# Lake Okaro Catchment Management Draft Working Paper

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# Acknowledgement

Environment Bay of Plenty staff for collection of lake data.

Cover photo: View to the north east over Lake Okaro towards Lakes Rotomahana and Tarawera. Photo by John Gibbons-Davies.

# Contents

# 1 Purpose of the Action Plan Working Paper

The purpose of this document is to:

- Set out the factors that influence the environmental quality of the waters of Lake Okaro;
- Explain the objectives of this draft working paper;
- Set out some options that will improve the current environmental quality of the lake waters;
- Provide the basis to select options or a mixture of options that will achieve the environmental quality objective for Lake Okaro in the Proposed Regional Water & Land Plan.

# 2 Introduction

The lakes of the Rotorua district are coming under increasing pressure from human development in their catchments. In some lake catchments, environmental quality has deteriorated to such an extent that use of the water is restricted and the values people hold for the lake are compromised.

Environment Bay of Plenty has set out a lake management policy structure in the Proposed Regional Water and Land Plan[1]. In the Plan, a minimum environmental quality target is specified for each lake to meet the desire expressed by lake communities: "that the quality of the lakes should not deteriorate further and that some should be improved". The minimum target for each lake has been set as a lake "Trophic Level Index[2]" (TLI). Five lakes currently exceed their TLI target. They are Lakes Okareka, Rotoehu, Okaro, Rotorua and Rotoiti.

As a response to these lakes exceeding their target TLI, the Plan requires action plans to be developed. Lake Okareka was chosen as the first lake for the preparation of an action plan because investigations into the effects of land use on the quality of the lake were in an advanced state. It was also thought useful to carry out the action plan consultation process at one lake first so that a model could be established for future lake action plans.

Lake Rotoehu and Lake Okaro are in the second tier of lakes to have action plans developed. Both these lakes have catchments that are largely agricultural in nature and both of these lakes have waters with very poor environmental quality.

Lake Okaro has experienced blue-green algal blooms over the summer months for a number of years. The lake is an important recreational resource in the Rotorua district but bathing is discouraged at Lake Okaro during blue-green algal bloom conditions.

Some fencing of the stream flowing into Lake Okaro has been carried out. This will be effective in reducing the load of nutrients flowing to the lake but major reductions remain to be achieved elsewhere to make a permanent difference to the lake.

[1] Appendix I Lakes policy in Regional Water & Land Plan (page 21)
[2] Appendix II Explanation of the Trophic Level Index (page 23)

# 3 Factors that Affect the Quality of Lake Okaro

Lake Okaro has a very small rural community. The rural land use includes dairy grazing and sheep and beef grazing units. The lake is used for recreation, including boating, water skiing and fishing. There is public access to the lake edge at the Rotorua District Council reserve. The lake edge includes wildlife habitat and natural wetlands.

Table 1 and Figure 1 show the extent of various land cover (1996) in the Lake Okaro catchment.

*Table 1 Land cover (1996) in the catchment of Lake Okaro.*

| Land Cover | Area | |
|---|---|---|
| | ha | % |
| Forest indigenous | 13.5 | 3.6 |
| Forest planted | 2.5 | 0.7 |
| Pasture exotic | 359 | 95.7 |
| TOTAL | 375 | 100 |

The lake area is 32 ha and there are direct inputs to the lake from rainfall. Each year nutrients are released from the lake bottom sediment into the lake water. The lake stratifies over the entire summer and the bottom waters rapidly become devoid of oxygen. When this happens nutrients become mobilised from the sediment and pass into the water. This releases the historic nutrient inputs back into the water. In the past there was a nett loss of nutrients from lake water to the sediment but now these nutrients are being fed back into the lake water each summer.

## 3.1 Lake Nutrients

The quality of lake water is determined by the nature of the inflowing waters. In the Bay of Plenty pumice catchments tend to produce clear streams. Our lakes also tend to be naturally clear with clarity determined by the quantity of algae growing in the lake and the amount of re-suspension of sediment and detritus in the shallow areas by wind and wave action. Okaro is a moderately deep lake and re-suspension of bottom material by wind action is not an issue.

Algal growth is driven predominantly by phosphorus and nitrogen. The more phosphorus and nitrogen that flows into a lake the more algae will grow. Whereas the turbulent waters of streams do not favour the growth of single cell algae but they flourish in the more still lake waters.

The soils of the lakes catchments tend to be phosphorus absorbing because of the allophane clay content, but the waters coming from cold-water springs tend to be high in phosphorus (Timperley, 1983) because of the minerals dissolved from the underlying volcanic geology. The extent and the type of activity carried out on the land can lead to phosphorus running off or leaching out of the land.

Pumice soils of the central volcanic plateau, in their natural condition, tend to have low nitrogen levels (Vincent, 1980). In a forest situation nitrogen is recycled within the forest and a small amount lost to leaching. Nitrogen is incorporated into pasture soils from nitrogen fixing plants and recycled through herbivores. Additional nitrogen may be added in fertiliser application and more nitrogen is lost to run-off or leaching than in the forest situation. Grazing animals enhance the turnover of nitrogen returning part of the nitrogen to the soil in dung. Nitrogen in urine spots has been shown to be a source of nitrogen leached from pasture (Russelle, 1996), particularly in the period from autumn to spring. Generally, the higher the intensity of the agriculture practiced in a pasture-grazing situation, the higher the levels of nitrogen leached and possibly phosphorus.

Sewage from human communities also contains nitrogen and phosphorus. Septic tank effluent disposal results in leaching of nitrogen to the groundwater and from there to a stream or lake. Phosphorus can be efficiently removed in allophanic soils, but absorption sites on allophane clay particles can become saturated.

Scientists have studied the average output of nutrients from different land uses and have categorised these with typical nutrient export coefficients[3]. Once the export coefficients have been determined then a spreadsheet model can be constructed to illustrate an annual nutrient budget[4]. Appendix VI shows a spreadsheet model for Lake Okaro based on export coefficients derived in the peer reviewed Lake Okareka Action Plan document.

Waterfowl recycle nutrients within a lake grazing on aquatic plants and return nutrients to the water (Bioresearches, 2002). They can increase the levels of soluble nutrients in the water, which are then available for algal growth. Waterfowl are not a driver of total lake nutrient levels in the way that external inputs are, but they can contribute to other issues such as bacterial contamination.

### 3.2 Sediment Nutrient Releases

The amount of nutrient released from the sediment of Lake Okaro can be calculated by examining the nutrient levels in the lake after mixing has taken place. The post stratification levels of dissolved reactive phosphorus and ammonium nitrogen, when the lake is homogenous, is taken to represent the amount of nutrient released into the lake from the sediment during stratification[5]. The values are relatively stable for Lake Okaro. A median value from 6 years of data between 1992 and 2001 was selected from the data set for the spreadsheet model in Appendix IV (0.38 tonnes/year phosphorus and 2.4 tonnes/year of nitrogen).

### 3.3 Bacterial Levels

Lakes generally have lower bacterial levels than rivers and streams because bacteria tend to attach to particles, which settle out more rapidly in lakes. It has been found that bacterial levels can be high around stream mouths, in the region of residences, where sewage discharges exist and where wildfowl congregate.

## 4 Objective of the Lake Okaro Action Plan

A large portion of the nutrient load present in the lake is generated from within the lake. The actions that can be taken will only directly reduce the external loads and this will lead to a reduction in the internal load in time.

As the load of external nutrients (nitrogen and phosphorus) increases the biology of the lake (the amount of algae growing in the lake) increases. These eventually die off and settle out to the sediment. The dead algae exert a BOD (biochemical oxygen demand) on the bottom water, when the lake is stratified. The more algae in the lake, the higher the BOD and the faster the rate of de-oxygenation of the bottom water. Once the bottom water is deoxygenated, nutrients are released from the sediment.

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[3] Appendix III Nutrient export coefficients (page 24)
[4] Appendix IV Spreadsheet model for Lake Rotoehu (page 25)
[5] Appendix V Sediment nutrient releases at Lake Rotoehu (page 26)

The objective of this action plan is to combine land use management and technology to reduce the annual nutrient load to the water of Lake Okaro by up to 3.32 tonnes of nitrogen and 0.4 tonnes of phosphorus to achieve a TLI of 5.0.

This has been calculated (Appendix VI)[6] as the required load reduction to meet the lake quality objective of the Proposed Regional Water & Land Plan. If the internal load (section 3.2) is subtracted from the overall objective the remaining load is 0.9 tonnes of nitrogen and 0.02 tonnes of phosphorus. If options can be implemented to reduce the external load by this amount then the improvement in lake quality would be marked.

| |
|---|
| 0.9 tonnes of nitrogen and 0.02 tonnes of phosphorus |

# 5 Working Party

A Working Party is proposed to discuss options to reduce the nutrient load on Lake Rotoehu. The Working Party is to be composed of the Tangata whenua, landowners, Rotorua District Council, Department of Conservation, Fish & Game New Zealand (Eastern Region), Federated Farmers, technical, planning and financial advisors.

[6] Appendix VI Lake Rotoehu Trophic State Targets (page 27)

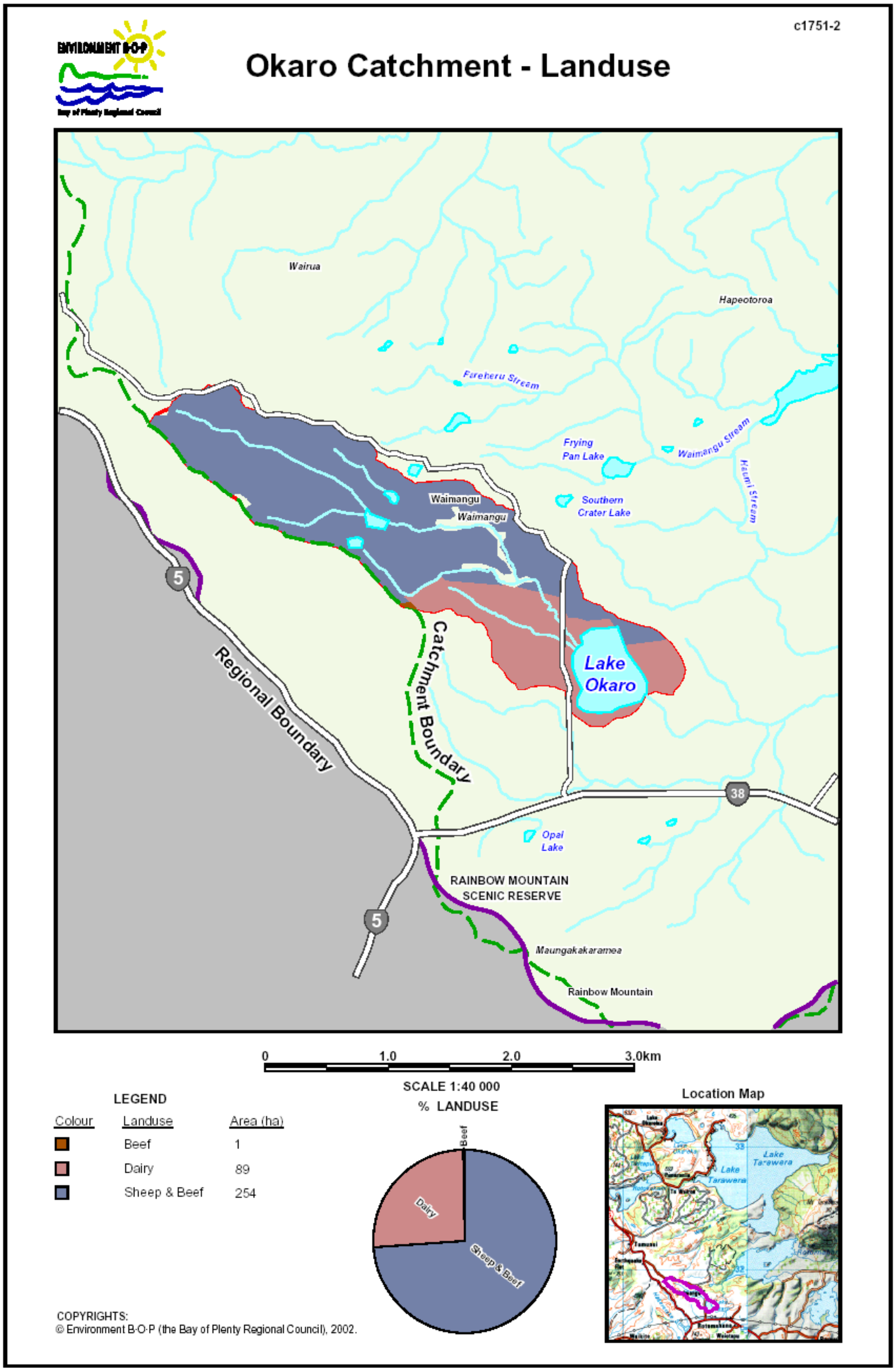


*Figure 1 Land use (1996) map of Lake Okaro catchment.*

# 6 Potential Actions to Reduce Nutrient Load

Several options are presented for achieving the desired nutrient input reduction to Lake Okaro. A combination of options could also be used. While all actions presented are considered possibilities, there will be variations in cost benefit from different options.

The options can be classified as: land management or technical.

## 6.1 Land Management

### Convert pasture to forest

Converting pasture to forest results in a significant reduction in nutrient export from the land parcel for both nitrogen and phosphorus. If the reduction in nitrogen export achieved by converting pasture to forest were 0.45 tonnes/km$^2$/year (Ray *et al*, 2000b) then about 200 hectares of pasture would have to be converted to forest to reduce the nitrogen load on the lake by 0.9 tonnes/year. This is based on the assumption that the conversion is from low production sheep and beef pastoral farming to forestry, whereas, in fact the grazing regime in the catchment could be more intense. Table 7 (page 22) indicates that the catchment loads calculated back from the in-lake nutrient concentrations were higher than the spreadsheet model in Table 5 (page 19) indicated. In Table 5 a low intensity grazing regime is assumed in the land use model.

Conversion of pasture to forest will reduce phosphorus output by 0.026 tonnes/km$^2$/yr. To achieve the required lake load reduction of 0.02 tonne/yr, then around 77 hectares of pasture would have to be converted to forestry.

Currently approximately 359 hectares of the lake's catchment is in pasture.

Conversion of pasture land to forestry would provide a benefit to the lake by reducing nutrient output but it is a long term solution.

As the external inputs to the lake are decreased the internal inputs will also decrease.

**Notes:**

## Riparian Retirement

Riparian retirement is achieved by the fencing off from grazing, of a strip of land along stream or lake margins. These strips are often 5 – 10 m wide with dense grassy vegetation achieving the greatest reductions in nutrient input to waterways. Riparian strips are effective in trapping sediment and reducing phosphorus inputs to waterways. However the long-term benefit and cost effectiveness can vary and be difficult to quantify.

Stream retirement has been carried out in the Lake Okaro catchment. There is a small portion of the lake edge that could be retired. This has a low impact grazing regime, however, the lakeside rushes are nibbled by the sheep and regeneration of this lake edge vegetation could enhance nutrient reduction of the groundwater flowing into the lake.

The cost of retiring a riparian strip of land varies greatly but some Environment Bay of Plenty retirement works have ranged from \$50,000 - \$500,000 per $km^2$.

## Notes:

## Wetland Enhancement/Creation

There are a number of different types of wetlands. Intact riparian wetland vegetation along lake margins or streams can form zones that are very efficient at removing nitrogen from groundwater by denitrification. This process depends on the build-up of organic rich sediments and abundant denitrifying bacteria and can result in up to 90% removal of nitrogen from typical background levels (Gibbs & Lusby 1996). In headwater and other large stream wetlands, the nitrogen removal capability is largely dependant on a similar process. Hence the nitrogen removal efficiency varies according to how much of the inflowing water seeps out through organic rich zones. High rates of surface flow over the top of a wetland will not achieve nitrogen removal.

There is an input of nutrients via the streams flowing into Okaro on the northern side of the lake. Total nitrogen (N) and phosphorus (P) loads are in the order of 0.7 tonnes N/year and 0.09 tonnes P/year (at normal flow). Nearly all the nitrogen under normal flow is present as nitrate-nitrogen and the phosphorus as dissolved reactive phosphorus. It would be possible to reduce the load of both nutrients by diverting the streams, partially or wholly, through wetlands designed to be incorporated into the retirement works along the course of the streams.

A NIWA Scientist, Dr Chris Tanner is designing wetlands that could be incorporated into the proposed retirement areas at Okaro to reduce the nutrient loads in the inflowing streams.

Other sites may also exist along the streams and around the lake where wetland creation may enhance nutrient reductions.

## Notes:

## 6.2 Technology

### Chemical coagulation of phosphorus

There is a high phosphorus content in the waters of Lake Okaro and it would be possible to precipitate some of this out with a coagulant.

| Period | Total phosphorus $g/m^3$ | Total Nitrogen $g/m^3$ |
|---|---|---|
| Jul 1991 – Jun 1992 | 0.116 | 1.290 |
| Jul 1992 – Jun 1993 | 0.092 | 1.016 |
| Jul 1993 – Jun 1994 | 0.108 | 1.259 |
| Jul 1994 – Jun 1995 | 0.138 | 1.194 |
| Jul 1995 – Jun 1996 | 0.166 | 1.272 |
| Jul 1996 – Jun 1997 | 0.147 | 1.492 |
| Jul 1997 – Jun 1998 | 0.119 | 1.246 |
| Jul 1998 – Jun 1999 | 0.126 | 1.754 |
| Jul 2000 – Jun 2001 | 0.099 | 1.014 |
| **average** | **0.123** | **1.282** |

Both alum and a Lanthanum and bentonite clay mixture called Phoslock have been investigated for use in absorbing phosphorus out of the water column. A trial is planned for November 2003 using Alum as Phoslock will not be available at that time. However, a trial of Phoslock will also be carried out in the future.

## Notes:

### Other Methods

- Public education on ways to reduce nutrients.

- Lake weed harvesting
  On balance, this is not recommended by Matheson and Clayton (2002).

- Control of waterfowl
  Based on the report of (Bioresearches, 2002) about 300 birds gathered at an average lake-side beach could raise the bacterial level beyond that safe for bathing.

  The waterfowl recycle nutrients stored in the weed on which they feed back into the lake water. A portion of the nutrients in their faeces will be available for the growth of algae in the lake.

These methods are unlikely to make major reductions in nutrient levels in the lake but assist in highlighting a philosophy of nutrient control.

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# Appendices

# Appendix I – Proposed Water & Land Regional Plan

Environment Bay of Plenty's Proposed Water & Land Regional Plan identifies adverse effects on lake quality as a major issue in the Bay of Plenty region.

Objective 10 of the Plan sets Trophic Level Indices (TLI) for each of the 12 Rotorua Lakes.

The Plan adopts an integrated catchment management approach to lake quality to address the effects of all activities in a catchment, in particular the discharge of nutrients. Nutrients result from both:

- Point source discharges (sewage discharges, septic tanks, dairy shed effluent), and
- Export (leaching) of nitrogen and phosphorus from land use activities (also referred to as diffuse discharges).

A 'package' of non-regulatory and regulatory methods is specified in the Plan to achieve nutrient management in the lakes catchments. This is illustrated in the following table:

| **Method** | **Explanation** | **Application** | |
|---|---|---|---|
| | | **All Lakes** | **Degraded Lakes** |
| **Non-Regulatory Methods** | | | |
| Riparian retirement | Encourage and fund the fencing and planting of riparian areas | ✓ | ✓ |
| Action Plans | Refer to this document | | ✓ |
| Land acquisition | Buy land from willing sellers for retirement from production *ie* as a regional park | | ✓ |
| Education on nutrient management | Educate community on appropriate nutrient management practices | ✓ | ✓ |
| Best management practices guidelines | Develop and document best nutrient management practices- Links to education | ✓ | ✓ |
| Environment B·O·P Environmental Programmes | Plans to address environmental effects from a property – site specific and developed with landowner | ✓ | ✓ |
| Lake quality monitoring | State of the environment monitoring | ✓ | ✓ |
| **Regulation** | | | |
| Rule 11 | See over page for explanation | | ✓ |
| Point source discharges | Discharges from sewage schemes, dairy sheds, etc to meet specified environmental standards | ✓ | ✓ |

## Rule 11

Rule 11 is a discretionary (restricted) rule that maintains Environment Bay of Plenty's discretion over measures to avoid, remedy or mitigate adverse effects on water quality, including surface water and groundwater (*ie* the rule is aimed at the issues that Environment Bay of Plenty is responsible for under the Resource Management Act).

Rule 11 only applies to the catchments of Lakes Rotorua, Rotoiti, Rotoehu, Okareka, Okaro (ie where there is degraded lake water quality), and only from the date the plan becomes operative.

Rule 11 addresses the diffuse discharge of nutrients from land use activities. Any intensification of land use activities or change in land use that results in a net increase in the export of nutrients (nitrogen or phosphorus) from a property will need a resource consent from Environment Bay of Plenty.

Some types of activities that result in a net increase in the export of nitrogen or phosphorus from properties are:

- Intensification of agricultural activities
- Intensification of dairying
- Dairy conversions
- Intensification of agricultural activities
- Cumulative effects of septic tanks
- Change of land use to unsewered rural residential
- Intensification of residential land use (including infill housing) in Okareka, Hamurana, Hinehopu, Okawa Bay, Mourea where the dwellings are not connected to a reticulated sewage system

Rule 11 is effects-based. If a person intensifies their land use, but does not cause an increase in the export of nutrients from the property, they are not subject to Rule 11. For example, the person may identify that they can off-set an increase of nutrients by retiring riparian margins, using a feed lot in winter, using a different stock food, *etc*. In this way the increase in nutrients is balanced by measures to reduce nutrients and there is no net increase in nutrients.

Rule 11 draws a 'line in the sand' regarding nutrients in the lakes catchments. The Rule aims to, at least, cap existing levels, and prevent additional inputs of nutrients from land use activities in the catchment. The community have already contributed to nutrient reduction measures (e.g. Rotorua sewage discharge to land system, riparian planting), and it would be unfair to allow land use changes to 'consume' the nutrient reduction benefits paid for by the community.

# Appendix II – Trophic Level Index (TLI)

The Trophic Level Index is an indicator of the environmental quality of a lake. It is made up of two chemical and two biological components but provides information relating to the wider ecology of the lake and is linked to the land use in the catchment of the lake. The Ministry for the Environment has adopted the TLI as a national indicator for NZ state of the environment reporting.

Burns, Rutherford and Clayton (1999) developed this index for New Zealand conditions because other similar indices, used internationally, were not adequate to deal with NZ lakes. The method of developing the index is described in Burns *et al* (1999). Four variables (sub-components denoted here as TLx) are used to calculate the TLI. They are chlorophyll *a* (indicates phytoplankton abundance), secchi disc (measures water clarity), total phosphorus and total nitrogen concentrations (main plant nutrients). An annual trophic level is calculated for each variable and the average of the four trophic levels is the TLI (Gibbon-Davies, 2001).

A TLI value has been set for each of the Rotorua lakes in the Proposed Regional Water and Land Plan to achieve an acceptable level of water quality. Where a current lake TLI is greater than that set in the plan, we would expect to see environmental ‘problems’. At Lakes Okaro, Rotoehu and Rotoiti there have been blue-green algal blooms (Wilding, 2000). Lake Rotorua is also subject to unusual blooms at times eg the foam algae (Wilding, 2000). Lake Okareka does not have blue-green algal blooms but some of the factors that indicate deterioration of quality have been increasing in magnitude e.g. deoxygenation (anoxia) of the bottom water and nutrient release from the sediment.

A large internal load of nutrients is generated from the sediment of Lake Rotoehu. The objective of the action plan is to lower the external load of nutrients to such an extent that the internal load becomes very low.

### TLI Equations

From Burns *et al* (1999).

TLc = 2.22 + 2.54 *log(Chla)* *[log* to base 10*]*
TLs = 5.56 + 2.60 *log*(1/SD – 1/40)
TLp = 0.218 + 2.92 *log*(TP)
TLn = -3.61 + 3.01 *log*(TN)
TLI = ¼ (TLc + TLs + TLp + TLn)

# Appendix III – Nutrient Export Coefficients

Catchment land use modelling is based on the premise that a certain area of land undergoing a certain land use will have a specific output of nitrogen and phosphorus that relates to that land use. This is termed its nutrient export coefficient. A range of geographical and climatic factors has an effect on the variation of this output. Also the way in which the land use is carried out can vary, which again results in variation in the average output.

Various nutrient export coefficients have been used for land use modelling in Rotorua lake catchments. There can be a large variation in the total output calculated from the land to the lake depending on which study is used to derive export coefficients. For this action plan the lake concentrations of nitrogen and phosphorus have been modelled as in Cooper and Rutherford (2002) for Lake Okareka.

The coefficients have units of kg/ha/year or tonnes/km$^2$/year and provide a nutrient output in kg/year, tonnes/year *etc* once the area of the particular land use is known. To derive the coefficients, catchments with specific land uses are monitored over an extended period of time. There are some difficulties in doing this in the typical volcanic catchments of the Rotorua lakes, where considerable runoff travels to the lake via groundwater.

Some specific studies have been undertaken to derive coefficients.

Cooper and Thomsen (1987) studied pasture, pine and native forest catchments at Purukohukohu between Rotorua and Taupo. Their data is frequently used for Rotorua lake catchments and was used by Bioresearches (1991).

Williamson *et al* (1996) modelled the Ngongotaha catchment of Lake Rotorua and export coefficients from that study have been used by Ray *et al* (2002a).

Macaskill *et al* (1997) sampled streams in the general Rotorua lakes area to determine the nutrient output differences between pasture, native and exotic forestry.

# Appendix IV – Annual Nutrient Budget for Lake Okaro

Below is a spreadsheet model that shows the relative contribution of nitrogen and phosphorus contributed to Lake Okaro from the different land use sources. Appendix V contains a brief explanation of how the target levels were calculated which has confirmed that the total load of the spreadsheet model produces a similar total to calculating the catchment load from the in-lake nutrient concentrations.

*Table 5 Spreadsheet model for Lake Okaro land use nutrient export.*

| Land cover | Area | | Export coefficient | | | Load | |
|---|---|---|---|---|---|---|---|
| | | | nitrogen | | phosphorus | nitrogen | phosphorus |
| | ha | | tonnes/km$^2$/year | | | tonnes | |
| | | *Note* | | *Note* | | | |
| Forest indigenous | 13.5 | *1* | 0.250 | *11* | 0.004 | 0.034 | 0.0005 |
| Forest planted | 2.5 | *2* | 0.250 | *12* | 0.004 | 0.006 | 0.0001 |
| Pasture exotic | 359 | *3* | 0.700 | *13* | 0.030 | 2.510 | 0.1077 |
| Rainfall | | *9* | | | | 0.128 | |
| Internal load | | *10* | | | | 2.400 | 0.3800 |
| TOTAL | | | | | | 5.078 | 0.4880 |

Note: (refers to the reference for the derivation of the export coefficient)

1 Ray and Timpany (2000b)
2 Ray and Timpany (2000b)
3 Ray and Timpany (2000b)
4
5
6
7
8
9 Calculated from Environment Bay of Plenty data.
10 Estimate
11 Rutherford and Cooper (2002)
12 Rutherford and Cooper (2002)
13 Rutherford and Cooper (2002)

# Appendix V - Sediment Nutrient Release

Below the sediment release is calculated from the concentration of dissolved nutrients in the water column after mixing has taken place. The volume is calculated from the surface area of 320,000 m$^2$ by the mean depth of 12.1 m.

| Date | Time | DRP g/m$^3$ | $NH_4N$ g/m$^3$ | DRP average g/m$^3$ | $NH_4N$ average g/m$^3$ | P tonnes | N tonnes |
|---|---|---|---|---|---|---|---|
| **BOP130017** | **18m Basin** | | | | | | |
| 06/08/92 | 11:40:00 | 0.063 | 0.296 | | | | |
| 06/08/92 | 11:40:00 | 0.063 | 0.319 | | | | |
| 06/08/92 | 11:40:00 | 0.064 | 0.318 | | | | |
| 06/08/92 | 11:40:00 | | | 0.063 | 0.311 | 0.25 | 1.20 |
| 17/08/93 | 10:53:00 | 0.111 | 0.676 | | | | |
| 17/08/93 | 10:53:00 | 0.111 | 0.671 | | | | |
| 17/08/93 | 10:53:00 | 0.113 | 0.696 | | | | |
| 17/08/93 | 10:53:00 | | | 0.112 | 0.681 | 0.43 | 2.64 |
| 08/08/94 | 10:30:00 | 0.114 | 0.830 | | | | |
| 08/08/94 | 10:30:00 | 0.114 | 0.785 | | | | |
| 08/08/94 | 10:30:00 | 0.120 | 0.764 | | | | |
| 08/08/94 | 10:30:00 | | | 0.116 | 0.793 | 0.45 | 3.07 |
| 24/06/97 | 12:00:00 | 0.123 | 0.565 | | | | |
| 24/06/97 | 12:00:00 | 0.124 | 0.566 | | | | |
| 24/06/97 | 12:00:00 | | | 0.124 | 0.565 | 0.48 | 2.19 |
| 13/07/00 | 11:40:00 | 0.034 | 0.453 | | | | |
| 13/07/00 | 11:40:00 | 0.034 | 0.459 | | | | |
| | | | | 0.034 | 0.456 | 0.13 | 1.77 |
| 19/06/01 | 12:56:00 | 0.079 | 0.684 | | | | |
| 19/06/01 | 13:00:00 | 0.082 | 0.727 | | | | |
| 19/06/01 | 13:03:00 | 0.090 | 1.260 | | | | |
| | | | | 0.084 | 0.890 | 0.32 | 3.45 |
| | | **average** | | | | **0.38** | **2.41** |

# Appendix VI – Lake Okaro Trophic State Targets

Rutherford and Cooper (2002) reviewed Environment Bay of Plenty's Lake Okareka Draft Action Plan Working Paper. The process followed in that review is followed here.

The ratio of TN/TP in Lake Okaro has ranged from 8 – 14 since 1990. Pridmore (1987) states that a TN/TP ratio of 10 – 17 should produce balanced phytoplankton growth. Therefore, the nutrient content of Lake Okaro is balanced with a tendency for nitrogen limitation.

Using the method of Rutherford & Cooper (2002) an even reduction was applied across the four parameters of the TLI in order to calculate the required reduction in nitrogen and phosphorus.

At Okaro this results in a reduction of 0.72 to each of the four component TLx values. Thus it has been estimated that an average lake concentration of 68 mgP/m$^3$ and 730 mgN/m$^3$ would give an average TLI of 5.0. Current lake concentrations are 123 mgP/m$^3$ and 1282 mgN/m$^3$, which implies that a reduction of 44% is required.

*Table 6 Current (1992-2001) and target lake quality and trophic indices.*

| | Chla mg/m$^3$ | SD m | TP mg/m$^3$ | TN mg/m$^3$ | |
|---|---|---|---|---|---|
| Current lake quality | 33.00 | 1.61 | 123.34 | 1281.84 | Gibbons-Davies, 2003 (average 1990-2001) |
| | TLc | TLs | TLp | TLn | Gibbons-Davies, 2003 |
| Current TLx | 5.86 | 4.99 | 6.30 | 5.73 | Average = 5.72 |
| | | | | | Target = 5.00 |
| Required reduction | 0.72 | 0.72 | 0.72 | 0.72 | ∴Reduction = 0.72 |
| Target TLx | 5.14 | 4.27 | 5.58 | 5.01 | |
| Target lake quality | Chla mg/m$^3$ | SD m | TP mg/m$^3$ | TN mg/m$^3$ | |
| | 14.1 | 2.20 | 68.00 | 730.00 | |

The target lake quality is higher than the quality of Lake Okaro has been at any time over the last ten years, although the secchi disc depth averaged 2.25 metres in 200/2001.

In Table 7, a calculation is carried out using the method of Rutherford and Cooper (2002) to enable a catchment load reduction to be assessed.

*Table 7 Estimation of current nutrient loads (based on average lake concentrations (1994-2001) and target nutrient loads to reach proposed target lake concentrations.*

| | **chla $mg/m^3$** | **sd m** | **TP $mg/m^3$** | **TN $mg/m^3$** | |
|---|---|---|---|---|---|
| Average 1990-2001 | 33.00 | 1.61 | 123.34 | 1281.84 | Gibbons-Davies (2003) |
| Target lake quality | 14.1 | 2.20 | 68.00 | 730.00 | |
| reduction | | | 45% | 43% | |
| Concentration reduction sought | | | | | |
| | | | 55.34 | 551.84 | |
| | | | | | |
| Lake area A $m^2$ | 320000 | | | | Donald (1997) |
| Lake volume $m^3$ | 3872000 | | | | Mean depth 12.1 m |
| Catchment runoff Q1 $m^3$/yr | 2400000 | | | | 375 ha 640 mm |
| Rainfall on lake Q2 $m^3$/yr | 187200 | | | | 32 ha 585 mm |
| Total inflow Q = Q1 + Q2 | 2587200 | | | | |
| Hydraulic loading Q/A m/yr | 8.1 | | | | |
| Predicted retention coefficient R | 0.57 | | | | |
| | | | **TP t/yr** | **TN t/yr** | |
| Estimated current load | | | 0.73 | 7.71 | M = CQ/(1-R) |
| Estimated target load | | | 0.33 | 4.39 | |
| Estimated reduction | | | 0.40 | 3.32 | |

The estimated current load is greater than the load calculated from the catchment land use in the spreadsheet model (Table 5). It is possible that the actual lake catchment is greater than the surface catchment and additional flow enters the lake from groundwater. Alternatively, the nutrient export from the catchment could be at a higher rate than the estimation used in Table 5.

Lake Okaro looking from east to west, with the outlet at the left and the reserve at the right end of the lake (older view).

Lake Okaro, looking to the north west, with the catchment running up to the top, left hand corner of the picture (2003) Picture by John Gibbons-Davies.