

Lakes Rotorua and Rotoiti Action Plan

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

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Status of Action Plan

This Action Plan is a non-statutory document. This means that it does not contain rules and cannot require changes to other statutory documents. It provides guidance for the management of Lakes Rotorua and Rotoiti. It may or may not result in changes to planning documents. Some of the actions may require resource consent. Any such decision will be made at the discretion of individual agencies and will follow statutory process.

The Action Plan is a live document and regular reviews will be undertaken to keep it up to date with science, technology and community expectations.

Chapter 1: Introduction

1.1 Lakes Rotorua and Rotoiti

1.1.1 Overview

This Action Plan encompasses Lakes Rotorua and Rotoiti and their catchments. It sets out what interventions (or actions) should be undertaken to reduce nutrient (phosphorus and nitrogen) inputs to Lakes Rotorua and Rotoiti. The Action Plan is a community document as all parts of the community are working together to improve water quality in Lake Rotorua. Some actions have already been completed and are proving successful, for example:

- Ohau Channel diversion wall (completed 2008).
- Reducing phosphorus in the Utuhina Stream (2007 ongoing).
- Upgrades to Rotorua's Wastewater Treatment Plant (ongoing).
- Reticulation of Okawa Bay, Mourea, Rotokawa, Brunswick and Hinemoa Point communities (completed).

This Action Plan outlines current known actions and sets out processes to identify future actions to improve water quality in Lakes Rotorua and Rotoiti.

1.1.2 Background information

Lake Rotorua (Te Rotorua nui a kahumatamomoe, *the basin like lake of Kahumatamomoe*) is the largest lake in the Bay of Plenty Region, and the most productive trout fishery in New Zealand.



Plate 1 Lake Rotorua shown with Rotorua township on its margins

With the town of Rotorua on its shores (see Plate 1 above), it is much valued for its aesthetic, cultural and recreational values and is used by locals and tourists alike. What happens to the water in Lake Rotorua also affects Lake Rotoiti as the two lakes are linked by the Ohau Channel.

Lake Rotoiti (Te Rotoiti-kite-a ihenga *The small lake seen by ihenga*) is a relatively large lake despite its name and is also valued by locals and tourists for boating and fishing.

The water of Lakes Rotorua and Rotoiti drains to Maketu via the Kaituna River. Improved water quality in the lakes will enhance the Kaituna River and Maketu Estuary.

Table 1 Physical parameters of Lakes Rotorua and Rotoiti.

Lake	Catchment area (ha)	Lake area (ha)	Max depth (m)	Mean depth (m)
Rotorua	50,055 (surface water) 65,538 (groundwater)	8,056	44.8	11
Rotoiti	12,234	3,370	125	31.5

Rotorua's longest running environmental issue has been the decline in water quality associated with discharge of nitrogen and phosphorus from land use activities. Both lakes are now degraded and suffer intermittently from algal blooms. The decline in water quality has a negative impact on fisheries and tourism, and their associated revenue for the district.

The community wants the decline in water quality in Lakes Rotorua and Rotoiti to be addressed. This is particularly important for Te Arawa, who view the Rotorua Lakes as taonga. Their relationship to the Te Arawa lakes and their environs continues to be the foundation of their cultural identity, cultural integrity, wairua, tikanga and kawa.

This Action Plan identifies actions that can be taken to reduce nutrient loss from urban, commercial, industrial and rural land to restore and protect the quality of Lakes Rotorua and Rotoiti. Some actions undertaken have dual benefits, for example sewage reticulation which is being undertaken will have human health benefits as well.

Reducing nitrogen and phosphorus is the most important step to restore lake water quality.

The signing of a Funding Deed in 2007 to help clean up the four worst-polluted Rotorua Lakes (Rotorua, Rotoiti, Rotoehu and Okareka) is an important milestone in the Rotorua Lakes Protection and Restoration Action Programme. Through this Deed, Central Government has committed \$72.1 million which Environment Bay of Plenty and Rotorua District Council will match dollar for dollar. A percentage of this money is earmarked for Lakes Rotorua and Rotoiti.

Environment Bay of Plenty coordinated the Action Plan process with assistance from a working party¹. The Action Plan document is a non-statutory document and has no power to require land use change; it can only provide direction.

1.2 Importance to Te Arawa

The lakes are of fundamental importance to the tangata whenua of Te Arawa. The practice of kaitiakitanga (stewardship) has been long-standing.

Te Arawa Lakes Trust (the Trust) was established under the Te Arawa Lakes Settlement Act 2006 and Deed of Settlement 2004 and receives and manages the assets on behalf of and for the benefit of the present and future members of Te Arawa.

Te Arawa Lakes Trust is representative of 57 hapu² and iwi as defined within the Te Arawa Lakes Settlement Act 2006. The Act returned 13 lakebeds to Te Arawa ownership.

The Management element of the Vision in the Strategy for the Lakes of the Rotorua district (2000) reflects this:

“At the cultural level, Te Arawa people have a traditional relationship with the lakes, rivers, streams and environs which requires an understanding of the distinctive Māori world view of resource management. This includes the need to protect the mauri of the lakes (indicating that the lakes have a life force of their own and are not inert, lifeless objects but are persons in their own right and therefore should be protected as such). The Māori dimension needs to be provided for by incorporating into resource management decision making and practice the following relationships:

- *The spiritual relationship.*
- *The relationship of dependency, cultural survival and identity.*
- *The rangatira relationship.*
- *The kaitiaki relationship.*
- *The mana relationship.*
- *The customary ownership relationship.”*

These fundamentally important relationships will be maintained and where possible enhanced.

¹ The Action Plan Working Party has members from the community organisations, stakeholder organisations, Rotorua District Council, iwi, Tourism Rotorua, Environment Bay of Plenty. It derives its existence from two sources. The primary source is Method 35 in the Regional Water and Land Plan. The working party is also authorised by the Rotorua Lakes Strategy Group.

² Ngati Hinekura, Ngati Hinemihi, Ngati Hinerangi, Ngati Hurunga Te Rangi, Ngati Kahuupoko, Ngati Karenga, Ngati Kawiti, Ngati Kearoa, Ngati Kereru, Ngati Kuri, Ngati Makino, Ngati Moemiti, Ngati Moko, Ngati Ngararanui, Ngati Ngata, Ngati Paruahanui, Ngati Piiiao, Ngati Pukaki, Ngati Rangiiwaho, Ngati Rangitearere, Ngati Rangitihiti, Ngati Rangiwewehi, Ngati Rehu, Ngati Rereamanu, Ngati Riri, Ngati Rongomai, Ngati Taeotu, Ngati Tahu, Ngati Tamakari, Ngati Tamateatutahi, Ngati Taohi, Ngati Tarawhai, Ngati Tawhaki, Ngati Te Purei, Ngati Te Rangiuuara, Ngati Takinga, Ngati Tu, Ngati Tuara, Ngati Tuheke, Ngati Tumatawera, Ngati Tunohopu, Ngati Tuohonoa, Ngati Tura, Ngati Tutaki-a-Hani, Ngati Tutaki-a-koti, Ngati Tuteniu, Ngati Uenukukopako, Ngati Wahanui, Ngati Wahiao, Ngati Waoku, Ngati Whakahemo, Ngati Whakauae, Ngati Whaoa, Tapuika, Te Toro o Te Rangi, Tuhourangi, Waitaha.

1.3 **Community concerns**

Community groups, associations and individuals have been voicing concerns about the Rotorua Lakes through formal and informal pathways for the last few decades. Original concerns about proliferation of weeds have since changed into concerns about water quality and also catchment land use effects on water quality.

Brentleigh Bond, Chair of the Lakes Community Board gives his thoughts on the issues:

'It is gratifying to have witnessed completion of the first actions necessary to return the water quality of Rotorua's iconic lakes to the desired state. But much more needs to be done and we must now address the difficult catchment management issues to achieve the requisite nutrient reduction targets to restore our lake assets. Future generations expect no less from us.'

1.4 **Why have we created an Action Plan?**

Te Arawa Lakes Trust (TALT), Rotorua District Council (RDC) and Environment Bay of Plenty have worked together as part of the Rotorua Lakes Strategy Group to develop a strategy to restore water quality in the Rotorua Lakes - the Rotorua Lakes Protection and Restoration Action Programme (the Restoration Programme).

Environment Bay of Plenty is developing 'Action Plans' for each of the 12 Rotorua Lakes that are part of the Restoration Programme. The key drivers for the development of these Action Plans are Method 41 of the Regional Water and Land Plan and the Strategy for the Lakes of the Rotorua District. Method 41 of the Regional Water and Land Plan sets out four stages for the development of an Action Plan and requires that an Action Plan to improve or protect lake water quality be developed for each of the lakes. Action plans focus on interventions (or actions) to reduce nutrients in the lakes.

This Action Plan, which has been developed in consultation with the community, sets out what actions should be taken to reduce nutrient (phosphorus and nitrogen) inputs into Lake Rotorua and Rotoiti. The Action Plan is an evolving document and will be reviewed and updated, for example, to allow for developments in technology or best management practices.

1.4.1 **Implementation**

The Action Plan outlines a programme of potential actions to achieve the targets. The inclusion and timing of specific actions will depend on an assessment of all known options. It will also depend on funding and resources being made available in the future annual plan budgets of local government and/or central government funding.



Plate 2 Ohau Channel Diversion Wall

Some actions have recently been completed such as the Ohau Channel Diversion Wall shown above in Plate 2.

The ongoing programme is one of adaptive management based on the outcomes of research, implementation of actions and monitoring both within the catchments and the lakes. The timeline to see the benefit of particular actions will vary.

1.4.2 Monitoring and reporting

An Action Plan reporting template will be developed to provide an annual progress update to councillors and the community.

Active monitoring of the effect of the Action Plan will ensure that areas needing more attention or improvement can be identified. An assessment will be made as to whether a set of easily understood indicators needs to be developed for the community to measure progress. This will be in addition to Environment Bay of Plenty's water quality monitoring, which includes monitoring water clarity, chlorophyll a, total dissolved nitrogen and total dissolved phosphorus.

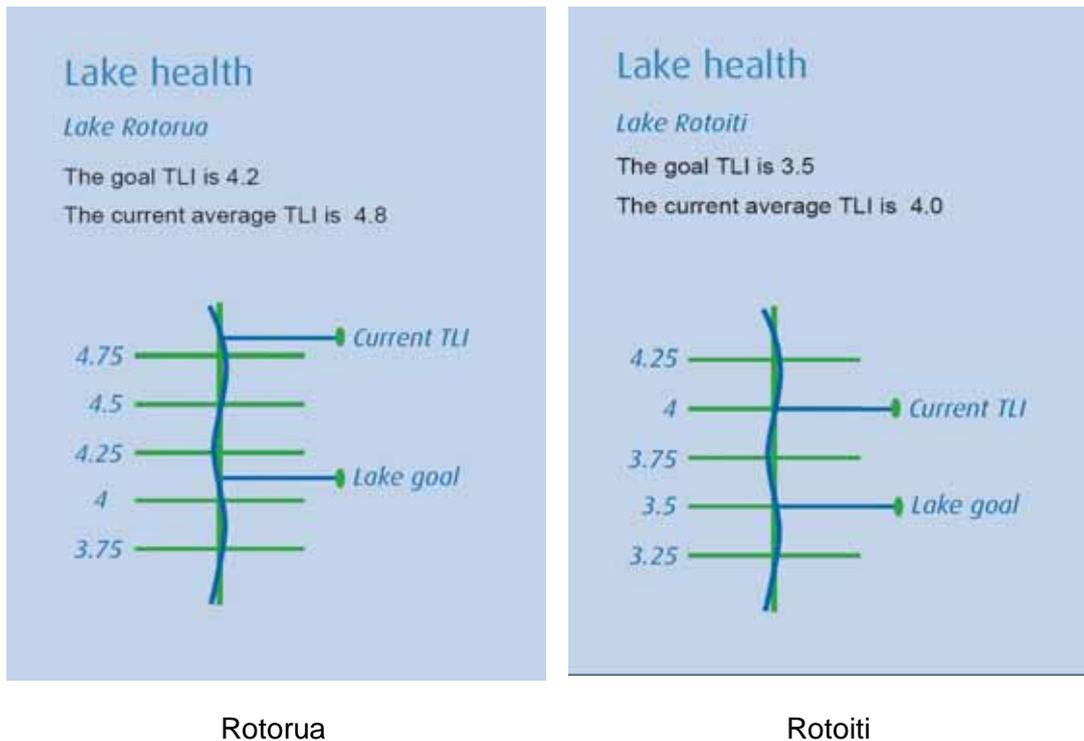
1.5 Lake dynamics

1.5.1 Nitrogen and phosphorus ratios

In most of the Rotorua lakes, the lower the nitrogen to phosphorus ratio, the poorer the water quality. The action plan focuses on both nitrogen and phosphorus because both nutrients play a significant role in controlling algal productivity in Lakes Rotorua and Rotoiti. These nutrients are naturally limited in lake systems, so if more nitrogen or phosphorus is added or removed from a lake, algae populations will eventually increase or decrease accordingly.

1.5.2 Trophic Levels Indices

Each of the 12 Rotorua lakes has a water quality goal that is identified in the Regional Water and Land Plan. These targets are based on a Trophic Level Index (TLI), which is an indicator of lake water quality. There are four key indicators used for TLI (see section 2.1 for further details). The higher the TLI, the lower the lake water quality.



The current three year average TLI for Lake Rotorua is 4.8 and the target is 4.2. The current three year average TLI for Lake Rotoiti is 4.0 and the target is 3.5.

1.6 What is the problem?

Nutrients already in the lake
Nutrients currently entering the lake
Nutrients in groundwater yet to reach the lake

1.6.1 Nutrients - Rotorua

Unsustainable amounts of nutrients from town sewage and agriculture have historically entered both Lakes Rotorua and Rotoiti. These nutrients are now within the bottom sediments of both lakes. Ecological process within the lake can result in these nutrients being released into the water column several times a year which has major effects on water quality. This process is referred to as the internal loading in the lake.

Internal loading in Lake Rotorua is 360 tonnes/yr nitrogen and 36 tonnes/yr phosphorus

Nutrients which are already in the lake are not the only issue for Rotorua. Current *inputs* to the lake from land use are around 556 tonnes/nitrogen/yr and 39.1 tonnes of phosphorus/yr.

The current *exports* of nitrogen from land are even higher than this (746 tonnes nitrogen/yr and 39.1 tonnes phosphorus/yr). As nitrogen takes a long time to reach Lake Rotorua, in the groundwater the inputs will continue to increase over time. This time nutrients take to land slowly pass through the groundwater system towards the lake is called the “groundwater lagtime”.

2009 inputs into Lake Rotorua are 556 tonnes/yr of nitrogen and 39.1 tonnes/yr of phosphorus³

To reach the TLI targets inputs to Lake Rotorua need to be 435 tonnes/yr of nitrogen and 37 tonnes/yr of phosphorus

Assuming the amount of nutrient leaving land does not increase above 2001-2004 levels the difference between where we are and where we need to be to reach our water quality goal for Lake Rotorua still increases over time.

- The difference between where we are and where we want to be in 2009 is: 121 t/N/yr and 2 t/P/yr.
- The difference between where we will be and where we want to be in 2055 is: 224 t/N/yr and 2 t/P/yr.
- The difference between where we will be and where we want to be in 2105 is: 264 t/N/yr and 2 t/P/yr.
- The difference between where we will be and where we want to be in 2250 is: 311 t/N/yr and 2 t/P/yr.

1.6.2 Nutrients - Rotoiti

Unsustainable amount of nutrients have entered Rotoiti from Lake Rotorua via the Ohau channel, from septic tanks and from farming. As with Lake Rotorua these inputs are now within the bottom sediments, but they contribute a much smaller amount.

Internal loading in Lake Rotoiti is 50 tonnes/yr nitrogen and 20 tonnes/yr phosphorus

The amount of nutrients entering Lake Rotoiti have been calculated prior to the completion of the Ohau Channel Diversion Wall (2008). When the nutrient reductions from the Ohau Channel Diversion Wall are quantified these input figures will drop considerably.

The nutrient inputs are not expected to increase over time as there is no groundwater lag time in the Rotoiti catchment.

Current inputs into Lake Rotoiti are 364 tonnes/yr of nitrogen and 29 tonnes/yr of phosphorus

To reach the TLI target for Lake Rotoiti inputs need to be 230 tonnes/yr of nitrogen and 13.3 tonnes/yr of phosphorus

The difference between where we are and where we want to be for Lake Rotoiti is 133 tonnes of nitrogen/yr and 15.7 tonnes of phosphorus/yr.

1.6.3 Effects

High nutrient levels in the lakes promote algal growth which can sometimes result in toxic algal blooms.

³ U Morgenstern & D Gordon; *Prediction of Future Nitrogen Loading to Lake Rotorua*. GNS Science Consultancy Report 2006/10; June 2006

The use of the lake for swimming and recreation by Rotorua and Bay of Plenty residents has been limited by these toxic algal blooms. Health warnings have been issued to the public not to enter both Lakes Rotorua and Rotoiti. Between 2000 and 2007 there were on average four weeks of blooms each year in Lake Rotorua and an on average 10 weeks of blooms each year in Lake Rotoiti. This year (2008-2009) there have been very few blooms in Lake Rotoiti which may be attributed to the success of the wall (this is yet to be scientifically proven).

The decline in water quality has also affected fish habitat. Essentially algae die, fall to the bottom and start decomposing which uses oxygen. When conditions do not allow surface oxygen to move to the bottom, an oxygen depleted zone is formed. This reduces the fish habitat to those upper level oxygenated areas.

1.7 What is causing the problem?

1.7.1 Lake Rotorua

Lake Rotorua's decline in water quality has resulted from years of unsustainable nitrogen and phosphorus inputs from residential, commercial, industrial and agricultural activities.

(a) Legacy

Prior to the 1960s sewage from Rotorua township was discharged to Lake Rotorua with minimal nutrient treatment. Historic intensification of agriculture also added nutrients to the lake through runoff and leaching of nitrogen and phosphorus.

Furthermore, algae populations which flourished in the past died and decomposed forming a layer of organic matter on the lakebed. This organic matter is continuing to build up at a rate of above 1 cm per year as a result of current input levels. When the lake stratifies in calm conditions the amount of algae dropping into the bottom waters determines the rate the bottom waters use up oxygen. When the oxygen is used up in the bottom water, nutrients move from the sediment into the lake water.

This cycle powers nutrient releases from lake bed sediment into the water column. About **360** tonnes of nitrogen and **36** tonnes of phosphorus are released annually from lake sediments. These nutrients can be recycled within the lake during mixing events which can occur several times a year.

The legacy of unconstrained nutrient inputs from sewage and agriculture is now an issue for the whole community to address. There is no intention to attribute blame for practices which were thought to be acceptable and even promoted at the time but solutions do need to be found.

(b) Current

Nitrogen and phosphorus exports from land come from a wide range of sources, these sources have been grouped into the following categories: rural, urban, and natural.

It is important to note at the outset that these figures are based on land use coefficients from 2003. These exports are calculated differently from inputs which are measured from inflows, groundwater ages and nitrogen concentrations. As a result there are minor variations.

Exports from all catchment sources based on 2003 coefficients are 783 tonnes of nitrogen/yr and 39.8 tonnes of phosphorus/yr

Of these sources rural land use contributes the most. Rural land use include all varieties of agriculture (such as beef, sheep, dairy, deer, cropping), horticulture and forestry. Not all rural land uses contribute to the same extent, with dairy farming exporting the most nitrogen and phosphorus per hectare per year.

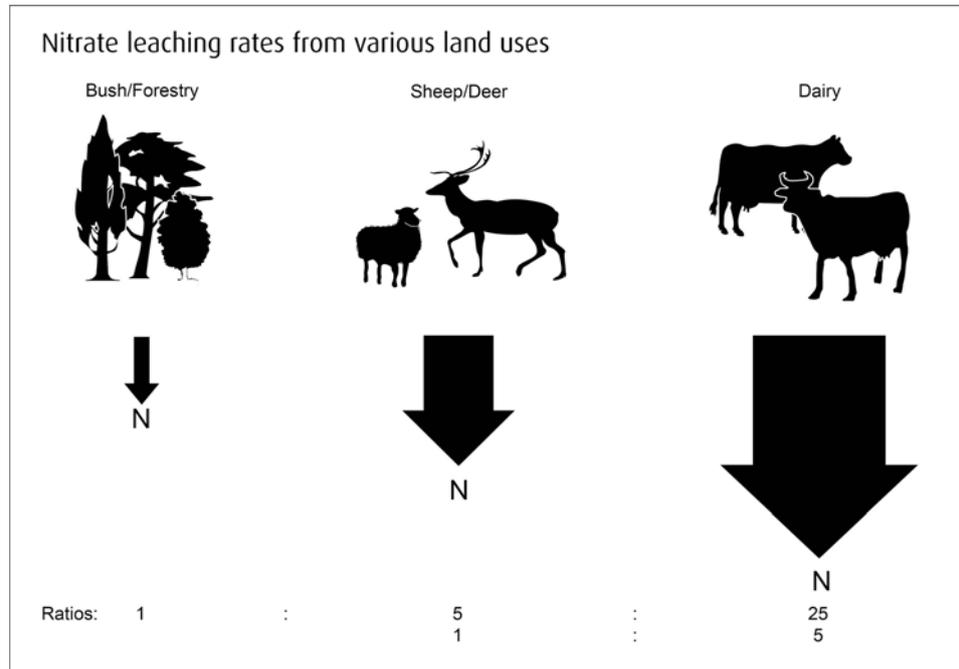


Figure 1 Nitrate leaching rates

At present the nutrient exports from land come predominantly from agriculture and cropping which contributes approximately 578 tonnes of nitrogen/yr and 17.5 tonnes of phosphorus/yr.

Rural⁴ sources contribute approximately: 619 tonnes of nitrogen/yr and 19 tonnes of phosphorus/yr

Natural inputs from geothermal, rain, springs and indigenous forest contribute approximately 115 tonnes of nitrogen/yr and 17.8 tonnes of phosphorus/yr.

Natural sources contribute approximately: 115 tonnes of nitrogen/yr and 17.8 tonnes of phosphorus/yr

Urban communities also contribute to nutrient exports from land but to a much lesser extent. Urban contributions come from the wastewater reticulation plant, septic tanks and also stormwater.

Urban land use contributes approximately: 50.1 tonnes of nitrogen/yr and 3.8 tonnes of phosphorus/yr

⁴ Rural includes: exotic forest, cropping and horticulture, pasture and lifestyle.

(c) Future

The full effects of current land use exports have not reached the lake. Where a nutrient enters the groundwater system will affect the time it takes for that nutrient to reach the lake. Therefore, it will be 150 years before some of the nutrients in the groundwater will enter the lake. This is going to cause problems long into the future and it is expected lake water quality will worsen before it improves.

1.7.2 Lake Rotoiti

Lake Rotoiti's water quality has been greatly affected by the decline in Lake Rotorua's water quality.

(a) Past

In comparison to Lake Rotorua, Lake Rotoiti has a smaller catchment and lower inputs of nutrients. Despite this nutrients have still built up in the sediments of Lake Rotoiti. The bottom sediments release approximately 50 tonnes of nitrogen and 20 tonnes of phosphorus per year which can be recycled between the water column and the lake bed.

(b) Current

Prior to the completion of the Ohau Channel diversion nutrient inputs from Rotorua into Rotoiti were approximately 250 tonnes or 70% of all nitrogen and 25 tonnes or 85% of all phosphorus to Lake Rotoiti⁵. The impact of the wall is yet to be quantified and is also a temporary measure. For these reasons the inputs from the Ohau Channel are included in the current totals.

Rotoiti does not have any groundwater lags so inputs from the catchment are not predicted to increase over time.

Sewage from non-reticulated communities around the lake contributes to the problem of declining water quality, but to a much lesser extent. Approximately 6.4 tonnes (1.7%) of nitrogen per year and 0.33 tonnes (1.1%) tonnes of phosphorus are contributed by septic tank discharges and stormwater from urban lakeside communities. The Okawa Bay sewage scheme, which has already been completed, will reduce these inputs.

⁵ The 250 tonnes-nitrogen and 25 tonnes of phosphorus per year is the entire Ohau Channel inflow entering Lake Rotoiti. However 40% of the time (mostly in summer) the Ohau Channel inflow is naturally directed down the Okere Arm to the Kaituna River. The remaining 60% of the Ohau Channel inflow that ends up in the main body of Lake Rotoiti equates to 150 tonnes nitrogen and 15 tonnes of phosphorus per year.

Chapter 2: What are our targets for Rotorua and Rotoiti?

2.1 Community targets

The community has aspirations for what the water quality in Lake Rotorua and Lake Rotoiti should be. These aspirations are for Lake Rotorua's water quality to be the same as it was in the 1960's and for Lake Rotoiti to have water quality similar to that of the 1970s.

These aspirations have been converted into Trophic Level Indices (TLI) targets. TLI is a measure of lake water quality which combines four indicators: total nitrogen, total phosphorus, chlorophyll *a* (algae), and clarity (secchi disc depth). The lower the TLI the better the quality. The current quality and targets are:

Lake Rotorua's current TLI is 4.8 and the target TLI is 4.2
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Lake Rotoiti's current TLI is 4.0 and the target TLI is 3.5
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The TLI is part of the Regional Water and Land Plan which became operative in 2008. The TLIs are well understood by engaged communities but there is a need to develop complementary water quality indicators which are more easily interpreted.

2.2 What do the targets mean to the community?

In practice achieving the TLI means different things to different people in the community. For some members of the community achieving the targets will mean that the lakes:

- are clean enough to support the mauri (life force) of the water;
- have thriving populations of flora and fauna; and
- support recreational and non-recreational uses, including swimming.

Other people in the community are concerned that in order to reach the targets they will suffer financially for the costs of reducing nutrient leaching from farming practices or upgrading their septic tanks.

2.3 What are our targets for Lake Rotorua?

The nutrient reductions required to meet the TLIs have been calculated by Environment Bay of Plenty using a process reviewed and approved by the water quality Technical Advisory Group (TAG) - a collection of New Zealand scientists that provide independent specialist advice.

The TAG group advised that to reach the target TLI at equilibrium no more than 435 tonnes of nitrogen and 37 tonnes of phosphorus should enter Lake Rotorua each year. The 2005 inputs into Lake Rotorua were 547 tonnes of nitrogen and 39 tonnes of phosphorus. The 2029 inputs are expected to be 655 tonnes of nitrogen per/yr and 47 tonnes of phosphorus.

***The nutrient reduction target for Lake Rotorua catchment by 2029 is:
250 tonnes nitrogen/yr and 10 tonnes phosphorus/yr***

2.3.1 Phosphorus

It is important to note that the difference between current phosphorus inputs (39.1 tonnes/yr) from the catchment and the sustainable load (37 tonnes/yr), is actually 2 tonnes. The target for phosphorus from the catchment has taken into account the 36 tonnes of phosphorus/yr being released from bottom sediments.

This is because the ratio of nitrogen to phosphorus in the lake determines whether green algae or toxin-releasing cyanobacteria dominate during summer. The greater the phosphorus concentration, the more frequent the cyanobacterial blooms. So aiming to reduce the lakebed sources of phosphorus will:

- slow the release of phosphorus from lakebed sediments, and
- stop cyanobacteria blooms (with their toxins and effects on recreation) dominating by making phosphorus the key limiting lake nutrient instead of nitrogen.

The TAG group have recommended a 10 tonne reduction (reflected above) in phosphorus per year from catchment inputs as achievable and necessary to improve lake water quality. This reduction will help mitigate the effects of phosphorus already present in the lake (which are difficult and costly to address). We are investigating the potential removal of 25 tonnes of phosphorus/yr from in-lake cycling.

The total target needed to reach our sustainable phosphorus inputs at equilibrium when in-lake and catchment inputs are combined is 38 tonnes phosphorus/yr (36 inlake +39.1 catchment – 37 sustainable load = 38 tonnes/yr)

Phosphorus inputs are not predicted to increase over time unlike nitrogen so this figure is predicted to remain relatively constant.

The stepped targets proposed for rural land use are:

- 3.5 tonnes of phosphorus/yr by 2019 (10 yrs)
- Increasing to 10 tonnes of phosphorus/yr by 2029 (20 yrs).

2.3.2 Nitrogen

To account for the groundwater lag effects, stepped targets have been established for Lake Rotorua. Groundwater lag times will postpone the benefits from some land use management/change action in the catchment.

Unlike phosphorus the nitrogen target does not take into account in-lake nutrient releases and counts towards catchment inputs.

When future groundwater inputs are included it is estimated that there will be 746 tonnes of nitrogen/yr entering Lake Rotorua by 2250 (this assumes the 2005 level of current inputs remain constant over time). Therefore the targets increase over time. It has been estimated that the nutrient reduction target for Lake Rotorua will need to increase to 311 tonnes nitrogen/yr by 2250.

The following reduction targets from rural land use are proposed as a step wise approach to achieving improved water quality:

- 30 tonnes of nitrogen/yr by 2012 (3 yrs)
- 86 tonnes of nitrogen/yr by 2019 (10 yrs)
- 170 tonnes of nitrogen/yr by 2029 (20 yrs)

A further 80 tonnes is required to meet our reduction target of 250 tonnes of nitrogen/yr by 2029. This will be achieved, by a combination of infrastructure upgrades in urban community, treatment of geothermal inflow and potentially in-lake interventions.

2.4 What are our targets for Lake Rotoiti?

For Lake Rotoiti no more than 234 tonnes of nitrogen/yr and 10 tonnes of phosphorus/yr should enter the lake. In Rotoiti the 2005 inputs were 364 tonnes of nitrogen/yr and 29 tonnes of phosphorus/yr.

The nutrient reduction target for Lake Rotoiti is 130 tonnes nitrogen/yr and 19 tonnes phosphorus/yr

2.5 How might the targets be achieved?

2.5.1 Rotorua

To achieve the targets for Rotorua we must tackle the legacy in the lake, as well as the current inputs and try and minimise the effects of the high nutrient ground water yet to reach the lake.

The nutrient reduction targets of 250 tonnes of nitrogen and 10 tonnes of phosphorus for current inputs to Rotorua are intended to be achieved in a 20-year timeframe.

If the load of phosphorus being injected into the lake from the sediments is reduced then the biological activity in the lake water is inhibited and decreases i.e. the lake clarifies somewhat and contains less algae. Sediment capping of phosphorus breaks the cycle of sediment nutrient release effectively stopping nitrogen and phosphorus release.

Stopping the effects of the legacy relies on reducing catchment inputs to ensure that we do not just revert back to pre-sediment capping by creating a new layer of algal bodies. In Rotorua they accumulate at a rate of about 1 cm/yr. In 10 years or so the capping layer will be buried if the algal biomass remains the same.

Urban infrastructure upgrades in Rotorua will contribute to a reduction in nitrogen by 50 tonnes and phosphorus by 3.82 tonnes/yr

To address land use inputs the Rotorua District Council and Environment Bay of Plenty propose to upgrade infrastructure and treat geothermal water, which will help achieve some of these targets (approximately 50 tonnes of nitrogen and 3.82 tonnes of phosphorus in Rotorua).

At this point in time improvements from rural land use are needed to help contribute to a reduction of 170 tonnes nitrogen/yr and 10 tonnes of phosphorus/yr

While the rural land target may look daunting it has been predicted that moving to best management within a three-year timeframe will reduce lake nitrogen inputs by 30 tonnes/yr (Smeaton and Ledgard 2006).

Furthermore, Smeaton and Ledgard (2006) suggested that a further 20% reduction from dairying (based on 56 kg/ha/yr benchmark load) and 10% from beef and sheep (based on 15 kg/ha/yr benchmark load) could be achieved within 10 years by adopting new research technology.

These suggestions may get us part of the way to a reduction in nitrogen of 170 tonnes and 6 tonnes of phosphorus per year. This means, that we will need to explore a range of possible innovations including, soil treatments to improve nutrient use efficiencies and possibly reducing effects of animal effluent; as well as interventions including incentives and regulations to get the nutrient reductions that are needed.

2.5.2 Rotoiti

For Lake Rotoiti it is expected that the Ohau Channel Diversion Wall and the proposed actions for community wastewater reticulation will reduce the lake nutrient inputs by at least the extent necessary to meet the nitrogen reduction targets. However, after all the proposed interventions are implemented monitoring will determine whether the water quality targets are being achieved. If not, further reductions in nutrients may be achieved by capping lake bed sediments. It is expected that no actions should take place until the Ohau Channel Diversion Wall has been in place for at least five years, so that the full impact of the wall can be assessed.

At present increases in discharges from rural land use are controlled by Rule 11 of the Regional Water and Land Plan and other changes to land use are controlled by the Rotorua District Plan.

Chapter 3: Addressing Rotorua's Past Inputs

3.1 Rotorua's past inputs

3.1.1 What is the problem?

The amount of nitrogen and phosphorus released from the lakebed sediments is estimated at:

Rotorua:	Nitrogen	=360 tonnes/yr
	Phosphorus	=36 tonnes/yr

This can be released from the bottom sediments, effectively recycled, up to 10 times per year.

3.1.2 Actions: Sediment

Lakebed sediments which are high in nutrients can be treated with flocculants/absorbent material which settles on the lakebed and prevents phosphorus releases. This method has been trailed at Lake Okareka and Lake Okaro. Dredging the sediments could also remove the problem, as could aeration of bottom water which stops nutrient release.

(1) *Lake bed sediment:*

The Technical Advisory Group should review further investigations to determine the most appropriate method to reduce the release of nutrients from the lakebed. In determining "appropriateness" Environment Bay of Plenty will have regard to the wider social, cultural, economic and environmental costs and benefits of any actions.

3.1.3 Expected outcome

Identify most cost effective method to mitigate the effects of nutrient releases from bottom sediments with the aim of reducing phosphorus by **25 tonnes/yr**.

The treatment will address nitrogen releases indirectly. If the load of phosphorus being injected into the lake from the sediments is reduced by treatment then the biological activity in the lake water is inhibited and decreases i.e. the lake clarifies somewhat and contains less algae. For Rotorua, during warm calm periods when the lake stratifies, there will then be less algal biomass dropping out of the water into the bottom waters. Therefore the rate of de-oxygenation will be decreased and it will become more likely that the lake will remix before nutrients are released from the sediment, either nitrogen or phosphorus. Sediment capping of phosphorus breaks the cycle of sediment nutrient release effectively stopping nitrogen and phosphorus release.

3.1.4 Actions: Biomass

Weeds such as hornwort take nutrients out of the lake water and can be harvested allowing the new growth to take up more nutrients. This method is currently being used on Lake Rotoehu.

(2) *Harvesting biomass to remove nutrients:*

A report will be prepared on the efficacy of using plant species such as hornwort or like species for the removal of nutrients from the water column. Business initiatives using the principle of biomass removal for profit should be promoted if effects on the environment are no more than minor.

3.1.5 Expected outcome

It is expected that following the analysis a decision can be made whether to proceed with further investigations into this option.

Investigations have been carried out into the use of freshwater mussels (kakahī) for reducing phytoplankton abundance⁶. Risks were identified that the nitrogen to phosphorus ratio will be skewed and to become more nitrogen limited which encourages cyanobacterial dominance. At this stage this action is not being investigated further.

Harvesting algal to remove dissolved nutrients from lakes has also been investigated⁷. The report showed that harvesting algal is a viable option if there are high nutrient levels and algal growth rates. If an efficient method of algal harvesting could be devised, it could prove a very effective way to reduce nitrogen concentrations. The problem to overcome is the amount of dry biomass in the water column: 6 g/m³, or a teaspoon for one cubic metre of lake water. Large volumes of water would need ongoing filtering which is not a cost effective action at present.

⁶ Phillips, N. (2007) Review of the potential for biomanipulation of phytoplankton abundance by freshwater mussels (kakahī) in the Te Arawa lakes. NIWA Client Report: HAM2006-125.

⁷ Warwick, S. (2006) Using plants (algae) to strip nutrients from streams and lakes. Department of Biological Sciences, University of Waikato, Hamilton.

Chapter 4: Addressing Rotorua's Current Inputs

The following section summarises the actions that address current inputs from human sources, including both urban and rural land use; as well as current inputs from natural sources into Lake Rotorua.

4.1 Urban land use inputs

4.1.1 What is the problem?

Significant inputs of nitrogen and phosphorus come from sewage and stormwater discharges from urban, commercial and industrial areas.

Septic tank effluent in the Brunswick/Rotokawa and Hamurana areas contributes approximately 10.84 tonnes of nitrogen/yr and 0.25 tonnes of phosphorus/yr to Lake Rotorua.

The Rotorua Wastewater Treatment Plant (WWT) has consent to discharge 30 tonnes of nitrogen/yr and a maximum of 3 tonnes of phosphorus/yr to the Waipa Stream annually. However once the effluent disposal field became saturated in 2001, the field began to leach up to 50 tonnes of nitrogen/yr. currently (2007) the WWTP is leaching 40 tonnes nitrogen/yr.

4.1.2 Actions and expected outcomes

(3) Rotorua Waste Water Treatment Plant improvement options include:

Continue to carry out plant and process improvements. Actions to date include methanol dosing to increase carbon, changes to effluent discharge regimes and expanding and re-contouring wetlands.

Improvements should result in a reduction of 15 tonnes of nitrogen/yr and the plant will consistently meet the WWTP's resource consent requirements despite increased demand. Upgrades to accommodate new sewage lines and more advanced treatment will be completed by 2016.

(4) Reticulation or septic tank up-grade:

By 1 December 2010 or 1 December 2014 (depending on the area), some residents around Lake Rotorua must join a reticulation scheme or apply for resource consent for an alternative option as required by Environment Bay of Plenty's On-Site Effluent Treatment Regional Plan.

The numbers of households affected are shown in Table 3 below.

Table 3 *Number of household proposed for reticulation or upgrades to septic tanks in the Rotorua Catchment*

Location	Reticulation proposed	Advance effluent treatment upgrade required
Hamurana/Awahou	290	
Brunswick/Rotokawa	285	
Mourea	103	
Total number of houses	678	900

An estimated reduction of 10.84 tonnes of nitrogen/yr and 0.25 tonnes of phosphorus/yr is expected after reticulation of lakeside settlements and upgrades to septic tanks. It is anticipated that all community reticulation will be complete by 2011.

(5) Stormwater upgrades:

The Rotorua District Council will, improve nutrient removal from stormwater by implementing Water Services Bylaw for one thousand commercial sites. They will also apply for comprehensive urban stormwater consent and Rotorua District Council will tighten up on monitoring and enforcement of high-risk facilities and trade waste dischargers.

An estimated reduction of 3 tonnes of nitrogen/yr and 0.5 tonnes of phosphorus/yr is expected after upgrades to stormwater systems by 2017.

4.2 Rural land use inputs

4.2.1 What is the problem?

Rural land use around the lakes has intensified and diversified considerably over the last 65 years. All of the rural land uses within the Rotorua Catchment affect the lakes through nutrient loss, but some land uses have a much greater nutrient loss than others.

The main source of nitrogen leached to waterways is from non-point sources such as animal urine spots during the winter period. Non-point source is generally harder to control compared with point source discharges which are all managed under Resource Management Act consents. Non-point source discharges can also take years to reach the lake.

The destruction of significant wetland habitat in the Rotorua and Rotoiti Catchments has exacerbated the effects of land use. Wetlands can remove significant amounts of nitrogen from farm runoff, springs or streams. They can also remove organic and particulate nitrogen and phosphorus as sediment and plant material settles out in the wetland.

4.2.2 Actions: Phosphorus

Streams carry much of the phosphorus to the lake and in particular Utuhina Stream carries 3 tonnes of phosphorus into Lake Rotorua every year. About 50% of the phosphorus in Utuhina Stream comes from rural land and around 2 tonnes of this is dissolved reactive phosphorus which can be treated.

(6) Reducing phosphorus in the Utuhina Stream:

Maintain treatment of Utuhina Stream to bind suspended phosphorus in the water column from existing phosphorus plant behind Depot Street.

(7) Treat phosphorus in streams:

Investigate the viability of chemical flocculation to remove phosphorus at other sites around Lake Rotorua.

4.2.3 Expected outcome

Consistent dosing of the Utuhina Stream should remove 2 tonnes of phosphorus (dissolved). Other forms of phosphorus may be removed, in addition to the dissolved reactive phosphorus, but this cannot easily be measured. It is estimated that a further 4 tonnes of phosphorus can be removed through treatment of other streams flowing into Lake Rotorua.

4.2.4 Actions: Land use

At present reducing nutrient leaching from farms is generally categorised under “land use change actions” or “land use management practices”.

Land use change is where the type of use is changed, for example from farming to forestry. Land use management practices involve changing the way you farm not the type of farm, for example a dairy farmer who invests in a wintering off pad for his cows to reduce leaching and soil degradation.

Both actions address the same problem but to varying degrees. Land use change has the potential to provide the greatest reduction however there are social and economic implications which require further analysis.

(8) Best management practices:

Landowners should use best practices, as determined by their respective industries.

(9) Innovation and new technology:

Investigate nutrient reductions associated with research technology and continue to investigate new technology.

(10) Assess existing regulatory intervention:

Assess the efficiency and effectiveness of Rule 11 at achieving its policy intent. Over the long term continue to investigate sanctions such as regulations and their ability to help achieve nutrient reductions.

(11) Explore non-regulatory interventions:

Investigate non-regulatory interventions such as incentives and their ability to help achieve the further nutrient reductions required. Continue collaborative approaches to finding solutions for improving water quality. Involve industries in reviewing and possibly delivering solutions.

Investigate mechanisms to enhance existing relationships with New Zealand fertiliser manufacturers, Fonterra, Dairy NZ, Federated Farmers, and Meat and Wool.

(12) Economic analysis:

Undertake economic analysis of the costs and benefits of different regulatory and non regulatory interventions aimed at removing 170 tonnes nitrogen/yr from rural land use from the Rotorua catchment.

4.2.5 **Expected outcomes**

Actions 8 and 9 aim to remove 170 tonnes of nitrogen and 10 tonnes of phosphorus from catchment land use by 2029 and is expected to be achieved in the following stepwise approach:

- 30 tonnes of nitrogen/yr (2012) removed using best management practices. This is expected to be achieved with economically viable farm management options.
- 56 tonnes of nitrogen/yr and 3.5 tonnes of phosphorus/yr (2019) are expected to be achievable using farm management options that will adopt known research technologies.
- 84 tonnes of nitrogen/yr 6.5 tonnes of phosphorus/yr (2029) is expected to be achieved using other research and management initiatives which will evolve over time to make this target realistic.

One of the outcomes of Action 10 will be improved knowledge about how efficient and effective existing regulatory interventions are at achieving policy intent. This action will be carried out by Environment Bay of Plenty and will apply to the existing Rule 11 of the Regional Water and Land Plan. The Rotorua District Plan is also being reviewed and district level planning mechanism to improve water quality are being investigated.

An interventions framework (Action 11) will be developed overtime which improves our knowledge about potential interventions both regulatory and non regulatory and their ability to help reduce nutrients. The interventions work will build in an analysis of macro and micro level costs and benefits (Action 12). We should also see improved relationships between all stakeholders by adopting a collaborative approach to land management.

Collectively Action 10, 11 and 12 will ensure that we have a process for the future to identify and implement interventions (regulatory and non-regulatory) which reduce nutrient discharges and help the whole community achieve the 170 tonne reduction in nitrogen/yr needed.

4.3 Natural inputs

4.3.1 What is the problem?

Natural inputs contribute 113.5 tonnes of nitrogen and 17 tonnes phosphorus to Lake Rotorua annually. The greatest natural inputs of nitrogen are from geothermal (42.2 tonnes of nitrogen/yr) and native forest and scrub (42.1 tonnes of nitrogen/yr) with the direct inputs to the lake from rain accounting for the remaining 29.2 tonnes of nitrogen/yr. The greatest natural input of phosphorus is from springs, which contribute 13 tonnes of phosphorus/yr.

The Tikitere geothermal field straddles the Lake Rotorua/Lake Rotoiti Catchment boundary. Upper and lower geothermal fields drain into the Waiohewa Stream. These geothermal flows of around 17 L/s contain 30 tonnes nitrogen, mainly in the ammonium form, possibly sourced from ancient buried vegetation that the geothermal fluid flows through. The upper field has a defined surface flow down to State Highway 33, but the lower field's outlets are more diffuse, and seep through the ground to join the upper field's flow.

4.3.2 Action

(13) Tikitere Geothermal field treatment:

Rotorua District Council and Environment Bay of Plenty will divert the high nutrient geothermal water via a series of de-nitrification beds and then pump the treated water back into the stream to enter Lake Rotorua.

At this point in time there are no proposed actions to treat other natural inputs of nitrogen or phosphorus.

4.3.3 Expected outcome

Only a residual amount of nitrogen would return to Lake Rotorua after passing through the de-nitrification beds. It is expected that 30 tonnes of nitrogen/yr would be removed from Lake Rotorua's inflows. The ecology of the Waiohewa Stream would be altered with less geothermal input in the Stream (like mud, boron and heat).

It is important to remember that the aim of this intervention is reducing nitrogen to Lake Rotorua. There would be no need to treat natural sources if not for the degradation caused by human interference.

Chapter 5: Addressing Future Inputs to Rotorua

5.1 Future inputs

5.1.1 What is the problem?

In the future there will be inputs of nutrients which continue long after current nutrient reduction target are met. Theoretically if all nutrient inputs were stopped in 2009 we would still have nutrient inputs to the lake over the sustainable load. This is due to the delay in groundwater reaching the lake (as mentioned above).

One such groundwater system enters the lake via the Hamurana Stream and transports approximately 53 tonnes of nitrogen/yr to Lake Rotorua. The ground water model predicts this to increase to 92 tonnes of nitrogen/yr in 50 years time.

5.1.2 Actions

(14) *Diversion of Hamurana Stream to Ohau Channel:*

Carry out further investigation into a diversion wall of some form to divert flows from the Hamurana Stream along the northern shore of Lake Rotorua to the Ohau Channel. The Hamurana flow would then form part of the Ohau Channel flow which would be directed down the Kaituna River by the Ohau Channel Diversion Wall.

(15) *Investigate the establishment of wetlands:*

Carry out further investigation of wetland creation and enhancement, building on existing works which have already been undertaken. Investigate floating wetlands in the lake to treat high nutrient inflows to the lake.

5.1.3 Expected outcomes

Improved knowledge about the likely success of a wall at diverting nutrients from Lake Rotorua and also improved knowledge on the social, economic, cultural and environmental impacts of the proposed wall. An analysis of the social, economic, cultural and environmental impacts of the proposed wall shall be carried out as part of any further investigation.

A staff assessment of the viability of establishing wetlands around the shores of Rotorua and within the lake itself is proposed. If appropriate sites are identified they would strip nutrients from old age ground water prior to entering the lake, or in the case of floating wetland, from the lake.

Floating wetlands are being trialled in Lake Rotoehu at present and may prove to be a useful tool for improving water quality in Lake Rotorua.

Chapter 6: Addressing Inputs to Rotoiti

6.1 Septic tank inputs

6.1.1 What is the problem?

Approximately 5.9 tonnes of nitrogen/yr and 0.21 tonnes of phosphorus/yr entering Lake Rotoiti come from septic tanks.

Natural inputs account for 67.6 tonnes of nitrogen and 1.1 tonnes of phosphorus to Lake Rotoiti annually. These inputs come from indigenous forest, natural springs, rainwater and geothermal activity. These sources are difficult to treat and no actions are being proposed to treat these sources at this time.

6.1.2 Actions

(16) *Community wastewater treatment*

By 1 December 2010 or 1 December 2014 (depending on area), members of lakeside communities must join a reticulation scheme, or apply for resource consent for an alternative option as required by the On-Site Effluent Treatment Regional Plan.

Table 4 Number of household proposed for reticulation or upgrades to septic tanks in the Rotorua Catchment.

Location	Reticulation proposed	Advance effluent treatment upgrade required
Okere/Otaramarae/Whangamarino	380	
Gisborne Point/Hinehopu	300	
Okawa Bay and part Mourea	160	
Total # of households	840	160

6.1.3 Expected outcome

5.9 tonnes of nitrogen/yr and 0.21 tonnes of phosphorus/yr will be removed once septic tanks in communities within Lake Rotoiti are reticulated and septic tanks are upgraded.

6.2 Ohau Channel inputs

6.2.1 What is the problem?

The Ohau Channel flow used to enter the main body of Lake Rotoiti delivering approximately 150 tonnes of nitrogen and 15 tonnes of phosphorus into the main body of Lake Rotoiti each year. A diversion wall structure was erected in 2008 to divert nutrient inflows from Lake Rotorua down the Kaituna River. The wall has only been established as an interim measure until Lake Rotorua's nutrient levels are reduced. The resource consent for the wall structure expires in 2017.

Nitrogen and phosphorus concentrations are not predicted to decrease significantly over the first five years, as removal of the Ohau Channel's volume from Lake Rotoiti will increase the average residence time of lake water from 2.4 years to 6.3 years. However improvements are being seen already.

It is generally agreed that the wall is a medium term solution (50 years) and that within the next 50 years land use changes would have occurred in Rotorua to reduce its current high nutrient loads and the wall can be removed.

6.2.2 Action

(17) Carry out on-going monitoring to determine success of wall structure.

6.2.3 Expected outcome

Monitoring will illustrate the actual levels of nutrient reductions to Lake Rotoiti as a result of the diversion wall and the impacts of the diversion if any on the lower Kaituna area. The expected results are a reduction of 150 tonnes of nitrogen/yr and 15 tonnes/yr of phosphorus.

Chapter 7: Summary of Actions

Table 1 Rotorua Actions with estimated annualised costs and timeframes.

#	Action	Nitrogen reduction (T/yr)	Phosphorus reduction (T/yr)	Estimated Cost ⁷ (\$/kg/yr)	Timeframe
Legacy					
1	Lake bed sediment treatment	0 ⁸	c. 25	TBA	After 2011
2	Harvesting biomass	Exploratory	-	-	-
Current					
3	Wastewater Treatment Plant upgrade	15	0	\$99 nitrogen	2006, ongoing
4	Wastewater reticulation for Rotorua and OSET	10.8	0.25	\$369 nitrogen	2009 to 2014 ⁹
5	Stormwater upgrades within Rotorua urban	3	0.5	TBA	By 2017
6	Reducing P in the Utuhina Stream	0	2 (dissolved)	\$210 phosphorus	2006, ongoing
7	P flocculation in two other streams	0	4	\$210 phosphorus	By 2010
8	Best management practices	30 ¹⁰	0		By 2012
9	Innovation and new technology	56 ¹¹ (2019 known tech) 84 (2029)	3.5 (2019 known tech) 6.5 (2029)		By 2019 By 2029
10	Assess existing regulatory interventions	Exploratory	0		By 2009
11	Explore non-regulatory interventions	Exploratory	0		On-going
12	Economic Analysis	Exploratory	0		By 2012
13	Tikitere geothermal	30	0	\$4 nitrogen	By 2010
Future					
14	Hamurana Stream diversion to the Ohau Channel	Exploratory with potential reduction of 53 (2005) 92 (2055)	6.3		After 2011
15	Wetland	exploratory	-	TBA ¹²	-

Table 2 Rotoiti Actions with estimated annualised costs and timeframes.

#	Action	Nitrogen reduction (T/yr)	Phosphorus reduction (T/yr)	Estimated Cost ⁷ (\$/kg/yr)	Timeframe
16	Community wastewater reticulation for Rotoiti	5.9	0.21	\$820 nitrogen	By 2014
17	Ohau Channel diversion wall	150	15	\$8 (N) \$81 (P)	2008 Ongoing monitoring 2058

Footnotes for Tables 1 and 2:

- 7 The cost per kg considers the total cost divided separately by the respective N and P reductions because there is no simple method for splitting costs between N and P. The annualised cost is an indicative estimate based on: cost of capital (at 10%) + annual operating costs + depreciation costs spread over the asset lifespan (which varies e.g. 4% annual depreciation cost used for the 25 year lifespan of the WTP upgrade). Figures are primarily based on Environment Bay of Plenty and Rotorua District Council Ten Year Plans. While some actions receive a 50% government grant, only total costs are shown.
- 8 Some indirect N reduction is likely once lower P levels suppress algal growth and N recycling.
- 9 Some households will not be reticulated and will require advanced OSET systems. The costs and nutrient reductions for such upgrades are not included in this table.
- 10 These are broad brush estimates based on OVERSEER© analysis by Smeaton and Ledgard (2006). The Rotorua Lakes Strategy Group has advised that at least the approximate 30 tonnes N/yr reduction is feasible in its view. Further analysis and discussion with landowners is needed on the feasibility and costs of Action 9 reductions.
- 11 The 20% reduction in N leaching is additional to the 30 tonnes N/yr indicated in Action 8 and based on the recommendation from the Action Plan Hearings Panel.
- 12 The Lake Okaro constructed wetland indicates annualised costs in the order of \$176/kgN/yr.

