ROTORUA DISTRICT COUNCIL

Environment Bay of Plenty
REGIONAL COUNCIL

Lake Okareka Catchment Management Action Plan

Draft Working Paper

Environment Bay of Plenty
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Working with our communities for a better environment

Project Support Team

The Lake Okareka Action Plan project is supported by a team comprised of Rotorua District Council and Environment Bay of Plenty staff: Paul Sampson, Nigel Wharton, Greg Manzano, Paul Dell, John McIntosh, Ruth Feist.

Cover photo: Lake Okareka

Foreword

We are pleased to extend this invitation to the people of the Lake Okareka catchment to join together to form a Working Party to ensure that the future environmental quality of Lake Okareka is enhanced. It is a deep felt concern for us that the natural resources of the Rotorua district and the Bay of Plenty region are suffering from the ever increasing pressures of our changing economic activity and lifestyles.

The reasons that people value the lake environment is put at risk by the very presence of communities and commercial, industrial and agricultural activities. It is not a matter of people creating "pollution", it is just that the common plant nutrients, nitrogen and phosphorus naturally flow out of the places we occupy. Lakes are very sensitive to how much nitrogen and phosphorus they can process. Unfortunately, we are becoming all too familiar with the events arising from having too heavy a dose of nutrients running into the lakes.

We wish to move into the future, protecting the uniqueness of the natural environment and the economic prosperity of the district. The accumulated nutrients in our lakes are from times gone by as well as from the present time. The Okareka Action Plan is a major step forward for the future management and control of the Rotorua lakes. The Action Plan will give you the opportunity to combine science, technology and landuse solutions in an economic model so that all issues and costs are identified. An immediate change can not be expected but an improving situation over the coming years. This is an important project and we look forward to your involvement.

This Working Party will form a basis for the Lake Okareka community to pioneer a strategy whereby our lake communities can come together and plot an acceptable course into the future. Rotorua District Council and Environment Bay of Plenty staff will support the Working Party fully. By the combined efforts of both Councils and the local community we are confident this joint initiative will provide for the sustainability and/or improvement of our lakes. Ourselves and our Councillors will take a great interest in your progress and wish you every success in determining the most appropriate solution.

Yours sincerely

Grahame Hall
Mayor
Rotorua District

John Cronin
Chairman
Environment Bay of Plenty

Contents

Table and Figures

1 Purpose of the Action Plan Working Paper

The purpose of this document is to:

- Set up a Working Party to address the nutrient load issues in the catchment of Lake Okareka, which have been highlighted in the Regional Water & Land Plan (RW&LP);
- Set out the factors that influence the environmental quality of the waters of Lake Okareka;
- Explain the objectives of this Action Plan.
- Describe a process whereby the community can discuss the issues and decide on the most appropriate actions to achieve the objectives;
- Set out options that will improve the current environmental quality of the lake waters;
- Provide the information necessary for the community to select options or a mixture of options that will achieve the environmental quality objective for Lake Okareka in the RW&LP.

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 for several reasons. These include the completion of recent studies for Environment Bay of Plenty, which provide useful information for determining how nutrient inputs to Lake Okareka relate to the in-lake nutrient levels (Rutherford and Cooper, 2002). In addition Rotorua District Council is considering possible sewage reticulation options for houses near the lake in response to bacterial contamination issues relating to septic tank systems.

Although Lake Okareka currently has the best quality of the five lakes requiring an action plan it is considered to be at a point where future deterioration could increase markedly. The lake is showing increasing evidence of depleted oxygen levels in the bottom water towards the end of summer and nutrients are being released from the sediment. If the level of nutrient release increases it will further enhance phytoplankton growth (hence decrease clarity) and cause even greater depletion of oxygen in the

[1] Appendix I Lakes policy in Regional Water & Land Plan (page 25)
[2] Appendix II Explanation of the Trophic Level Index (page 27)

lower levels of the lake. This cycle of deterioration is much more difficult to reverse than it is to avoid. It is therefore important to act now to safeguard the quality of this lake for the future.

Consideration of a number of these factors made it timely to look at the Lake Okareka situation first. This document brings together the information needed to begin the process of developing action plans in consultation with the community.

The Lake Okareka action plan will form a blueprint for future lake action plans.

3 Draft Working Papers

Draft working papers were produced by each of Rotorua District Council and Environment Bay of Plenty. The current document has been developed from a fusion of both documents and it has been developed to provide an agenda for the action plan working party.

4 Objective of the Lake Okareka Action Plan

The objective of this action plan is to combine:

- land use management,
- technology and
- funding options,

to reduce the annual nutrient load to the water of Lake Okareka by 2.32 tonnes of nitrogen and 0.07 tonnes of phosphorus to achieve a TLI of 3.0 to comply with a policy of the Regional Water & Land Plan.

This has been calculated (Rutherford and Cooper, 2002)[3] as the required load reduction to meet the Lake Okareka quality objective of the Proposed Regional Water & Land Plan.

5 Working Party

A Working Party is proposed to discuss options to reduce the nutrient load on Lake Okareka. The Working Party is to be composed of representatives from the Department of Conservation, Fish & Game New Zealand (Eastern Region), Federated Farmers, land owners, the Lake Okareka Ratepayers Association, Tangata whenua, Rotorua District Council and Environment Bay of Plenty. An Environment Bay of Plenty politician would chair the meetings.

[3] Appendix III Lake Okareka Trophic State Targets (page 29)

6 Brief for Working Party

Table 3 provides the brief for working party members. An initial meeting of the groups would be held to disseminate the information and to discuss the process. Each member would then be required to carry out a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis within his or her own group to put before the combined working party. The SWOT analysis would be of methods in this report or methods proposed by the group to achieve nutrient reductions in the inputs to Lake Okareka. Options should be evaluated from the group's perspective. Particular information is also sought from each group as outlined in the brief (Table 3).

Table 3 Brief for Working Party.

Working Party member	Brief/Required Output
DoC, F&G NZ	SWOT analysis. Identify potential wetland construction sites and issues. Management of wildlife
Federated farmers	SWOT analysis Disseminate information to members Farming costs Nutrient/farming management practices National philosophy on nutrient budgeting
Land owners Large – big blocks Small - lifestyle	SWOT analysis Aspirations – willingness to convert or retire land. View on conversion of land.
Lake Okareka Ratepayers Association	SWOT analysis Promotion of the concept and options to the local community. Catchment values.
Tangata whenua	SWOT analysis Cultural expectations.
RDC & Env Bay of Plenty	Technical/planning • Project management • Public information • Promotion Finance • Funding concepts/options

The working party will meet for a one-day extensive consultation meeting where the outputs of individual members of the working party will be presented and discussed.

7 Project Plan

Table 4 outlines the project plan for the development of the Lake Okareka Action Plan.

Table 4 Lake Okareka Action Plan Development (Project Plan)

Date	**Action**
February 2003	Complete EnvBOP/RDC Draft Action Plan
March 2003	Public meeting
March 2003	Set up Working Party Working Party SWOT Analysis
April/May 2003	Working Party Discussion (all day meeting in Rotorua) Develop implementation strategy
July 2003	Funding policy
August 2003	Agreed options
November 2003	Public consultation Local community plan Coordination with District Plan and Regional Plan

8 Factors that Affect the Quality of Lake Okareka

Lake Okareka has residential and rural communities although the lake catchment does not have the most intensive forms of agriculture. The lake is extensively used for recreation, including boating, fishing, water skiing and bathing. Public reserves around the lake provide good access and allow people to value the experience of the natural environment. There are wildlife habitats, natural wetlands, a native forest backdrop to the east and partially to the south, and road access connects the lake to the western Okataina walkway. All these values are highly regarded by the permanent residents and visitors alike.

Table 1 and Figure 1 show the extent of various land cover (1996) in the Lake Okareka catchment. Table 2 and Figure 2 shows a further detailed breakdown of the type of farming on pasture.

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

Land Cover	Area	
	ha	%
Bare ground	8	0.5
Forest indigenous	513	31.6
Forest planted	93	5.8
Pasture	839	51.6
Scrub mixed	125	7.7
Urban	45	2.8
TOTAL	1624	100

The lake area is 346 ha and there are direct inputs to the lake from rainfall.

Table 2 Farming type on pasture in the Lake Okareka catchment.

Land Cover Pasture	Area	
	ha	%
Sheep and beef	691	42.6
Sheep	15	0.9
Beef	83	5.1
Deer	32	2.0
Other	16	1.0
TOTAL	839	51.6

8.1 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. Algal growth is driven predominantly by phosphorus and nitrogen. The more phosphorus and nitrogen that flows into a lake the more algae will grow.

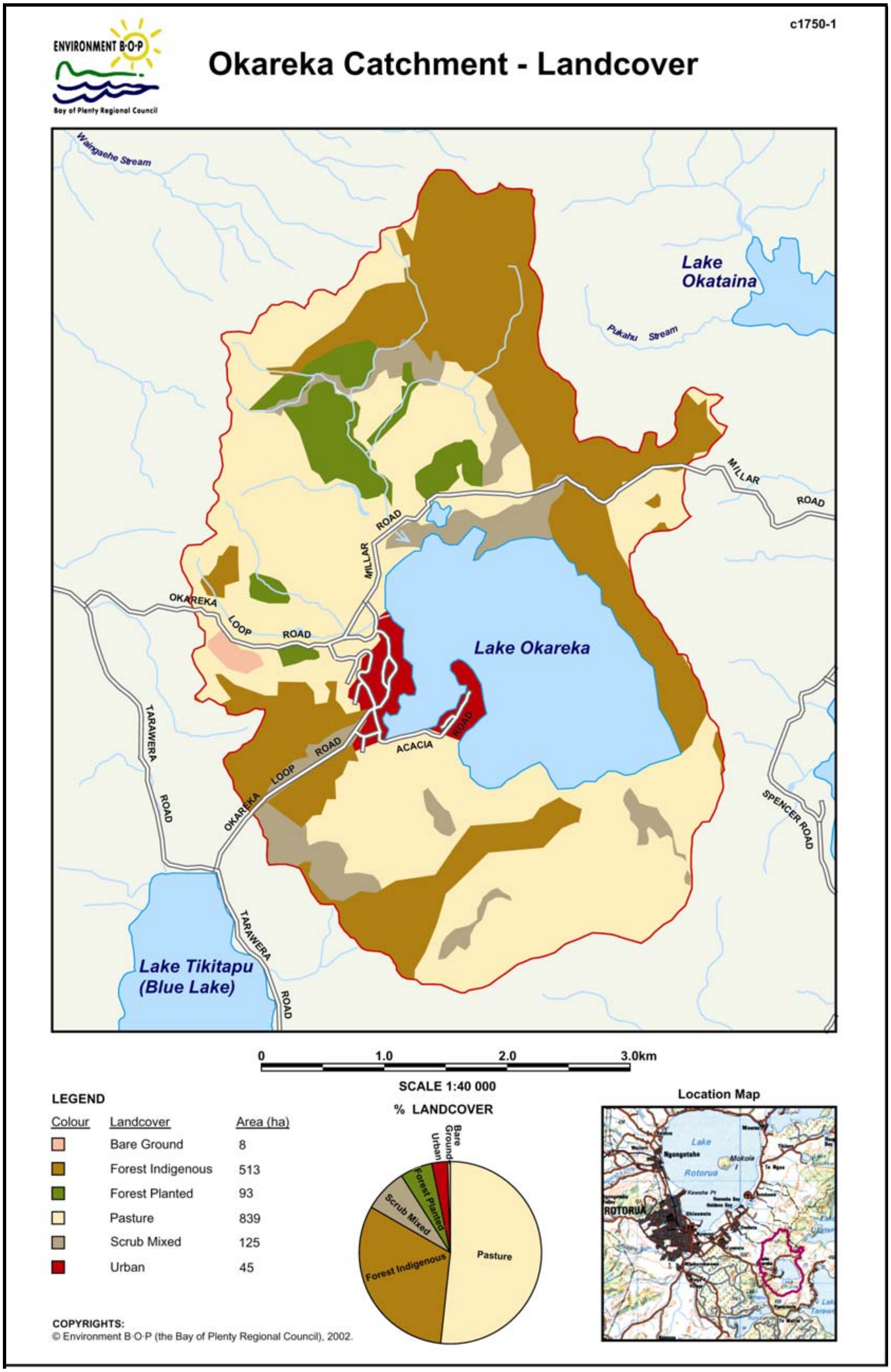

Figure 1 Land cover (1996) map of Lake Okareka catchment.

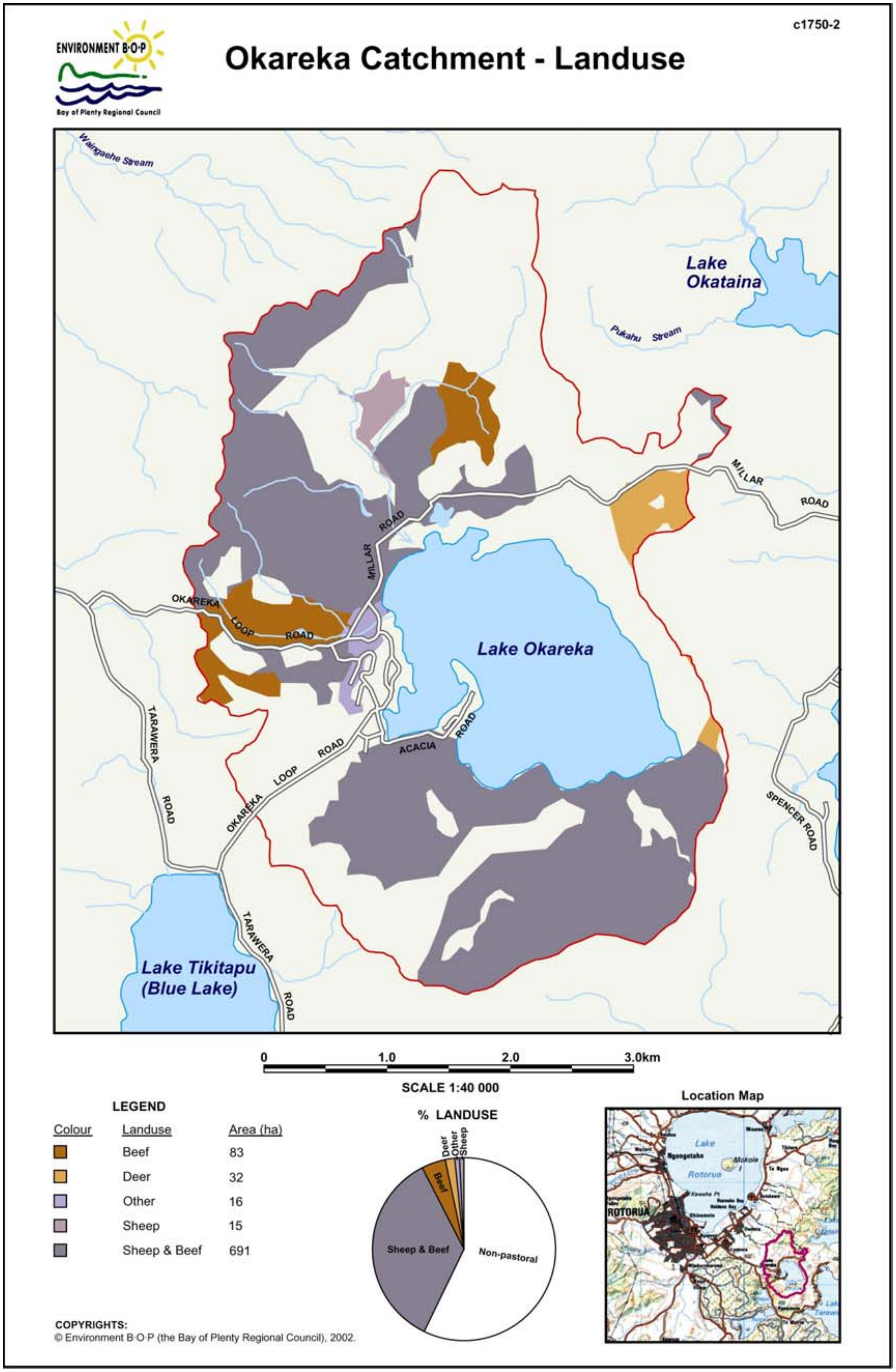

Figure 2 Land use (1996) of pasture in Lake Okareka catchment.

The soils of the lake catchments tend to be phosphorus absorbing because of the allophane clay content, but the waters coming from cold 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 a low nitrogen content (Vincent, 1980). In a forest situation nitrogen is recycled within the forest and a small amount lost to leaching. Increased levels of nitrogen exist in pasture soils from nitrogen fixing plants and fertiliser application and more nitrogen is lost to run-off or leaching. 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[4]. Once the export coefficients have been determined then a spreadsheet model can be constructed to illustrate an annual nutrient budget[5].

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.

8.2 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] Appendix IV Nutrient export coefficients (page 31)
[5] Appendix V Spreadsheet model for Lake Okareka (page 33)

9 Potential Actions to Reduce Nutrient Load

Several options are presented for achieving the desired nutrient input reduction to Lake Okareka. 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 and in the certainty of outcome. Any change will require capital and on-going operating costs. When options are compared these factors will be taken into consideration.

The options can be classified as: land management/land use, technology and the financial implications of these.

Land management involves changing land use to a form that has a lower nutrient output. It could also be changing the way the land use is carried out so that lower levels of nutrients are lost.

Environment Bay of Plenty has established a large amount of retirement of stream banks and lake margins to protect the quality of water from direct runoff. This reduces nutrient output but not by the large amounts needed to remediate a whole lake. However, wetlands can enhance the nutrient reduction and it may be possible to incorporate these into retirement areas to achieve a greater reduction.

Sewage treatment is the major technology that is effective in reducing nutrient inflows to lakes. However, the various SWOT analyses may come up with additional possibilities.

The funding policies of the local authorities will have an influence of the implementation of options.

Mechanisms to consolidate any nutrient reductions will have to be discussed.

Notes:

9.1 Land Management / Land Use

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 of nitrogen/km^2/year (Ray *et al*, 2000b) then about 515 hectares of pasture would have to be converted to forest to reduce the nitrogen load on the lake by 2.32 tonne/year.

For phosphorus the conversion of pasture to forest results in a reduction in output of 0.026 tonnes of phosphorus/km^2/yr. To achieve the required lake load reduction of 0.07 tonne/yr, around 270 hectares of pasture needs to be converted to forestry. The requirement to meet the nitrogen load reduction is greater and thus becomes the driving consideration.

Currently 839 hectares of the lake's catchment is in pasture. Clearly, a major change in land use would be required to achieve this action.

An estimate of the cost to convert pastoral land to forestry is $301,500 per km^2. To convert 515 hectares would cost $1,552,725. Any land acquisition would be an additional cost or a cost may be involved in covenanting land.

There are a raft of other land use options such as utilising land for lifestyle blocks and/or the placing of limits on stocking rates.

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.

Rotorua District Council has been granted funding through Environment Bay of Plenty's Environmental Enhancement Fund to retire 0.3 km^2 (30 ha) of lake margin from grazing. This conversion of grazing land to forest/scrub is calculated to reduce the nitrogen input to the lake by 0.14 tonne/year and phosphorus by 0.008 tonne/year. Depending on the vegetative nature of this riparian retirement in the long-term, it could provide a further reduction of nitrogen inputs to the lake if a de-nitrifying wetland environment results along the lake margin.

The cost of this project (included an all-mobility accessible walkway) was estimated to be $266,620. This did not include the cost of the land. Cost per km^2 for this type of work would be approximately $890,000.

The cost of retiring a riparian strip of land varies greatly but some Environment Bay of Plenty retirement works ranged from $50,000 - $500,000 per km^2 (cost of land not included).

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 through a wetland will not achieve nitrogen removal.

There is an input of nutrients via the stream at Millar Rd with total nitrogen and phosphorus load in the order of 1.0 and 0.03 tonnes/year respectively (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 stream, partially or wholly, through the wetland that is located nearby. There are potential conflicts between nutrient renovation and trout spawning values of this stream that would have to be resolved for this option to be applied.

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

Notes:

9.2 Technology

Septic tank reticulation

Rotorua District Council has recognized a potential public health issue at Lake Okareka related to septic tanks, and investigations have been carried out for remedial planning purposes. A treatment scheme to reduce microbiological contamination from sewage could also serve to reduce nutrient inputs to the lake. It would be expected that such an option would greatly reduce nitrogen inputs to the lake. However, it would not be expected to further significantly decrease phosphorus inputs compared with the current situation. If septic tank systems are operating efficiently very little phosphorus should be entering the lake from these sources.

There are currently 288 houses in the Lake Okareka catchment using septic tank systems.

Using the assumption that a septic tank leaches 10g/person/day of nitrogen and that each household at Lake Okareka has an average of 2.3 people, then the current 288 houses will in total, leach 2.42 tonne/year of nitrogen. If treatment technology reduces the nitrogen content of the effluent by 80%, then reticulation of all 288 houses could reduce the nitrogen input to Lake Okareka by 1.94 tonne. Sequential Batch Reactors (SBR) can remove up to 98% of the nitrogen from sewage.

For Okareka the capital cost of SBRs is estimated at $3,030,000. The amount of operating cost is $280,000 pa. The capital costs plus operating costs over 20 years would amount to $6,000,000 for the removal of 2.4 tonnes/year of nitrogen. Phosphorus reductions are also possible.

Notes:

Other Methods

- Public education on ways to reduce nutrients.

- House and garden BMPs (Best Practical Methods).

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

- Control of waterfowl
  Bioresearches (2002) estimated that wildfowl at Okareka numbered 630. Swan (200) were the most numerous, followed by Scaup (170) and Mallards (110). If all of the faeces of the birds went into the lake this would amount to 0.7 tonne of nitrogen and 0.25 tonne of phosphorus. However, the waterfowl recycle nutrients stored in the weed on which they feed back into the lake water. A portion of these nutrients fed back in this manner will be available for the growth of algae in the lake, whereas they would not otherwise be.

  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.

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

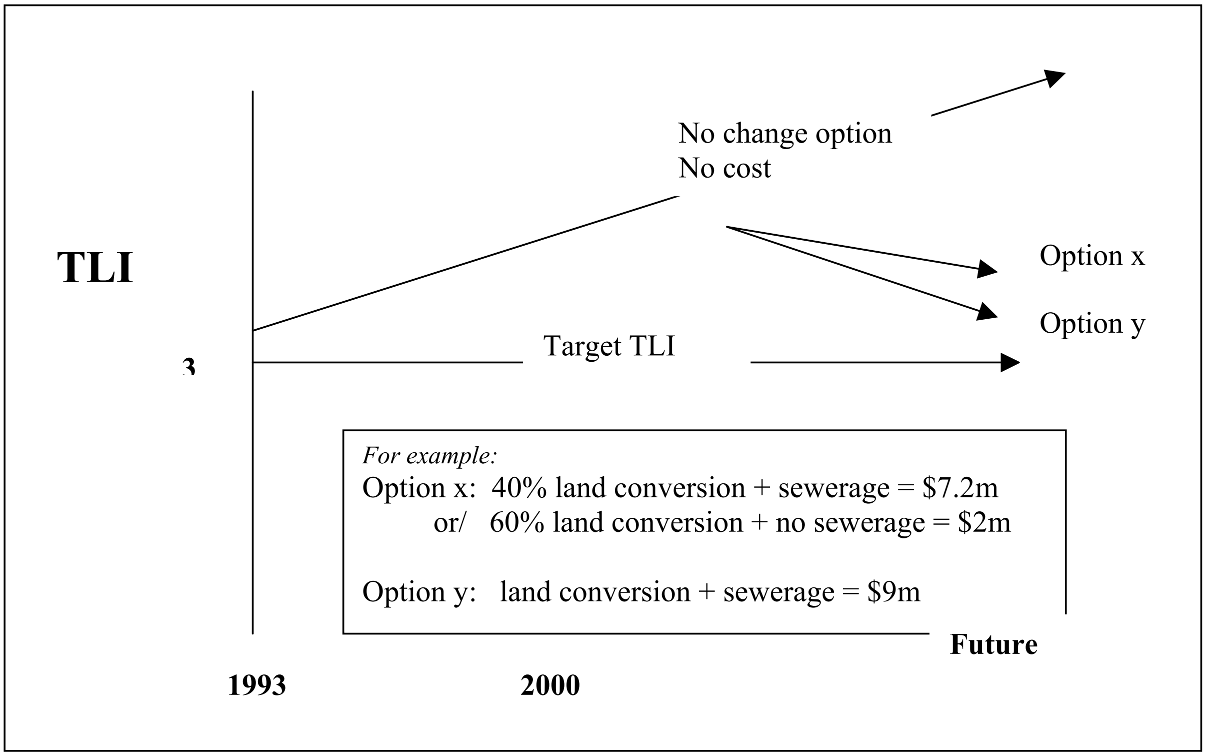

Figure 3 "What to do scenarios" with costs (example only – not exact).

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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 *i.e.* 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 Bay of Plenty 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 (*i.e.* 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 (i.e. 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 (*eg* 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.

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/algal 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 *eg* deoxygenation (anoxia) of the bottom water and nutrient release from the sediment.

A small internal load of nutrients is generated from the sediment of Lake Okareka. If this load were to increase further in response to increased deoxygenation of the bottom waters, then it would become very difficult to control the quality of the lake. The objective is to lower the external load of nutrients to such an extent that the internal load remains 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 - Lake Okareka Trophic State Targets

Rutherford and Cooper (2002) reviewed Environment Bay of Plenty's Lake Okareka Draft Action Plan Working Paper.

The ratio of TN/TP in Lake Okareka was found to be about 36, which indicates that it is phosphorus limited. However, the strategy recommended was to reduce both phosphorus and nitrogen.

Rutherford and Cooper recommended that to achieve an average Trophic Level Index (TLI) of 3.0, each sub-index of the TLI should be reduced by 0.3. The authors thus estimated that average lake concentrations of 5 mgP/m^3 and 183 mgN/m^3 would give an average TLI of 3.0. Current lake concentrations are 6.5 mgP/m^3 and 230 mgN/m^3 implying that a reduction of 21% is required.

To determine which catchment model was giving the most appropriate result, catchment loads were estimated using a well-established method (Hoare, 1980, 1987). This method relates the catchment load to the in-lake levels of nitrogen and phosphorus. The load being discharged annually from the catchment was estimated as 11.3 tN/year and 0.32 tP/year.

Load reductions that would have to be achieved by reducing inputs from land use were 2.32 tN/year and 0.07 tP/year.

Appendix IV - 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 Cooper and Rutherford (2002) have modelled the lake concentrations of nitrogen and phosphorus to determine the most likely nutrient export coefficients.

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).

Ray *et al* (2002b) sampled groundwater around the perimeter of Lake Okareka as well as using stream inflow data to calculate export coefficients.

Bioresearches have also incorporated an urban component to account for the output from urban lands. This is a significant load so should be included.

Appendix V - Annual Nutrient Budget for Lake Okareka

Below is a spreadsheet model that shows the relative contribution of nitrogen and phosphorus contributed to Lake Okareka from the different land use sources. Appendix V contains a brief explanation of the report of Rutherford and Cooper (2002), 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.

Spreadsheet model for Lake Okareka land use nutrient export.

Land cover	Area		Export coefficient			Load	
			nitrogen		phosphorus	nitrogen	phosphorus
	ha		tonnes/km^2/year			tonnes	
		Note		*Note*			
Bare ground	8	*1*	0.500	*10*	0.100	0.040	0.0080
Forest indigenous	513	*2*	0.250	*11*	0.004	1.283	0.02105
Forest planted	93	*3*	0.250	*12*	0.004	0.233	0.00437
Pasture	839	*4*	0.700	*13*	0.030	5.873	0.2517
Scrub mixed	125	*5*	0.250	*14*	0.004	0.313	0.0050
Urban	45	*6*	0.800	*15*	0.080	0.360	0.0360
Septic tank	288 houses	*7*				2.376	
Rainfall		*8*				1.300	
Internal load		*9*				0.500	
TOTAL						12.278	0.3249

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

1 Estimate
2 Ray and Timpany (2000b)
3 Ray and Timpany (2000b)
4 Ray and Timpany (2000b)
5 Ray and Timpany (2000b)
6 Williamson (1993)
7 Ray and Timpany (2000b) assumes 10g/day/person nitrogen discharge and an occupancy rate of 2.26.
8 Hoare (1987)
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)
14 Rutherford and Cooper (2002)
15 Williamson (1993)

Plate 1 Lake Okareka, viewed from east to west, across the urban area to Lake Rotorua in the background. The Millar Rd stream catchment is at the top, right. The riparian area currently being retired is the lake margin at the bottom left.

Plate 2 The urban area of Lake Okareka showing the peninsula with farmland behind and to the right the road heading south to Tikitapu (the Blue lake). The bush catchment to the right of the road drains to the stream that enters the lake at the base of Summit Rd. This stream has very low nitrogen levels, which suggests that denitrification works efficiently in the adjacent wetland.

Plate 3 *Lake Okareka, viewed from west to east, across the urban area to farmland on the southern edge of the lake, where the riparian margin of Lake Okareka is currently being retired from grazing. Lake Tarawera is in the background.*

Plate 4 *The outlet of Lake Okareka flows a short distance from the lake from where it is piped through the hill to join a spring fed stream flowing into Lake Tarawera.*