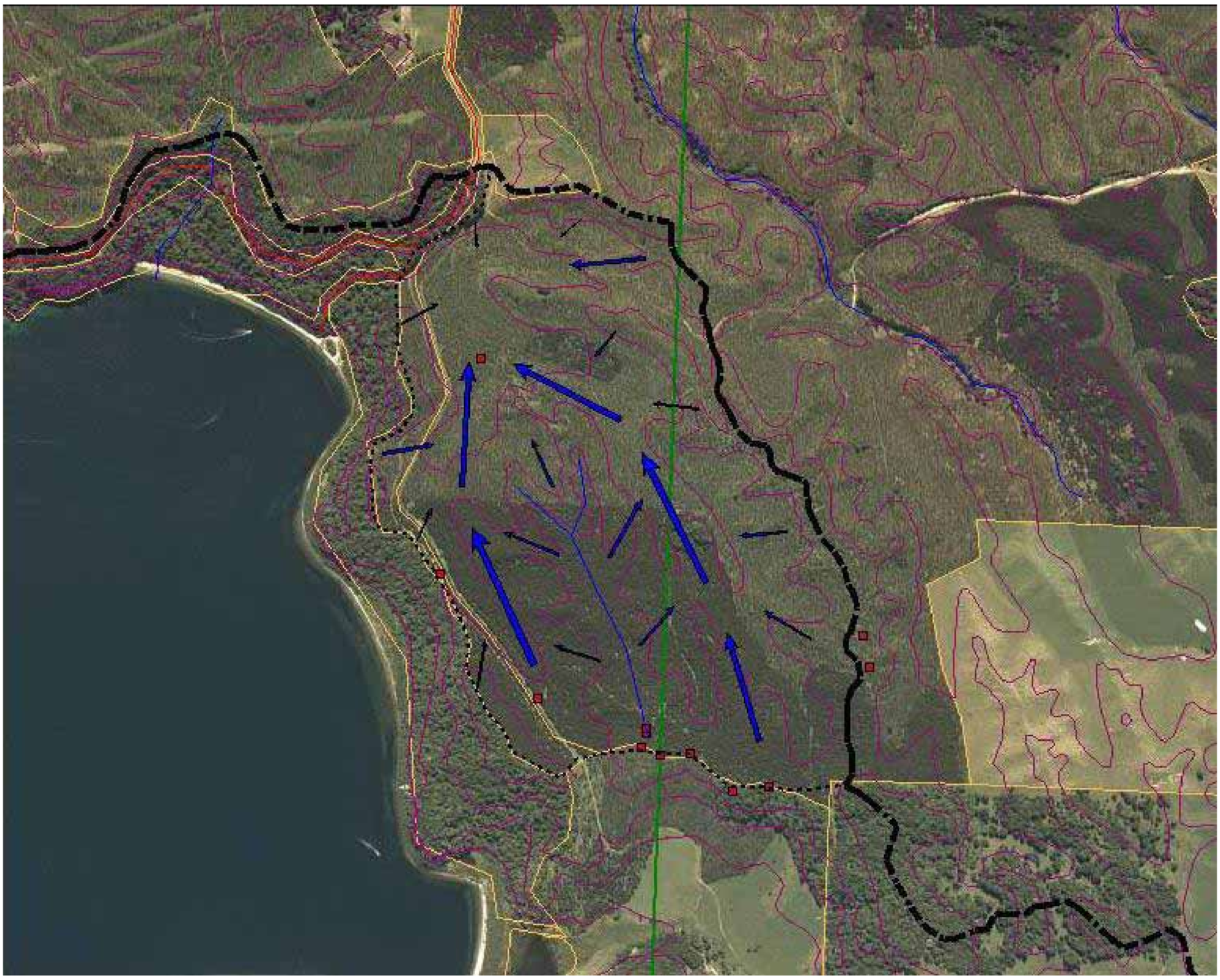
2.7 Groundwater and surface water runoff

Lake Rotoma soils have a very high absorption rate. Rainfall in the catchment averages around 2,100 mm per year and most of this sinks through the soil to groundwater aquifers. Surface water enters the lake via two permanent streams. One of these is near the petrol station/Rotoma Trading Post, and the other is known as Fish Creek or Te Muriwai. There are also at least three ephemeral streams, and small water channels that form during heavy rain. Groundwater enters the lake through springs emerging around the lake margin, and direct sub-surface inflows.

For some of the Rotorua Lakes, groundwater flows can differ from surface water flows. Historic volcanism, volcanic deposits and ground faulting can direct shallow and deep groundwater in different directions. At this stage, there is no evidence to suggest that Lake Rotoma's surface water catchment is not the same as its groundwater catchment. The catchment boundaries are clearly defined by ridges, and limited water balances indicate that water in = water out.

The north-western corner of the catchment may be an exception. It is an enclosed basin with no apparent outlet. It is 98 ha in size – 5.8% of the surface water catchment (excluding the lake). Groundwater could either flow to Lake Rotoma, westwards to the Morepara Stream, or elsewhere. The picture below shows the land contours and expected surface/groundwater flows.

This land area should be tagged for further research to establish its subsurface water flows. If they flow to Lake Rotoma, the land should be checked for ways to reduce nutrient loss from its land use.



Chapter 3: Water quality

Lake Rotoma has the best lake water quality out of the twelve large Rotorua Lakes in the Bay of Plenty region, with a 3-year average TLI of 2.6. This oligotrophic (low nutrient enrichment) state reflects the lake's depth and small catchment land area in pastoral land use. The lake and catchment is sampled for a number of different water quality parameters. The figure below shows the different sampling locations.

3.1 Attenuation

The low catchment/volume ratio means that lake water has a high average retention time in the lake, estimated to be about nine years. Similar to Lake Tarawera, these results in a high attenuation rate of nutrients. Both lakes have a similar depth, and have similar stratification behaviour (‘*warm monomictic*’ lakes: the lake columns separate into a warm upper layer and cooler bottom layer during summer and autumn). Therefore Lake Rotoma will have high attenuation rates like Lake Tarawera. However this cannot be measured accurately as there are few surface water inflows and no surface water outflow. So this Action Plan gives Lake Rotoma a nutrient attenuation rate of 70%[13].

The rate of diatom deposition on the lakebed has more than doubled since the 1886 Mt Tarawera eruption[3]. This shows there has been a significant increase in nutrients into the lake, possibly from farming development in the catchment. The lake’s depth and lake retention time have buffered the lake from significant lake water quality decline.

However, there are some minor indicators that lake water quality is slowly getting worse during the 1992 – 2006 water quality analysis period that Environment Bay of Plenty has monitored[14].

3.2 Dissolved oxygen

Dissolved oxygen in the bottom waters of the lake have decreased significantly from 1993 to 2006. The rate of oxygen depletion in bottom waters during the summer and autumn months (when the lake separates into two layers) has also increased since 1996. At the moment this is just an indicator. The oxygen levels are still high enough for bottom-dwelling aquatic life to survive.

When a lake loses all the oxygen in the bottom waters (usually around a TLI of 3.1 – 3.5, like Lakes Tikitapu and Okareka), some of the nutrients that have settled out to the lakebed over time are released into the water column. As a lake becomes eutrophic, the nutrient cycling from the lakebed sediments start to dominate lake water quality. For example, about 360 tonnes of nitrogen and 36 tonnes of phosphorus is released into Lake Rotorua up to ten times per year. In comparison, Lake Rotorua receives about 547 tonnes of nitrogen and 40 tonnes of phosphorus from its catchment every year.

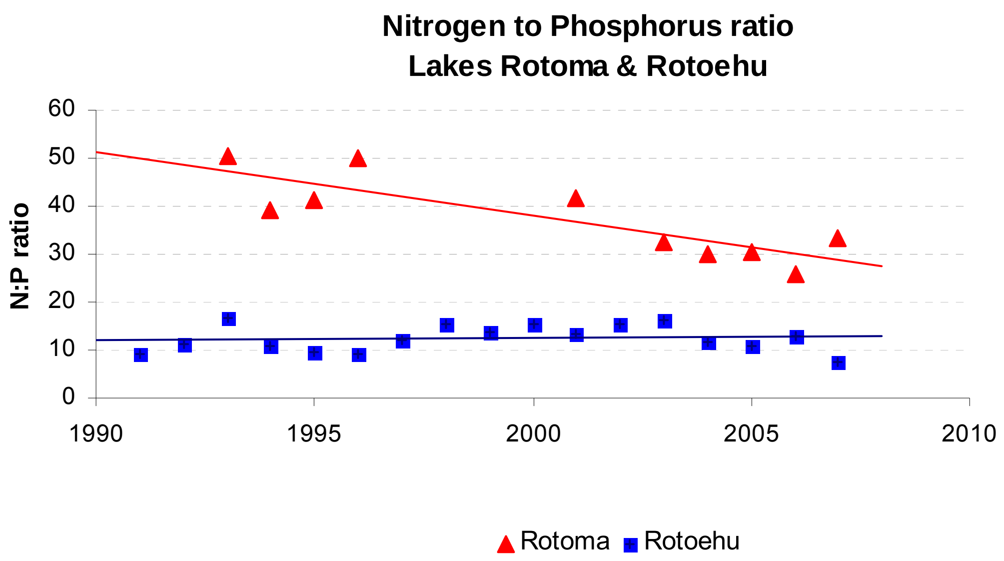
3.3 Nitrogen

Total nitrogen concentrations in Lake Rotoma have stayed constant over time, despite year to year fluctuations. However, there has been an increase in ammonium-nitrogen and nitrate-nitrogen concentrations in the bottom waters since 1992.

3.4 Phosphorus

Total phosphorus concentrations in the lake have approximately doubled since 1992 in the bottom waters and surface waters (using a seasonal regression trend line). This is also reflected in the N:P ratio in the lake.

[13] Based on non-specific discussion from Hoare.
[14] Scholes, P., Bloxham, M. Rotorua Lakes Water Quality 2006 Report. Environment Bay of Plenty Environmental Publication 2007/12.



Lake Rotoma is phosphorus-limited, meaning that phosphorus is the limiting factor that controls the growth of algae. In most lakes, the lower the N/P ratio, the poorer the water quality, such as Lake Rotoehu; although there are notable exceptions where P concentrations are naturally high, for example, Lake Taupo and Lake Tarawera. For these lakes, both nitrogen and phosphorus can be the limiting nutrient. A lake is no longer phosphorus-limited at an N/P ratio of about 10 – 15.

3.5 Estimated nutrient loss from the catchment

The following table shows the estimated nutrient loss from the differing types of land use around Lake Rotoma. Nutrient loss coefficients for each land use type. The sources of the coefficients are listed as footnotes beneath the table.

Table 2008 land use export coefficients for the Lake Rotoma catchment

Land cover	Area	Export	Load				
		TN	TP	TN	%	TP	%
	ha	kg/ha/year	kg/year		kg/year		
Bare ground	8	5	1.0	40	0	8	1.1
Native forest	643	3[15]	0.075[16]	1,929	11	48	6.5
-with sheep/beef grazing[17]	24	5	0.15	120	1	4	0.5
-with dairy grazing	18	10	0.15	180	1	3	0.4
Exotic forest	265	3	0.095[18]	795	4	25	3.4
-with dairy grazing	126	10	0.15	1260	7	19	2.6
Scrub	59	3	0.04	177	1	2	0.3

[15] Standard values for native bush/exotic forest/scrub. Research indicates values ranging ~1.5 – 4.0 kg/ha/yr.
[16] Macaskill et. al. (1997), Nitrogen and Phosphorus in Streams Draining Catchments of Different Land use in the Rotorua Lakes Region. Table 19 states that P loss from native forest around Rotorua Lakes that P loss from native bush is about 80% less than from exotic forest.
[17] "with dairy/sheep/beef grazing" = mid-range estimate assuming 3/4 months grazing pasture equivalent.
[18] Cooper, A.B., Thomsen, C.E. (1988), Nitrogen and phosphorus in stream waters from adjacent pasture, pine and native forest catchments. *New Zealand Journal of Marine and Freshwater Research* 22, 279-291. Sampled from sites similar to Rotoma: central volcanic plateau, average slope 17˚, porous pumice and ash soils.

Land cover	Area	Export	Load				
		TN	TP	TN	%	TP	%
	ha	kg/ha/year	kg/year		kg/year		
Sheep/beef	415	15[19]	0.38[20]	6,225	34	158	21.5
Dairy grazing	16	40[21]	0.38	640	4	6	0.8
Recreation area[22]	14	4	0.1	56	0	1	0.1
Wetlands	32	0	0	0	0	0	0.0
Urban built[23]	48	3	0.7	144	1	34	4.6
Septic tanks (251 HUE)[24]				2,530	14	250	34.0
Rainfall to lake[25]	1,115	3.6	0.16	4014	22	178	24.2
Waterfowl[26]				*100*	*1*	*60*	*2*
Catchment total	**2,783**			**18,110**	**100**	**736**	**100**

The above method estimates nutrient loss from the land use, but doesn't necessarily account for nutrient attenuation between the land use and the lake. However, the balance between estimating the lake nutrient load from land use and from in-lake nutrient levels is quite close (19,730 kgN/yr, 720 kgP/yr).

Another way to estimate nutrient loss from the catchment is to work back from in-lake concentrations. This method uses the nutrient concentrations, lake attenuation percentages and lake water retention times. Using this method, the estimated nutrient loss from the catchment is:

TN = 19,730 kg-N/yr.

TP = 720 kg-P/yr.

These figures indicate that there is likely to be some attenuation of nutrients in the catchment itself, especially for phosphorus. Wetland areas may transform some nitrates into nitrogen gas. It's expected that some phosphorus is settling out in the two lagoons on Lake Rotoma's eastern shoreline, as a significant area of farmland drains to these lagoons. Both are still estimates, but together give a reasonable reflection of the actual nutrient inputs to Lake Rotoma. They also highlight the relative importance of reducing the phosphorus inputs to the lake.

Future water quality modelling of Lake Rotoma will refine these input estimates, as well as the nutrient reduction targets.

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[19] Average values generated by OVERSEER and NPLAS from benchmark data around Lakes Rotoma, Rotoehu and Rotoiti.
[20] OVERSEER prediction for sheep/beef farm in Rotoma catchment, 'easy hill' 15˚ - 25˚ slope, default pumice soils. Same figure applied to dairy grazing.
[21] Average Rotorua dairy farm N loss = 50 kg-N/ha/yr. Dairy grazing assumes slightly less intense land use.
[22] Estimate values only.
[23] Standard values sourced from Rotorua city's stormwater sampling 2005/06.
[24] Rotorua District Council: Estimate of Household Unit Equivalents, maximum loading rate for 2014. 1 HUE = 2.8 fulltime residents. While this summer maximum may overestimate annual loads, the overestimate in the resident population may balance out the unaccounted load from lake visitors. One fulltime resident's average wastewater nutrients from septic tank = ~3.6 kg-N/yr, ~0.7 kg-P/yr. N estimate is from NIWA literature review; includes ~10% N removal in tank/soils. P estimate is from Environment Bay of Plenty's Water Quality Technical Advisory Group's review of P export research from septic tanks near the Rotorua Lakes margins in November 2007.
[25] Pers. Comm. Max Gibbs (NIWA), 2006.
[26] Some of the nutrients consumed by waterfowl come from the lake, so are termed 'nutrient recycling'. The nutrient input is included in the budget for comparison only.

3.6 Two-stroke motors[27]

Two-stroke motors in boats produce 10 times the amount of pollution as four-stroke motors. Even modern efficient two-stroke motors produce much more pollution. This results in relatively large amounts of combustion products and unburned fuel (10 – 25%) being mixed into surface waters. A single jet ski can emit up to 23 litres of fuel in just two hours of operation.

However, this fuel does not accumulate in the lake. It is largely eliminated by evaporation, biodegradation, dispersion and photo-oxidation. Some contaminants like Poly-Aromatic Hydrocarbons (PAHs) tend to concentrate in the surface layer at toxic levels, but still remain for less than a day. Under normal use, there is no significant water quality degradation caused by outboard motors in large (>250 ha) and deep (> 6 metres) lakes.

[27] Dupree, C. (2007) Potential impacts of emissions from outboard motors on the aquatic environment: a literature review. NIWA Client Report HAM2007-026, March 2007. Prepared for West Coast Regional Council.

Chapter 4: Lake pest control

4.1 Aquatic pest plant and pest fish control

Lake Rotoma is at high risk of hornwort infestation from Lakes Rotoehu or Rotoiti. This is a major concern because hornwort is widely regarded as the most prolific, damaging lake weed in New Zealand. Hornwort can grow in lake water up to 14.5 metres deep, in beds up to 7 metres high[28].

[28] "Hornwort – our worst submerged weed" Aniwaniwa Issue 18 2001, NIWA publication. http://www.niwa.cri.nz/pubs/an/18/pests3.htm, downloaded 30/8/07.

The map shows the areas in Lake Rotoma that are up to approximately 15 metres deep, and could be at risk if a hornwort fragment entered the lake.

Aquatic pest plant and pest fish control is managed by the Rotorua Lakes Aquatic Pest Management Plan. A technical advisory group of Environment Bay of Plenty (lead agency), Rotorua District Council, Fish & Game, and Department of Conservation prepared this Plan. Te Arawa Maori Trust Board and Land Information New Zealand have also joined the working group as lake owners.

To avoid accidental spread, the focus is on stopping weed fragments getting into the lake. Extensive publicity tells people to clean weed off their boat and trailer: signs at the main road entrances to Rotorua, and at boat ramps including Rotorua and Rotoehu, sponsorship of fishing events, student weed awareness surveys, newspapers, giveaways, school education kits, and so on.

The Environment Bay of Plenty student surveys show an increase in awareness of aquatic pest issues in the Rotorua Lakes. In the 2005/2006 survey, 90% of boat users had a high or medium level of awareness of aquatic pest issues.

Environment Bay of Plenty has installed a weed cordon around the Whangaroa Bay boat ramp. If a new lake weed enters Lake Rotoma by someone using that boat ramp, it is likely to stay within the cordon. This area is checked regularly to ensure that new weeds are not established. Any new weeds in this area are controlled by spraying with herbicide.

4.2 Control of Canada geese and black swans

The counts of birds from aerial trend counts over the last five summers (up to 2007) have been averaged. For swan, direct counts of birds were taken on Lake Rotoma. Swan move between lakes, but movement is limited, so using the direct counts gives us a fair estimate of swan per year (swan-years).

Canada Goose have higher mobility. The trend counts show that the counts on each lake are more variable from year to year, but total counts for the Rotoiti-Rotoehu-Rotoma complex are less variable, and this matches what is known about the more mobile nature of the population in this area. Rotoma counts are a sub-set of the Rotoiti-Rotoehu-Rotoma population, and this group moves around. Sometimes the population is all on Rotoma, and sometimes it is on the other lakes. The trend counts show that on average (over the last five years) 11% of this population is counted on Rotoma, so this has been used to calculate the effective "goose-years" for Rotoma.

Nutrient inputs from swan and goose has been calculated from two reports. The first is Sagar et al 1995 - Review of the ecological role of black swan. NIWA science and technology series 25. The Goose inputs are calculated from a relationship given in the Sagar report for annual effective goose-use days as derived by Manny et al 1994 (Nutrient addition by waterfowl in lakes and rivers; predicting their effects on productivity and water quality. Hydrobiologia 279/280:121-132). Both of these reports used actual guano nutrient contents for these particular species rather than a generic nutrient amount for birds as a group - the figures used by Bioresearches.

The calculated nutrient excreted from geese and swan of 44kg TN/yr and 19kg TP/yr. There are other waterfowl that use the lake and trying to account for them is difficult because the faecal estimates (gm pr kg of body weight) from the Bioresearches report is a mixed waterfowl average, although their calculation suggest that swan and geese account for the vast majority. 44kg TN and 19kg TP are the estimated figures - if they were direct inputs. This is an issue that has been highlighted in the text - swan spend most of their time grazing on aquatic macrophytes taking up nutrients from the lake and then re-releasing them as they are excreted. Geese however graze pasture and then excrete some back into the lake so this would be a direct input. Trying to quantify the proportion simply recycled verses that of the actual input adds a further level of complexity that is unnecessary given the low amount of nutrients actually involved.

The area of the table originally commented on at was the % values in the Table in Section 3.5. Given the total nutrient input of P is 1773kg then 60kg would be 3.4%, and using the values derived above of 19kg P the % drops to 1.1% (1773-60+19=1732, so 19/1732 = 1.1%). A similar calculation is used to determine N. Waterfowl are minor contributors to the nutrient enrichment of Lake Rotoma.