Friends of Lake Hayes submission on the Proposed Queenstown Lakes District Plan Stage 2

July 24, 2018

I am Mike Hanff, current Chairman for Friends of Lake Hayes Society Inc (FOLH). I am going to talk to our submission. FOLH have asked Dr Marc Schallenberg, a freshwater scientist from the University of Otago with lots of experience on Lake Hayes to support our submission. If you have any technical questions relating to managing potential impact of develop in the Lake Hayes Catchment or the Lake itself he will be happy to address them as part of our submission

FOLH society was incorporated in October 2008 by a group of residents concerned about the health of Lake Hayes and the water quality of its catchment. The society has around 120 members and is led by an executive committee of 10 residents at Lake Hayes including prominent members of the local community.

Since 2006, the health of the lake has deteriorated significantly culminating with severe blooms of the nuisance algae, *Ceratium hirundinella* and potentially toxic cyanobacteria, and with high levels of *E. coli* in the summer of 2017- 18. This ultimately led to Otago Regional Council (ORC) erecting signage warning people to avoid, swimming in, drinking the water and to keep pets away. FOLH has initiated many community discussions all supporting getting something done to improve the situation. Increasing interest in the poor state of the lake was reinforced by the significant increase in submissions to the ORC Long Term Plan process, requesting the ORC to act on this situation. FOLH has reviewed 5 significant scientific studies focusing on the poor state of the lake that have been completed since 1972. These studies have made similar recommendations which have been repeated in the most recent studies: Lake Hayes Restoration and Monitoring Plan (Schallenberg & Schallenberg 2017) and Lake Hayes Water Quality Remediation Options (Gibbs 2018). As a result of this latest study FOLH now recognizes the critical importance of reducing the amount of new sediment and nutrients entering the lake from the catchment. If we don't do this then all of our efforts to improve water quality in the lake itself will be wasted.

The lake Hayes catchment starts with the head waters of Mill Creek flowing off Coronet Peak, Mooney Swamp, Slope Hill . These then flow through what is now Millbrook Resort, descending a 30-metre water fall into what is now a proposed Wellness Retreat, then runs through Ayrburn Farm across Speargrass Flat into Lake Hayes. It captures a large part of proposed new Wakatipu Basin Rural Amenity zone and Lifestyle precinct. In the 1960's, the then Catchment Board drained many of the wetlands and straightened the creek to improve farming. Before this, Mill Creek meandered through wetlands and was shaded by clumps of trees. The wetlands acted as a sink for high rainfall events, absorbing high creek flows laden with sediment nutrients. The water processed by the wetlands then slowly drained into the lake in dry periods leaving much of the nutrients in sediment in the swamps. The trees which shaded the creek kept the oxygenated water cool in summer which helped the lake by allowing the oxygenated creek water to plunge into the bottom waters of the lake after it entered the lake. This maintained healthy habitats throughout the lake resulting in prolific bird life (last count 45 species (J. Darby 2018) and a strong fishery (Schallenberg & Schallenberg 2017). Surveys of the lake indicate it provides an ideal habitat for what is one of the largest populations of Crested Grebes in the country hosting 30-40 breeding pairs (J.

Darby 2018). The Crested Grebe is a rare and threatened native bird in New Zealand with a known population < 700 birds.

A study carried out in the late 1990s by the ORC's Dr. Brian Caruso calculated that around 2.4 tonnes of phosphorus per year was added to the lake from the catchment via Mill Creek. Most of this phosphate arrived attached to sediment which was mobilised by activities in the catchment. He identified that around 80% of the annual load enters into the lake during high rainfall events, which this year for example have numbered 4 (see photos attach i). FOLH this year commissioned Chemsearch Ltd. to sample these events and results have shown that current total phosphorus concentrations are even higher than those measured by Caruso during similar events 20 years ago. This suggests that the phosphorus problem has only got worse over the last 20 years. The further deterioration of the lake over this period supports this assertion.

Post-1960, the drainage of wetlands in the catchments and increasing catchment development both appear to have increased sediment and phosphorus loads to the lake. Lake Hayes has effectively become the sink for most of the sediment and nutrients generated by the catchment. Unless earthworks in the catchment are carefully managed, some of the disturbed soil will end up in the lake as sediment with phosphorus attached to it.

QLDC & ORC haven't ignored this problem. The Lake Hayes Management Strategy (1995) stated,

> This Strategy details objectives and policies for future sustainable management of lake and catchment. This Strategy outlines the actions the ORC proposes to carry out in the catchment and regulatory matters recommended for consideration in the forthcoming Regional Plan: Water and the Queenstown Lakes District Plan. This separate but coordinated and consistent response recognises the different functions afforded to District and Regional Councils under Resource Management Act 1991.

In addition, page 5 of "Snapshot" QLDC Proposed Lakes District Plan Stage 2, which sought public submissions on Plan Stage 2, states,

"Proposed Wakatipu Rural Amenity Zone & Wakatipu Basin Life Style Precinct are based on the outcome of the Wakatipu Land Use Planning (March 2017) Study.".

The Lake Hayes catchment is a major part of the new proposed zones covered in QLDC Wakatipu Land Use Study 2017 brief (section 3.2) It States

"*Identify the environmental characteristics and amenity values of the area that should be* maintained and enhanced."

Unfortunately, this study used evaluation metrics without reference to existing policies and recommendations set out in ORC/QLDC Lake Hayes Management Strategy (1995). One of the primary goals of the management strategy was to reduce P loadings by 20% from 1994.

The current District Plan relies on developers to provide "expert advice' on issues around Mill Stream and water/ quality /runoff management. Development activities are supported by this advice. Apart from state of the environment monitoring done by the ORC at the mouth of Mill Creek, no monitoring or management measures have been put in place to assess the environmental performance of developments in the catchment during flood events, which is when around 80% of the annual phosphorus mobilisation through Mill Creek occurs. Clearly this system is not designed to protect Lake Hayes or Mill Creek from adverse contamination. This is partly why we have seen no improvement in water quality in Mill Creek over the past 10 years (LAWA website). Current levels of nutrient, sediment and *E. coli* loads are not tenable if we want to improve the health of the lake.

The FOLH request that a specific **Lake Hayes + Catchment Plan** with robust water quality protections and monitoring be developed and implemented. We consider that this plan could be largely aligned with the existing Lake Hayes Management Strategy (ORC 1995), but it should also prescribe Best Management Practices for developments in the catchment. We agree with scientific studies that indicated that the best long-term prospect for safeguarding the lake is a strict focus on restricting catchment contaminant loads (N, P, sediment and *E. coli*) to the lake. We also agree with scientific reports that stated that without addressing catchment contaminant loads, in-lake remediation activities will not provide a long-term fix for the lake. FOLH contends that if sediment and nutrient inputs from the catchment are not reduced then Lake Hayes will continue to have water quality issues. These will not only impact negatively on the growing numbers of users of the lake but also on the public perception of the Queenstown tourism and Clean Green NZ brands.

We recommend that a collaborative Lake Hayes + Catchment Plan should be an integral part of the new proposed Wakatipu Basin Rural Amenity Zone and Lifestyle Precinct in the Proposed Queenstown Lakes District Plan Stage 2.

The FOLH recommendations in this submission reflect the concerns of our community. We realise that our recommendation for a Lake Hayes + Catchment Plan require responses from, and collaboration between both the relevant Regional and District Councils, as already indicated in the ORC's collaborative Lake Hayes Management Strategy (ORC 1995).

To help get the ball rolling, the FOLH has initiated discussions with Dr Melissa Robson, of the Nutrient Policy Specialist Team at Landcare Research Ltd. (Lincoln). She has reviewed the Lake Hayes Management Strategy (ORC 1995) and has prepared a document outlining a process by which a Lake Hayes + Catchment Plan and implementation pathway could be developed. (append.ii) It is the FOLH's intention to seek funding from ORC to progress this initiative.

Thank you for the opportunity to deliver our submission. Over the years a lot of work in the community and supported by scientists and councils has been done to understand the issues. Given the current enthusiasm within the community regarding improving Lake Hayes and its catchment, I think we have fantastic opportunity to creatively solve the problem of sustainable growth within our spectacular environment.

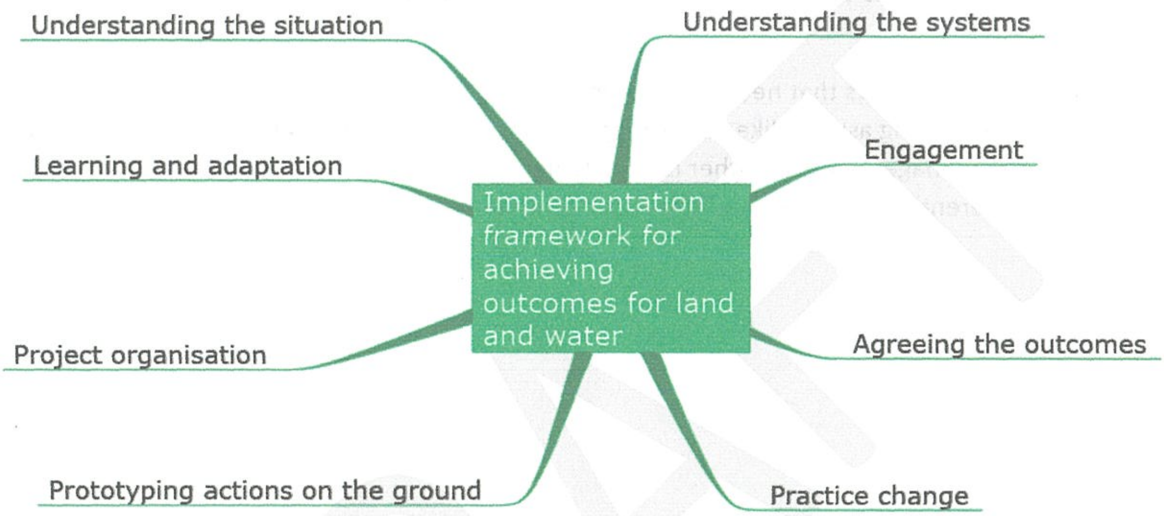
Appendix I.

Mouth of Mill Creek 7/07/2018

Cnr Rutherford Rd & Slope Hill Rd 7/07/2018

Proposed steps for moving from a strategy for Lake Hayes to action on the ground

The proposed steps broadly follow an adaptive management framework of 'Plan>Do>Monitor>Review'. They are intended to assist moving on from a strategy document to achieving action on the ground. Multiple aspects have been identified as important for this transition[1], figure below, and although there will be multiple iterations of some of these aspects throughout the process, some broad sequential steps have been identified.



Step 1. Identify a group of interested citizens broadly representative of the interested community and issues in the area and who are interested in action on the ground. This is likely to be revisited after steps 2 and 3. The group might include community, farming, viticulture, tourism, developers, recreation, district and regional council. It would need to involve mana whenua.

Step 2. With this group, build a good understanding of the catchment situation, environmental, economic, social, institutional and cultural. Understanding all the factors that are influencing the situation you are trying to manage, or address, is the first step in building an accurate picture of what implementation approach has the greatest chance of success. This step also involves understanding what the matters of concern are for different people. This information has been largely, although not entirely collected, through the previous strategy documents.

Step 3. Build a simple system understanding of the area, looking at the causes of the different issues, understanding the community and networks and understanding the adaptive capacity of the area to make change. Building a systems view is about looking at the system in question in its entirety, enabling consideration of the different drivers, and their relationships and influences across scales and timeframes.

[1] Research currently underway at Manaaki Whenua

Step 4. Based on the previous steps, assess if all the necessary people are involved, then determine and agree long-term outcomes (these don't just have to be environmental) and note how the group thinks those outcomes might be achieved.

Step 5. For each of the long-term outcomes, use the systems understanding developed in step 2 and try and understand all the contributing factors to achieving that outcome. Identify what needs to change with those who actions are influencing the situation. Detailing what practices might need to change, who would be involved, why they might change and who could help.

Step 6. Of all these possible actions, prioritise some. Based on how the group thinks change occurs, identify your proposed course of action and methodology over the short term to influencing the changes required. Identify how you will know if you have been successful or not, and consider how you will learn and adapt to this information (noting that some environmental impacts take some time to be seen).

There are two other aspects that need to be considered throughout. Firstly the 'project' organisation, considering aspects like resourcing, who is making decisions and with what authority, governance, risk management. The other is engagement, considering the purpose, plan and process for engaging different stakeholders and the wider community into the implementation effort

Before the Proposed Queenstown Lakes District Plan Stage 2 Hearings Panel

In the matter of	Proposed District Plan Stage 2 (Lake Hayes catchment (Wakatipu Basin) rezoning request)
For submitter	The Friends of Lake Hayes Society Incorporated

Statement of evidence of Marc Schallenberg for the Friends of Lake Hayes Society Incorporated

Dated July 24, 2018

1. My name is Marc Schallenberg. I have a PhD in freshwater science and 25 year's professional experience (1 year at the National Institute of Water and Atmospheric Research and 24 years at the University of Otago) specialising in lake science, management and restoration. I have worked on-and-off on issues associated with Lake Hayes since 1995 and last year I wrote a comprehensive scientific review as well as a monitoring and restoration strategy for Lake Hayes (Schallenberg & Schallenberg 2017).

2. I have read and am familiar with the Code of Conduct for Expert Witnesses in the current Environment Court Practice Note (2014), have complied with it in preparing this evidence and will follow the Code when presenting evidence at the hearing.

3. I've been asked by the Friends of Lake Hayes (FOLH) to address the issue of proposed rezoning in the Lake Hayes catchment. I have undertaken an analysis of Otago Regional Council (ORC) water quality monitoring data for Lake Hayes and Mill Creek (the lake's main inflow).

4. I've compared the data with two key sets of water quality limits: (1) the National Policy Statement for Freshwater Management (MfE 2017) and (2) the Otago Regional Council Regional Water Plan (ORC 2016) to determine how the current water qualities of the lake and creek compare to the limits, which have been set in place to protect the freshwater values in Lake Hayes and Mill Creek.

5. This information should be of interest to the commissioners and QLDC because it shows that many of the statutory water quality limits are already exceeded, indicating: (1) that there is no headroom left in this system for further increases in contaminant concentrations and (2) that to meet the statutory limits, contaminant losses from land to water will need to be decreased, in some cases substantially. This has serious implications for aspects of the District Plan Stage 2, as applied to the Lake Hayes catchment.

Key results of my analysis

6. If national and regional water quality limits set to protect the ecology and human values of Mill Creek and Lake Hayes are to be met in the future, substantial reductions in some contaminant concentrations in the creek (nitrate) and the lake (total nitrogen and total phosphorus) will need to be achieved. In addition, levels of other contaminants in Mill Creek must not be allowed to increase (*E. coli*, dissolved reactive phosphorus, and turbidity).

7. Phosphorus losses from the catchment to the lake are poorly understood because the sampling design used by the ORC to monitor Mill Creek misses the majority of phosphorus transfer, which occurs during a few, episodic floods per year. Total phosphorus concentrations in the lake indicate that inputs from the catchment are excessive and need to be reduced.

8. These facts challenge initiatives to further develop the catchment because contaminant transfers from land to water will generally increase with increasing development, population growth, land use intensification, etc.

9. A an overallocation situation similar to this occurred in the Lake Taupo catchment, where a rigorous debate between scientists, stakeholders and regulators resulted in the implementation of a nitrogen cap-and-trade system, which was designed to safeguard the values of Lake Taupo. A similar process (but for nitrogen, phosphorus, sediment and *E. coli*) might be of use

in the Lake Hayes catchment, where contaminant limits set by Central and Regional Governments are being exceeded.

Lake Hayes:

10. The FOLH have been working since 2008 to raise awareness of the poor state of the water quality of Lake Hayes and to encourage the ORC to undertake measures to improve water quality. Figure 1 shows the trophic state of the lake from 2005 to 2016, confirming what the FOLH have been telling the ORC - that the lake is in a poor state.

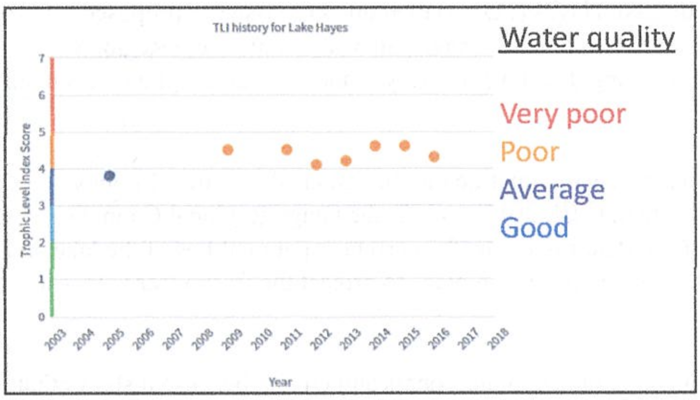


Figure 1. *The trophic state (state of nutrient enrichment including algal blooms) of Lake Hayes derived from ORC data published on the Land Air Water Aotearoa (LAWA) website (accessed July 20, 2018). The data show that the lake has had "poor" water quality since at least 2008, sometimes bordering on "very poor".*

11. The analysis of lake and creek water quality attributes summarised in Table 1 shows that both Lake Hayes and Mill Creek already exceed water quality targets set by Central and Regional Government. In particular, the lake exceeds targets for all three water quality attributes, including the national bottom line for chlorophyll *a* concentration (algal biomass) and it is very close to the national bottom line for phosphorus concentrations. It also exceeds the ORC's limits set for Lake Hayes for nitrogen and phosphorus concentration.

12. Where attributes are at, or exceed, the limits, there is no headroom left to allow further increases in nutrient concentrations in the lake. Where the attributes exceed the limits, the nutrient concentrations and algal biomass will need to be reduced to meet the water quality limits.

13. Previous studies on Lake Hayes by Cook (1973), Mitchell & Burns (1981), Robertson (1988), Caruso (2001), Schallenberg & Schallenberg (2017) and Gibbs (2018) indicated that careful management of contaminant transfers from the catchment to the lake is required to improve the water quality of Lake Hayes. In fact, the ORC's Lake Hayes Management Strategy (ORC 1995) called for an initial 20% reduction in the total phosphorus load to the lake to attempt to improve the condition of the lake. The strategy also stated that 80% of the total annual phosphorus input to the lake was attributable to Mill Creek.

Table 1. Summary of current water quality conditions of Lake Hayes and Mill Creek in relation to applicable water quality targets in the National Policy Statement for Freshwater Management (MfE 2017) and the Otago Regional Council's Regional Water Plan (ORC 2016). Red text indicates attributes that are currently very close to, or exceeding, the limits.

Attribute	National Policy Statement (NPS)		ORC Water Plan (6a)
	Current state	**Proximity to NPS bottom line**	**Proximity to ORC limit**
Lake Hayes			
Total nitrogen	C - moderately impacted	Some headroom exists	Exceeds limit[1] - no headroom; reduction required to meet limit
Total phosphorus	C/D - very close to bottom line; degraded state	No headroom	Far exceeds limit[1] - no headroom; reduction required to meet limit
Chlorophyll *a*	D - high risk of regime shift and persistent degraded state	Reduction required to meet bottom line[2]	N/A
Mill Creek			
Nitrate (ecosystem health)	N/A	N/A	Limit is always exceeded[2] - no headroom exists; substantial reduction required to meet limit
Dissolved reactive phosphate	N/A	N/A	Slightly below limit - minimal headroom exists
Turbidity	N/A	N/A	Slightly below limit - minimal headroom exists
E. coli (recreation)	Near to bottom line (yellow-orange threshold indicating c. 3% infection risk)	Close to bottom line - almost no headroom exists	Close to limit - almost no headroom exists

[1]limit is supposed to have been met by 2012
[2]limit must be met by 2025

14. The ORC's data show that the total phosphorus concentration in Mill Creek has not been declining in recent years (Figure 2), showing a relatively constant median concentration of around 0.025 g/m^3. However, the Otago Regional Council avoids measuring water quality when streams are in flood. However, it is during floods that Mill Creek delivers around 80% of the annual load of phosphorus from the catchment to the lake (Caruso 2000; Chemsearch Ltd., unpubl. data). It is during floods that the effects of land use on total phosphorus, suspended sediment and *E. coli* concentrations in streams are most apparent.

15. Phosphorus is mainly attached to sediment particles and Mr. Hanff has shown photographs of the visual effect of sediment-laden water entering Lake Hayes from Mill Creek during floods. So, the limited ORC data shown in Fig. 2 doesn't reflect the bulk of the phosphorus load to the lake and thus it is unclear whether the total load has been constant, declining or increasing over time. To illustrate the importance of floods on the total phosphorus concentrations in Mill Creek (and on the loads to the lake), I've replotted Figure 2 along with some total phosphorus measurements for Mill Creek measured during flood conditions (Fig. 3; the figure has been re-scaled to show the extreme concentrations).

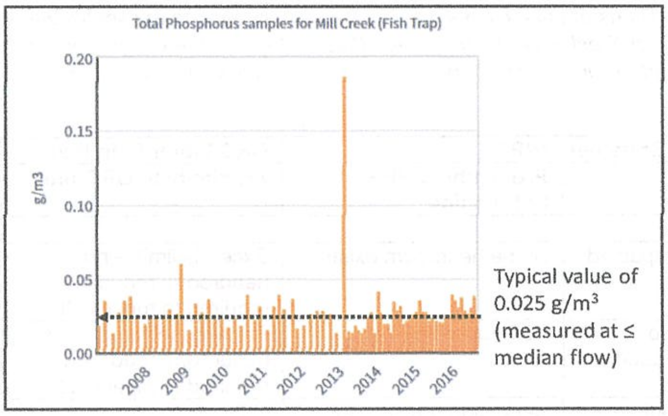


Figure 2. *Total phosphorus concentrations at the Fish Trap in Mill Creek from 2007 to 2016, showing no decline in concentrations measured at or below the median flow of the creek. ORC data from LAWA website (accessed July 20, 2018).*

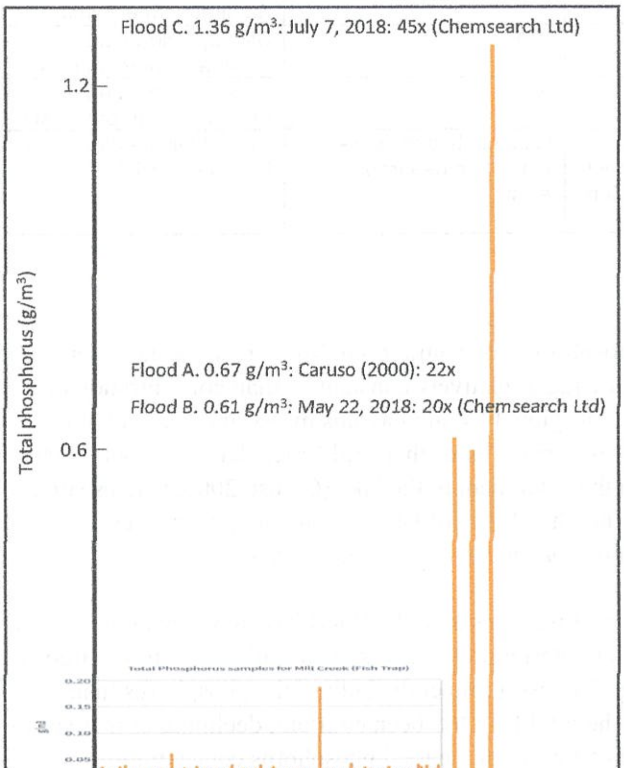


Figure 3. *Total phosphorus concentrations at the Fish Trap in Mill Creek from 2007 to 2016, presented together with measurements taken during three floods. ORC data from LAWA website (accessed July 20, 2018). Flood A and C were measured by Chemsearch Ltd (FOLH unpubl. data) and Flood A was reported in Caruso (2000). Also indicated are the multiples of the ORC median concentration (0.025 g/m³) that is represented by each flood measurement.*

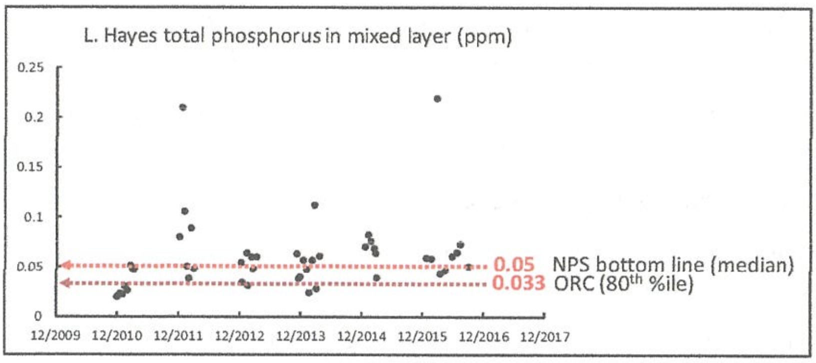


Figure 4. *Total phosphorus concentrations in the surface waters of Lake Hayes (mid-lake site) from 2009 to 2016), showing it approximately meets Central Government's national bottom line (MfE 2017) and fails the ORC's limit for Lake Hayes (ORC 2016; 80% of the measurements in a 5-year period should be below the limit). ORC data.*

16. While the limitations on monitoring mean that it's unclear what the actual phosphorus loads to the lake are, what is clear from Figure 4 is that that total phosphorus concentrations in Lake Hayes have not been declining, are very near the national bottom line (unacceptable concentration; MfE 2017) and exceed the ORC's limit for total phosphorus concentration for Lake Hayes (ORC 2016).

Mill Creek:

17. Table 1 shows that the water quality limit in Mill Creek is currently exceeded for nitrate concentrations and approaches the limit for *E. coli* concentrations. Every nitrate sample from Mill Creek taken from Mill Creek between 2007 and 2016 greatly exceeded the ORC's nitrate limit for the creek (Fig. 5). Nitrate is readily leachable from fertilisers, animal urine, septic tanks and other sources through the generally dry and porous soils of the Mill Creek catchment and, therefore not surprisingly, Table 1 also shows that total nitrogen levels in Lake Hayes exceed the ORC's limit for the lake. Controlling and managing the nitrate losses to the creek and lake in this catchment are substantial challenges. As with phosphorus, nitrogen losses from the catchment are likely to increase with increasing development of the catchment, unless effective mitigations are put in place.

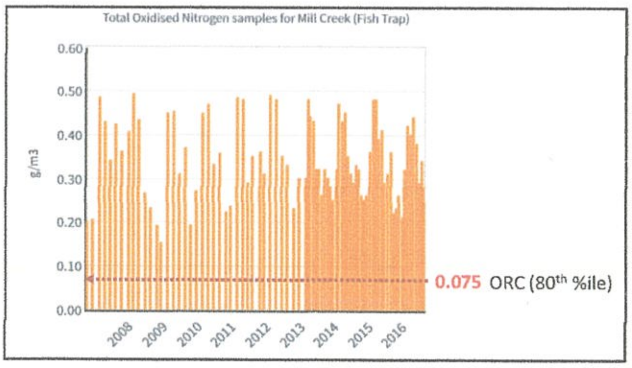


Figure 5. *Nitrate (total oxidised nitrogen) concentrations for Mill Creek from 2007 to 2016, showing the ORC's nitrate limit for Mill Creek (ORC 2016; 80% of the measurements in a 5-year period should be below the limit). ORC data from LAWA website (accessed July 20, 2018).*

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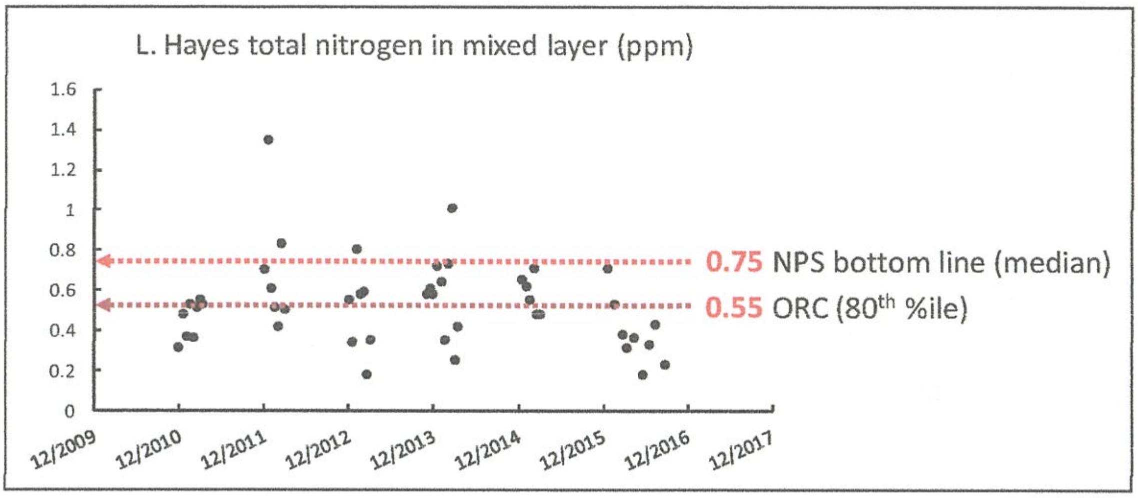
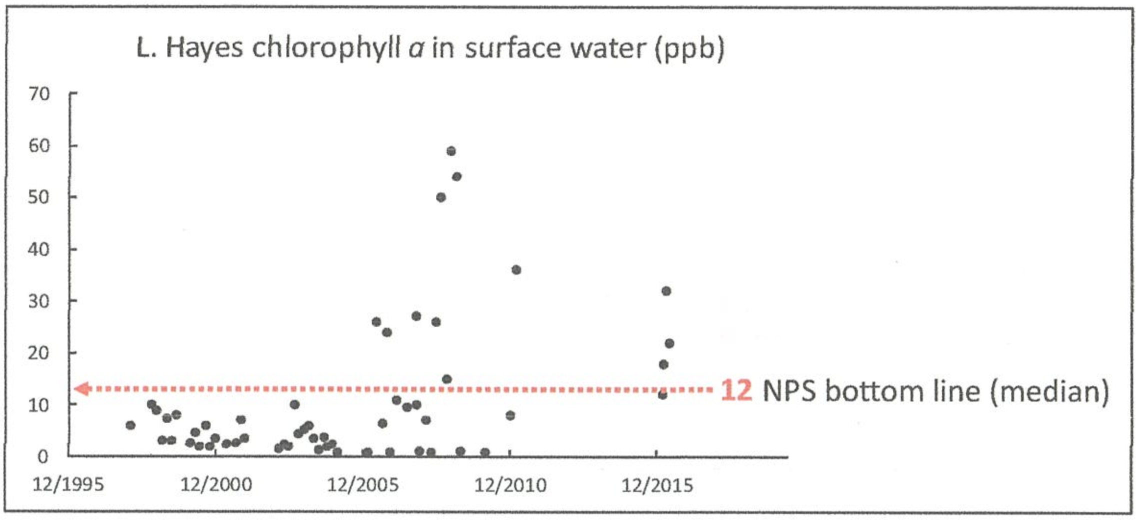
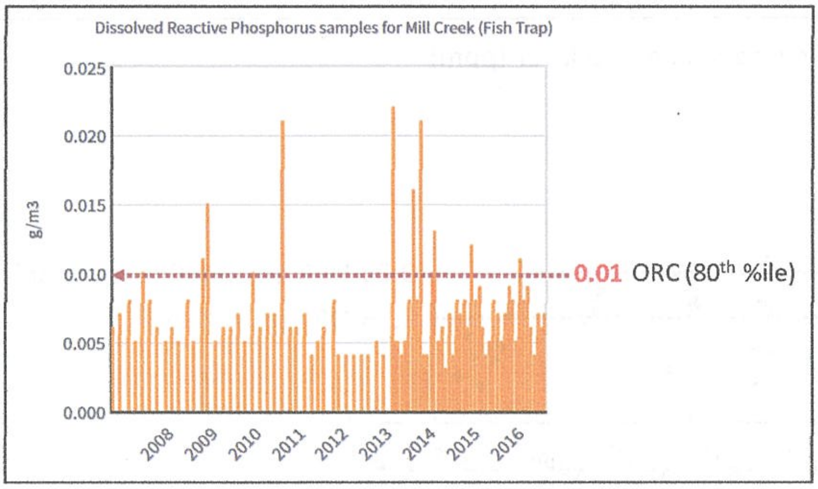
Appendix 1. Supporting information

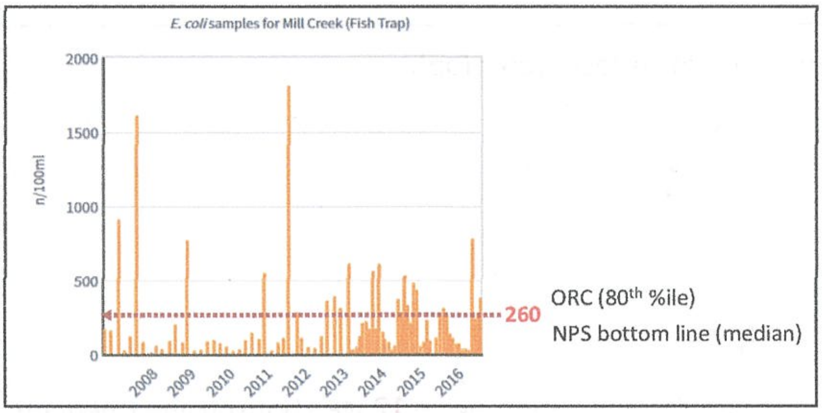
Lake Hayes

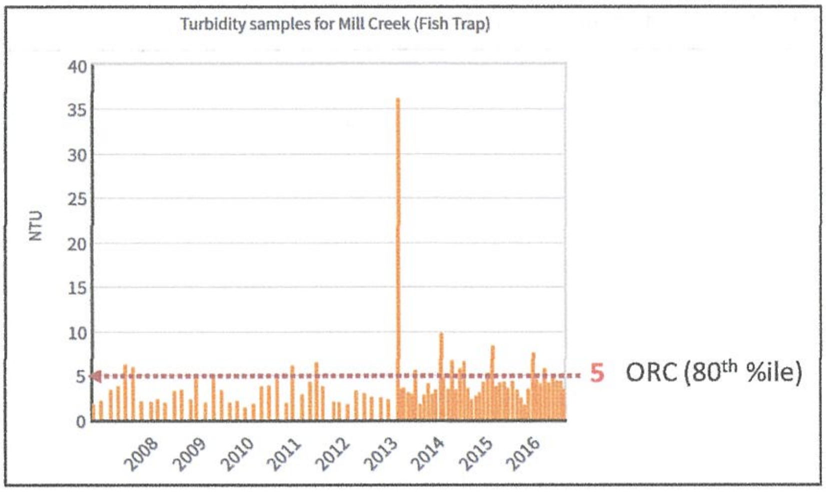




Mill Creek


Dissolved Reactive Phosphorus samples for Mill Creek (Fish Trap)
g/m3
0.025
0.020
0.015
0.010
0.005
0.000
0.01 ORC (80th %ile)
2008
2009
2010
2011
2012
2013
2014
2015
2016


E. coli samples for Mill Creek (Fish Trap)
n/100ml
2000
1500
1000
500
0
260
ORC (80th %ile)
NPS bottom line (median)
2008
2009
2010
2011
2012
2013
2014
2015
2016


Turbidity samples for Mill Creek (Fish Trap)
NTU
40
35
30
25
20
15
10
5
0
5 ORC (80th %ile)
2008
2009
2010
2011
2012
2013
2014
2015
2016

Lake Hayes Management Strategy

Otago Regional Council/
Queenstown Lakes District Council
September 1995

ISBN: 0-908922-26-4

Foreword

The Otago Regional Council and the Queenstown Lakes District Council are pleased to present this Management Strategy for Lake Hayes. It reflects the concerns that both Councils and the community have about the continuing water quality problems of the lake, and the need to take action to address the resultant decline in recreational, fishery and scenic values.

This strategy details the objectives and policies for future sustainable management of the lake and catchment. The strategy outlines the actions the Otago Regional Council proposes to carry out in the catchment and regulatory matters recommended for consideration in the forthcoming *Regional Plan: Water* (prepared by the Otago Regional Council) and the Queenstown Lakes District Plan. This separate but coordinated and consistent response recognises the different functions afforded to District and Regional Councils under the Resource Management Act 1991.

Tourism has grown rapidly over recent decades in the Wakatipu basin with Lake Hayes being an important component of those scenic resources which attract tourists to the area. The conservation of the Lake Hayes resource is of regional and national importance both economically, recreationally and for its intrinsic and scenic values.

The effects of poor water quality in Lake Hayes have been noticeable to the general public since the first algal bloom in 1969. The lake supports a recreational fishery of Brown Trout and Perch and native fish species including Upland Bully, Koaro and the long-finned eel. People enjoy swimming, boating and fishing in the lake, however recreation and habitat values are restricted at times of the year due to the poor water quality.

The Councils wish to thank the community for their comments received on the draft strategy. These have been important in shaping this finalised form of the strategy which will direct the future management of this important regional and national asset.

Thank you for your interest and support.

Chairperson,
Otago Regional Council

Mayor,
Queenstown Lakes District Council

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1. Introduction

1.1 Why is a strategy needed?

Over approximately the last thirty years Lake Hayes has become increasingly eutrophic (nutrient rich), this being characterised by anoxic water, poor water clarity, frequent algal scums, fish deaths and insect pests. This state of eutrophication has been found to be due to the movement of phosphorus bound to soil from the land to the lake, where it contributes to an already massive phosphorus load. Phosphorus is released from lake bed sediments in autumn when bottom waters lose all oxygen, favouring the rapid growth of algae and associated problems. Numerous reports have been written on the lake's water quality, its causes and possible solutions.

The most comprehensive scientific study to be carried out on the lake and catchment was done by Barry Robertson of the Otago Catchment Board in 1983-84 (Robertson, 1988).

This report described a phosphorus budget and seasonal cycle for Lake Hayes. These were related to past and present uses of the catchment. The report identified several possible management options to address these problems. It is intended that this strategy in association with the Queenstown Lakes District Plan and the Otago Regional Council's *Regional Plan: Water* will be the instruments used to implement methods for improving water quality in Lake Hayes.

The overall goal of this strategy is:

To improve the water quality of Lake Hayes, to achieve a standard suitable for contact recreation year round and to prevent further algal blooms.

1.2 Implementation of the strategy

This strategy is a non statutory document which has been developed by the Otago Regional Council and the Queenstown Lakes District Council and finalised following community comment. It proposes methods to be used by the Otago Regional Council (subject to the Annual Planning Process under the Local Government Act), and regulatory matters to be considered in the *Regional Plan: Water* and the Queenstown Lakes District Plan. These matters will be coordinated to ensure all resource issues are dealt with by the agency responsible for such functions. The Otago Regional Council is currently preparing a *Regional Plan: Water*, which will address all water issues in Otago. Regulatory mechanisms required to address the resource issues surrounding Lake Hayes will be considered within the proposed *Regional Plan: Water*. Regulatory mechanisms associated with land use will be included in the Queenstown Lakes District Plan and any associated District Plan changes. Consultation between the Otago Regional and Queenstown Lakes District Councils will be ongoing to ensure the goal of this management strategy is achieved.

Discussions will be held with affected land owners over the implementation of this strategy. Agreement will be a necessity on the proposed actions such as riparian margin enhancement, wetland creation and fencing of areas. The priority will be on:

- Riparian margins and fencing
- Bank stabilisation
- Wetland protection and recreation.

It is expected that over the next three to five years, the implementation of the strategy will result in a reduction in phosphorus inputs.

1.3 What is eutrophication?

Lake Hayes is eutrophic. This means there are excess levels of nutrients in the lake, with the lake ecosystem suffering as a result. Eutrophication is the term normally used to describe the natural "aging" process of a lake. While the lake may begin as a pool of clear fresh water, it slowly begins to accumulate silt and plant nutrients, resulting in an increase in the growth of water plants and a decrease in the depth of water. Ultimately the lake can reduce to a wetland ecosystem. Normally this will take thousands of years to occur.

Unfortunately, human activities in lake catchments can speed up this process. Construction of roads and houses, cultivation, livestock, eroded soils, drainage of wetlands, effluent discharge, fertiliser use and streambank erosion all contribute to phosphorus being washed downstream to the lake.

One of the first noticeable signs of eutrophication, is the periodic rapid growth of small floating water plants, or algae. If the water is warm enough, and has enough nutrients, a "bloom" of algae may occur, resulting in the water taking on red, yellow or green colours. However these algae soon out-grow the supply of plant nutrients and the "bloom" begins to die. The rotting of the algae uses up the available oxygen in the water and the lake begins to smell.

This is the state in which we now find Lake Hayes. The value of the lake as a recreational facility and as a wildlife and fishery habitat is affected by periodic algal blooms.

The vast majority of nutrients enter the lake from the Mill Creek catchment in the form of phosphorus attached to soil particles, as well as some dissolved phosphorus and nitrates. Phosphorus has been found to be the nutrient responsible for the eutrophication in Lake Hayes. While the phosphorus is not immediately available to the algae, their later release to the water controls the algal blooms.

When the phosphorus-loaded sediments enter the lake, they sink to the bottom. The surface water warms up over summer and being lighter than the cold water below, does not mix with underlying cooler layers. Plants which die in the lake fall to the bottom and, as they decay, use up the oxygen in the cooler lower layers of water. Under these low-oxygen conditions the phosphorus may be released from the silt particles into the water.

While there is now a nutrient-rich layer of water, there will not be an algal bloom as there is not enough warmth or light at the bottom of the lake. However, during winter the surface water cools and the layers of water mix quite easily. In spring, with warmth and light, the surface water is nutrient-rich and conditions are right for an algal bloom. This results in conditions which are less than desirable for the fish, angler, swimmer and sailor.

1.4 What can be done about eutrophication?

Firstly the amount of nutrients entering the lake must be reduced, and secondly the nutrients already in the lake must be immobilised or removed. The amount of phosphorus entering the lake may be minimised by controlling phosphorus inputs to streams and by controlling phosphorus inputs into the lake. The actions proposed in this strategy have been developed in order to achieve these controls. They include such actions as reducing erosion of phosphorus-rich soil in the catchment and on the stream banks and collecting as much silt as possible as it moves down the catchment.

Locking up the phosphorus already in the lake is more difficult. Mechanisms which can help achieve this do so by stopping the anoxic release of phosphorus for at least one year by artificial means. This approach is explained in the section on nutrient inactivation in Appendix 1.

1.5 Alternative methods for improving water quality

With technological changes, investigations and monitoring, the Council may become aware of more suitable techniques for dealing with the issues surrounding Lake Hayes. This will be assessed as the strategy is reviewed and at any other time when additional information becomes available and, if appropriate, Council will modify this strategy.

Before deciding on the mechanisms to be used in this strategy, the possible alternative methods of improving the water quality of Lake Hayes were explored. They are summarised in Appendix 1.

1.6 Reducing external phosphorus inputs and lake recovery

With reduction of external inflows of phosphorus there will still be a large pool of sediment phosphorus in the upper sediment layer of the lake. This will be released at a relatively constant rate during anoxic conditions, until such time as the pool begins to deplete or anoxia becomes less intense. It is not clear from studies in other lakes how long this will take. In some lakes a measurable decline occurred in 5-10 years and in other lakes there was no change after 10 years or more. Recovery time will depend on how quickly internally released phosphorus can be flushed from the lake, how much is added to the sediment from the external load and the initial extent of the pool available for release.

After consideration of these methods, the best option for addressing lake eutrophication from the point of view of long term sustainability is considered to be by treating the cause of eutrophication, prior to treating those symptoms associated with it. For this reason the Otago Regional and Queenstown Lakes District Councils, in consultation with the Lake Hayes community have chosen to firstly address the external phosphorus inputs into the lake by way of a number of phosphorus control methods. Other studies have found that internal lake treatment methods are effective only after external lake phosphorus inputs have been substantially decreased. Hence the methods in this strategy are prioritised to address external nutrient input.

1.7 Matters taken into account in formulating this strategy

- Kawarau Water Conservation Notice. Evidence presented in support of the application by the Otago Regional Council
- Proposed Regional Policy Statement for Otago
- Department of Lands and Survey, 1982: *Lake Hayes Reserves Management Plan*, Management Plan series number RR20. Department of Lands and Survey, Dunedin
- Robertson B M, 1988: *Lake Hayes Eutrophication and Options for Management, Technical Report.* Otago Catchment and Regional Water Board, Dunedin
- Robertson B M and Associates Environmental Consultants and Royds Garden Ltd, 1989: *Lake Hayes Eutrophication and Options for Management, Internal Treatment Evaluation and Preliminary Design.* Otago Catchment and Regional Water Board, Dunedin
- Mitchell *et al: Eutrophication of Lake Hayes and Lake Johnson.* Report to Ministry of Works
- Queenstown Lakes District Plan (in preparation)

1.8 Monitoring the strategy

Monitoring to determine the degree to which the strategy is achieving its objectives will be required. That monitoring will assess the degree to which the eutrophication of the lake is decreased, over time, and will be used in the review of the strategy. The parameters that will need to be monitored include:

- Water quality in Mill Creek and Lake Hayes
- Mill Creek flow information
- Lake levels
- Land use.

1.9 Strategy review

A review of this strategy will take place at five yearly intervals or sooner if required.

It will assess the changes to the quantity of external phosphorus entering Lake Hayes, and chemical composition of the lake and any change to trophic status. When a 20% reduction in the total annual phosphorus load to Lake Hayes has been achieved, from 1994 figures, and/or in-lake phosphorus concentration achieves that of the water quality class, the Otago Regional Council will, in association with the Community consider the need for in-lake treatment methods including piping nutrient rich waters from the bottom of the lake.

This may be required if the lake is still experiencing algal blooms and the community wants an alterative option to external load reduction.

2. Description of the Catchment

2.1 Topography

Lake Hayes is believed to have been formed following the scouring of the bed by the Wakatipu glacier and subsequent separation from the ancestral Lake Wakatipu by outwash from the Shotover River. The catchment itself reflects its glacial origins in its topography having steep to moderately steep mountain lands, with a highest point of 1600m at Coronet Peak. There are also broad fans and terraces over the flood plain, moderately steep hills and associated rolling hills around the perimeters of the catchment.

2.2 Geology

The dominant geology is Palaeozoic metamorphic schist, with lesser areas of quaternary outwash gravels, till and morainic deposits and late glacial lake beds.

2.3 Vegetation

The original vegetation in the catchment was native tussock, which has been cultivated on the lowlands into pasture and crops. Sward grass predominates on the poorer soils in the valley and on the low altitude steep faces. Also present on these faces is native matagouri and exotic briar. Above these species are found sward grass and short tussocks. Some oversowing with white clover has occurred at these altitudes. Above approximately 1000m snow tussock *(Chionochloa rigida)*, blue tussock *(Poa colensoi)* and *Festuca mathewsii* are present.

2.4 Soils

Two broad soil types have developed, the yellow grey earths or loess soils on the valley floor, and the yellow brown earths on the steeply sloping faces of Coronet Peak. Nutrient status is generally medium to high on the valley floors and low on the faces. Perhaps the over-riding consideration in terms of phosphorus transport to the lake, is the ease with which these soil types are picked up and carried in suspension by moving water (Robertson 1988).

2.5 Erosion

Some erosion in the catchment is found within the streams. This can be through bank collapse from stock pressure and high energy stream flows or slip erosion on the steep faces of water bodies on the lower slopes of Coronet Peak. Robertson identified in 1989 that slight to moderate sheet and wind erosion has occurred on all slopes in the catchment. A more recent 1994 inspection by the Otago Regional Council found a healthier stream channel with beds and banks generally in a very well vegetated and stable state.

2.6 Catchment water quality

The major inflow into Lake Hayes is Mill Creek. Its water quality is characterised by high sediment and nutrient loads, particularly phosphorus. This is due to the soil and rock types in the catchment as well as the effects of land use. Limestone is also present in high concentrations, and this is thought to have exacerbated the release of phosphorus from sediment.

Appendix 2 summarises the characteristics for Lake Hayes from recent trend analysis of water quality monitoring data.

2.7 Land use and tenure

Pastoral farming with some mixed cropping are the predominant land uses in the Lake Hayes catchment. The area has undergone extensive changes in recent times with the subdivision of some of the larger runs into small blocks. Land in the valley and on the rolling hills is freehold with many separate titles, while Coronet Peak is Crown land in pastoral lease.

2.8 Social descriptors

The Queenstown Lakes District has experienced extensive growth over the last decade. The resident population figure has increased by 21.5% since 1986. The Lake Hayes catchment and Wakatipu Basin is consistent with this growth trend. Retailing, a major industry in the Queenstown area is also experiencing strong growth. With such growth comes the requirement for housing and subdivision. Lake Hayes has traditionally been a popular holiday location, while in recent times more permanent residents have been developed. It is well located for both work in Queenstown and Arrowtown and will most likely develop further with the Queenstown Lakes District Plan's proposing the settlement of satellite communities.

2.9 Iwi values associated with the Lake Hayes area

The association Kai Tahu whanui have with Lake Hayes and the wider area of the Lakes District is of ancient origin. In tradition and mythology the relationship stems from the time of creation, the source of mauri and wairua, elements that connect Manawhenua with the environment, and constitute mana.

In tradition it was the journey of discovery south through the centre of the island by Rakaihautu and his people of the Uruao canoe, the Waitaha, that marks the first human contact with the Lakes District of "Te Waka Aoraki" (South Island).

Lake Hayes is known to Kai Tahu as "Te Whaka-ata a Haki-te-kura", a name that refers to the mirror image of Haki-te-kura a famous ancestress noted for her exploits, whose image was reflected in the lake.

The Wakatipu Basin was occupied for many centuries by sections of first the Waitaha followed by the Kati Mamoe and latterly the Kai Tahu, an amalgam of people who over time merged in whakapapa into a single entity known collectively as Kai Tahu whanui.

The Wakatipu basin was important for the resources that it provided to the mobile units of Maori who regularly travelled inland to gather pounamu (greenstone) from the source, to gather mahika kai, and to reside at selected places around the edge of the lakes over the summer months. Trading of resources with neighbouring hapu was a prime activity.

Water
Kai Tahu advocate the respect and protection of all water resources. In traditional times classifications existed for many of the water resources of Otago. Water bodies fed from the interior mountains were regarded particularly highly. Waters that provided food resources were treasured. Protocols existed to ensure that appropriate conduct of people occurred in, on and by water so as not to offend or desecrate the natural balance that existed between land, water and the people dependent on it.

Modification
Kai Tahu consider that the breakdown of the ecosystem of Lake Hayes and the extensive modification of the catchment to the lake is symptomatic of other areas in the Otago region. It is hoped that the exercise that is jointly being undertaken to mitigate the effects of land and water modification of the last 150 years on Te Whaka-ata (Lake Hayes) and its catchment area will be adopted elsewhere in Otago.

Taoka
The lake is still regarded as a taoka. The customary practice of gathering mahika kai in and around Te Whaka-ata (Lake Hayes) has long since disappeared, although Kai Tahu people do fish there in a recreational capacity. The halting of customary practice can be linked to historical events that hindered and fragmented the traditional communities of Kai Tahu, limiting a people who were once mobile hunter gatherers to confined spaces and resources. Contributing factors include drainage of wetlands, pollution of mahika kai resources and reduced access.

The fact remains however that Kai Tahu still retain the rangatiratanga or customary authority over Te Whaka-ata (Lake Hayes) and the waters that feed the lake.

Consultation
Initial consultation on Te Whaka-ata (Lake Hayes) with Kai Tahu runanga has occurred at a hui held at Kaka Point in December 1993. Runanga from Otago and Southland were present at this hui. Discussion focused on the modification issues affecting the catchment area and the effect of this on the waters of Te Whaka-ata (Lake Hayes).

Archaeological
Sites of cultural occupation or cooking places may be disturbed or unearthed in the catchment area of Te Whaka-ata (Lake Hayes) through development, catchment works or natural erosion.

Where and if earth works are proposed as part of the management strategy for Te Whaka-ata (Lake Hayes) it may be necessary to consult Kai Tahu over possible disturbance of archaeological sites. In a situation where possible cultural archaeological sites may exist Iwi prefer that a site survey (visual) be carried out prior to any work commencing.

Native fishery
While the Te Whaka-ata (Lake Hayes) native fishery is no longer part of the seasonal mahika kai resource of Kai Tahu, the Iwi have a responsibility as kaitiaki of the native fishery to seek the improvement of the native habitat.

2.10 Recreational use

Lake Hayes is used for a variety of recreational pursuits. These include on-water activities such as swimming, fishing, rowing, and sailing and land based activities associated with the general use of the reserves around the lake.

3. Erosion and Land use Practices

3.1 Introduction

The degradation of Lake Hayes water quality is related to land use practices, and the associated runoff of phosphorus. With the growth of agriculture and other industries in this catchment since 1910, waters in the Lake Hayes catchment have been subjected to dairy shed effluent, cheese factory discharge, outlet restrictions, irrigation race discharge, the application of superphosphate fertiliser, increasing livestock numbers and land cultivation, drainage of wetlands and soil erosion. In combination these practices have the effect we see today on Lake Hayes' water quality. Some of these practices no longer occur, and the effects of others can be mitigated.

The transfer of phosphorus from pasture into the streams is linked to the transfer of sediment. This transfer may be by the direct movement of overland flow, the erosion of streams by flood flows, degradation of streambanks due to livestock influences, and by animal dung entering water bodies. Streambank riparian margins are advantageous in reducing these phosphorus sources. The establishment of riparian margins along the length of Mill Creek will primarily reduce stock access, trap sediment that would otherwise get into the stream, and help stabilise banks.

Streambank erosion occurs along sections of Mill Creek and this also contributes to phosphorus loading on the lake. General soil erosion throughout the catchment, in combination with the soil types present, also contributes to lake sediment and phosphorus. Many of the mechanisms needed to reduce the further flow of phosphorus into Lake Hayes amount to what would be done in any area for the purposes of soil conservation and sustainable land management.

3.2 Issues

3.2.1 Land use practices in the Lake Hayes catchment contribute to the eutrophication of Lake Hayes.

Explanation

The process of lake eutrophication has been accelerated in Lake Hayes due to natural geology, and the effects of human land use which result in the transfer of phosphorus into water bodies. This results from:

(i) Runoff of nutrients from farms due to fertiliser application and animal wastes.

It is estimated that superphosphate losses in the order of 0.5-2.0% of the fertiliser applied can occur into nearby water bodies. Subsequent losses of phosphorus varies depending on soil phosphorus retention, the land and climatic condition at the time of, and immediately following application, stock management and erosion characteristics.

Animals are also responsible for large amounts of phosphorus entering waters. They do this through runoff, by the addition of phosphorus through dung, by changing the soil-grass system, and in the decomposition of their bodies.

(ii) Loss of vegetation on and adjacent to river banks.

Vegetation adjacent to water bodies acts as a nutrient sieve, capturing and utilising nutrient before it enters the water body. When vegetation is lost from a river, lake or streambank, the soil surface is more susceptible to erosion and the battering of water flows. Closely grazed grass cannot sieve particulate matter efficiently and animal trampling lowers the infiltration capacity of the soil and increases the likelihood of soil runoff.

(iii) Drainage of wetlands.

Wetlands can take up large quantities of nutrients through their plants and the deposition of sediment. Drainage of wetlands in the Lake Hayes catchment removed a natural nutrient trap. As a result the lake has become the predominant nutrient sink.

3.2.2 Erosion in the catchment adversely affects water quality.

Explanation
Studies have shown that the majority of phosphorus entering Lake Hayes is bound to sediment. Minimising erosion throughout the catchment therefore becomes an important factor in lake rehabilitation. The primary sources of sediment are the erosion of stream banks, hill slopes and to a lesser extent sediment within the stream channel.

3.3 Objectives

3.3.1 To avoid the adverse effects of land use on water in order to improve water quality in Lake Hayes and its catchment.

Explanation
The relationship between land use practices and water quality are well established. In association with other factors, these practices represent the overriding causes of lake eutrophication. Addressing the cause of the problems associated with Lake Hayes is the method most closely related to the principles of sustainable management. Situations must be avoided where runoff potentially containing contaminants could enter water without firstly being treated or buffered involving sediment or nutrient entrapment. This objective is intended to promote mechanisms to limit the adverse effects of land use activities.

3.3.2 To minimise erosion in the Lake Hayes catchment.

Explanation
A decline in soil and streambank erosion in the Lake Hayes catchment will be accompanied by a decline in the amount of sediment-bound phosphorus entering Lake Hayes. As the sediment in the bed of Lake Hayes is primarily responsible for the continual release of phosphorus into the lake water at lake turnover, a decline in the amount of sediment and the associated concentration of bound phosphorus is expected to aid lake recovery. This is because, as time goes on, phosphorus gradually gets leached out of the sediments and/or becomes buried by fresh sediment containing less phosphorus.

3.4 Policies

3.4.1 To avoid the contribution that phosphorus and sediment from non-point source pollution makes to phosphorus loading on Lake Hayes.

Explanation
In 1984 an estimate of the total annual phosphorus load to Lake Hayes from all sources was 2400 +/- 480 kg per year. For the period of 1990-93, this was estimated to be in the order of 400-1000 kg per year. The intent of this policy is to control the contribution from non-point source discharges in the Lake Hayes catchment, to ensure a decline in the total annual phosphorus loading rates. In 1994 a re-estimate of the contribution of phosphorus to Lake Hayes from the Mill Creek catchment alone was estimated to be 80% of the annual external phosphorus load.

Non-point source pollution is the predominant source of phosphorus input into Lake Hayes. The ease of transport of phosphorus into water bodies is a result of the fine-textured (rock-flour) soils present, as soil particles are easily picked up and carried in suspension by moving water. Soils in the area have relatively high natural phosphorus levels, and as a result will contribute phosphorus wherever erosion occurs. A reduction in the amount and concentration of phosphorus entering Lake Hayes will eventually result in a lower overall nutrient status in the lake, thereby slowing the eutrophication process and aiding lake recovery.

3.4.2 To protect existing wetlands, ponds and other nutrient sinks, and to establish new ones by land owner agreement, in the Lake Hayes catchment.

Explanation
Wetlands, ponds and other nutrient sinks act as valves or sinks to regulate or trap the flow of nutrients and sediments from surrounding terrestrial systems. Wetland macrophytes, phytoplankton and emergent vegetation are capable of taking up large amounts of phosphorus, especially during the first few years of addition. The loss of wetlands can result in increased sediments and nutrients entering water bodies. Because of their benefits in entrapping nutrients the protection of existing wetlands, ponds and other nutrient traps, and the establishment of new ones will be encouraged, wherever possible.

3.4.3 To ensure the retention of current riparian margins, and the development of new riparian margins throughout the Lake Hayes catchment.

Explanation
In order to reduce the transfer of nutrients from pasture to surface water, the Otago Regional Council needs to promote the future development of riparian margins throughout the catchment and protect current riparian margins. Riparian margins are accepted as being the best management practice for the control of non-point source pollution. Riparian margins act to reduce the contribution of nutrients, entering as both particulate and dissolved phosphorus. They do this by processes of infiltration, deposition, filtration, adsorption and absorption. Phosphorus loads to water bodies have been shown to reduce by 24% with riparian retirement.

3.4.4 To ensure that land use activities are considered in terms of their effect on the water quality of the receiving waters.

Explanation
This strategy proposes that water quality classes for Mill Creek and Lake Hayes be established in the proposed *Regional Plan: Water* (see 4.4.3). Classification aims to advance water quality improvements. The intent of this policy is to encourage the consideration of the future use of land, within the context of improving water quality in the Lake Hayes catchment. As land and soil qualities and land use are the predominant causes of poor water quality in the Lake Hayes catchment, improvement will only be achieved when the adverse effects of land use are avoided, remedied or mitigated.

3.5 Proposed Otago Regional Council actions

3.5.1 The Otago Regional Council will negotiate with land owners adjacent to Mill Creek and Lake Hayes for the establishment of riparian margins.

Explanation
Riparian margins are the best management practice for the control of non-point source pollution, providing benefits to water quality. Fenced riparian margins are also beneficial to farming as they prevent stock losses into the river channel, and with planting, contribute to river bank stability.

3.5.2 Where the Otago Regional Council provides for works to be carried out on lands adjacent to water bodies in the Lake Hayes catchment, the Council will consider entering into an appropriate agreement with the land owner to protect these works.

Explanation
Under Section 30 of the Soil Conservation and Rivers Control Act 1941, the Council can have the maintenance of works which they have fully or partially funded attached to the title of a property. This will ensure the works carried out for the purpose of soil conservation and water quality protection are safeguarded in the event of future changes in land ownership and management practices.

3.5.3 The Otago Regional Council will consider providing assistance to fence off the water body from areas of high phosphorus input.

Explanation
The areas which are found to be priority areas requiring fencing due to the contribution of high phosphorus levels as a result of current erosion occurring at these sites will be agreed through individual negotiation with land owners. Because the fencing off of all water bodies in the Lake Hayes catchment will be a costly exercise, work will have to take place over several years. The Otago Regional Council does not intend purchasing land, but rather working towards an agreement with land owners on the cost of fencing, the provision of alternative water supplies, and stock and vehicular access across water bodies where necessary.

3.5.4 The Otago Regional Council will consider carrying out stream bank stabilisation works in areas contributing high phosphorus levels.

Explanation
Some of the phosphorus inputs are derived from the erosion of water courses. The sites contributing the highest phosphorus inputs will be considered as priority intervention areas. Erosion can be alleviated by depositing rock at bank erosion sites.

3.5.5 The Otago Regional Council will advocate and provide assistance towards the protection and re-establishment of wetlands in the Lake Hayes catchment.

Explanation
Wetlands play an important role in water quality improvement by slowing the flow of water through catchments and acting as nutrient sieves. The peaks of flood flows are also diminished through the catchment as a consequence of wetlands. Negotiation and providing assistance to land owners to protect and re-create wetlands are considered the most effective mechanism for achieving the establishment of wetlands. Although there is insufficient land available in the catchment for one large wetland that will achieve major reductions in phosphorus loadings, it is still considered beneficial that small scale ponds and wetlands be developed.

3.5.6 The Otago Regional Council will provide technical advice and assistance to land owners wishing to establish riparian margins.

Explanation
The provision of technical advice and assistance to the community, is considered to be an important mechanism for assisting in the establishment of riparian margins.

3.5.7 The Otago Regional Council will provide advice and assistance to the community, as a means of encouraging sustainable land use practices in the Lake Hayes catchment.

Explanation
Community groups including Landcare groups are an important focus for locally driven initiatives aimed at cooperation between land owners to help achieve sustainable land management. Community groups have shown success in addressing, supporting and encouraging solutions to problems that can occur in land use practices. Being community driven they are seen to be preferable mechanisms to address problems rather than the use of regulation.

The form of advice and assistance provided could be educational material, updated land use practices and other information which encourages sustainable land uses.

3.6 Regulatory matters recommended for consideration in the *Regional Plan: Water*

3.6.1 Controlling the modification of wetlands.

Explanation
All wetlands in the Lake Hayes catchment play a role in slowing the rate of flow of water through the catchment, and acting as sediment traps. These functions are highly beneficial for improving water quality. The requirement to obtain a consent when wishing to modify wetlands would ensure that adverse effects can be addressed. In most cases modification of a wetland will require the taking, use, damming or diversion of water.

3.6.2 Controlling berm management practices.

Explanation
The contribution stock make to the phosphorus loadings of Lake Hayes is well established. Because of the potential effects stock can have on water bodies, consideration should be given to establishing rules with the proposed *Regional Plan: Water* to regulate the proximity of grazing near water bodies.

Because non-point source pollution is the major source of contamination in the catchment, the preservation of current riparian margins is an important factor in maintaining water quality. Due to the current deteriorated state of Lake Hayes regulatory control needs to be considered as a way of avoiding further adverse effects to the water quality in those area where erosion is most severe. Education, and advocacy, are however also appropriate mechanisms to achieve the increase in riparian margins throughout the catchment

3.7 Regulatory matters recommended for consideration in the Queenstown Lakes District Plan

3.7.1 The allocation of the maximum size of esplanade reserve possible in new land subdivisions, or esplanade strips or access strips and the requirement for the fencing and planting of such areas by the developer as part of the subdivision consent.

Explanation
District Councils are required to set aside esplanade reserves when land is subdivided. The Queenstown Lakes District Council may take and if necessary pay compensation for land subdivided in the Lake Hayes catchment, in recognition of the need to provide riparian margins to improve water quality. It is also possible under Section 235 of the Resource Management Act to create esplanade strips for maintaining and enhancing water quality. This mechanism may be costly to the Queenstown Lakes District Council and will not be used until the success of negotiated establishment of riparian margins can be ascertained. The provision of access strips may also lead to improved riparian management.

3.7.2 The protection of existing and future riparian margins in the catchment.

Explanation
District Councils are often the first point of contact for the prospective land developer, and hence are an important linking mechanism in ensuring current and future riparian margins are recognised and protected from future development.

3.7.3 The inclusion of a land disturbance strategy to control the potential effects of land disturbance adjacent to water bodies in the Lake Hayes catchment as part of any resource consent issued.

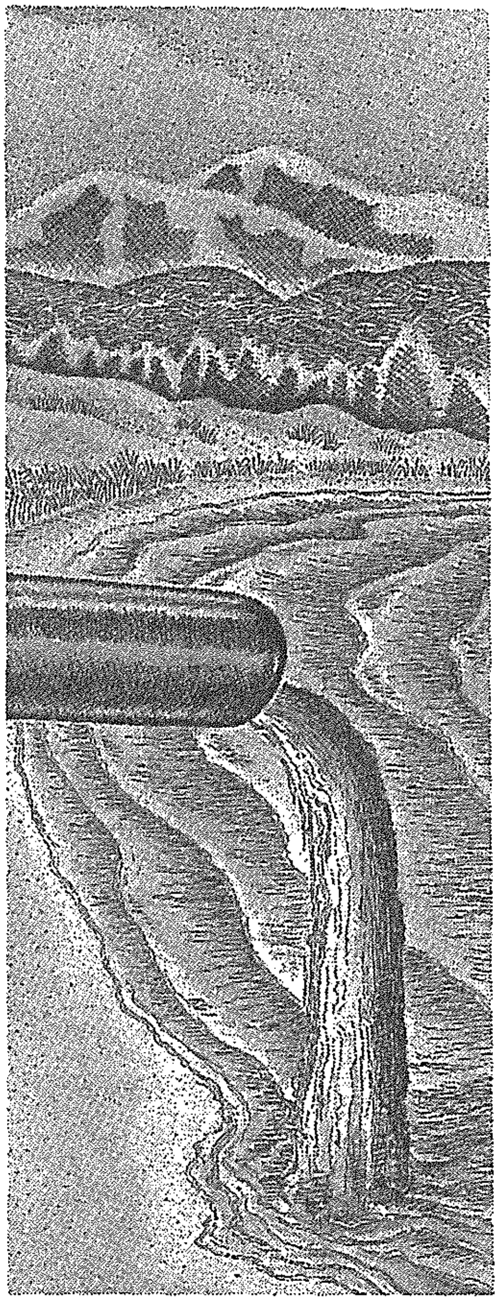
Explanation
District Councils have functions under the Resource Management Act to control the use, development and protection of land and the subdivision of land. Disturbance to the land, as occurs with most development, has the capacity to increase sediment loadings on water bodies. Recent work on Coronet Peak in forming new tracks and development works associated with improving the area as a ski-field have highlighted the change in sediment loadings that can occur as a result of land disturbance. In circumstances where the use of water is not directly related to the development, the District Council may be the only authority involved in the granting of consents. In these situations, it is important that the Queenstown Lakes District Council consider

how land disturbance will take place, and whether there is likely to be any runoff into a water body.

3.7.4 The future land uses in the catchment with regard to their impact on water quality and soil conservation.

Explanation
Future land use planning has the capacity to consider and provide for mechanisms that will prevent the future deterioration of Lake Hayes water quality.

4. Point Source Discharges to Land, Water



4.1 Introduction

Point source discharges refer to the discharge of a contaminant from a specific and identifiable source, onto or into land, air or water. The discharge of a contaminant into a water body from a identifiable point can have effects which occur far beyond that point of discharge. In combination with the surrounding water quality present, a point source discharge can contribute to further degradation of the water quality. Because of their easily identifiable location and mechanism of release, it is easier to control and mitigate adverse effects from point source discharges than from the corresponding diffuse pollution source.

There is also a greater amount of technology available to treat contaminants which are traditionally discharged from an identifiable outlet. In the Lake Hayes catchment point source discharges tend to emanate from sewage disposal, ponds, and irrigation supply. The effects of such activities can be avoided, remedied and mitigated with adequate planning and design. With growth expected in both the tourism industry and residential settlement in this catchment, it is important that the associated issues of waste disposal and land management do not exacerbate the current poor standard of water quality. The intent of this section of the strategy is to establish a framework to ensure current and future point source discharges do not continue to contribute phosphorus to the Lake Hayes catchment.

4.2 Issues

4.2.1 Point source discharges within the Lake Hayes catchment contribute to the phosphorus loads entering Lake Hayes.

Explanation

Wastes from industries which have high nutrient content such as that from dairy farms and cheese factories has increased the nutrient loading of Lake Hayes in the past. Other point source discharges still occur today which contribute phosphorus to the lake.

4.2.2 Leaching of septic tanks contributes to the phosphorus loading of Lake Hayes.

Explanation

Septic tanks may have an adverse effect on catchment water quality where their location, maintenance or surrounding soils structure is inadequate for the nutrient loads they are carrying. Past studies in the catchment have indicated that septic tanks do contribute to the overall nutrient loading of the lake.

4.3 Objectives

4.3.1 To ensure that point source discharges in the Lake Hayes catchment do not contribute to the phosphorus loading in the lake.

Explanation
Point source discharges are usually able to be controlled and treated to ensure the discharge does not contain nutrients in levels that will adversely affect Lake Hayes. Current and future point source discharges will be required to show that their discharge to water will not contravene any water quality standard proposed for the water body.

4.4 Policies

4.4.1 To restrict the phosphorus and nutrient levels in point source discharges in the Lake Hayes catchment to ensure a decline in the total annual phosphorus loading rates of Lake Hayes.

Explanation
A decline in the phosphorus input into the lake from point source discharges will further assist lake recovery. To achieve long term lake recovery the high nutrient loading to the lake needs to be addressed. The impact of leaf litter on the phosphorus loadings of Lake Hayes is to be investigated.

4.4.2 Through the proposed *Regional Plan: Water*, current septic tank discharges which do not meet the proposed standards outlined in Appendix 3 will be required to meet that standard. All new on-site disposal systems will be required to operate to the standard outlined in Appendix 3.

Explanation
Some of the current septic tanks in the Lake Hayes catchment result in poor treatment of effluent and adverse effects on the ground and surface water resource. This policy requires those systems to be upgraded so that after treatment the effluent conforms to the standard specified in Appendix 3. All new systems must be designed to achieve the standard specified in Appendix 3.

4.4.3 Through the proposed *Regional Plan: Water*, water quality classes will be adopted for Lake Hayes and its tributaries, and Mill Creek.

Explanation
This policy aims to provide for the management of the lake and tributaries that reflects what the lake is used for, and provide for the improvement of the lake water quality.

4.4.4 To encourage the connection of subdivisions and areas of development to reticulated sewerage systems.

Explanation
Many of the houses and developed areas in the Lake Hayes catchment use septic tank systems. Encouraging the connection to reticulated sewerage systems recognises the potential contamination source of those septic tanks and their effect on phosphorus levels in the lake.

4.5 Regulatory matters recommended for consideration in the *Regional Plan: Water*

4.5.1 Establishing water quality classes for Mill Creek and Lake Hayes.

Explanation
The development of water quality classes for Mill Creek and Lake Hayes will be considered within the regulatory framework of the proposed *Regional Plan: Water*.

4.5.2 The control of the discharge of contaminants including stormwater and sewage.

Explanation
Regulation in the form of water quality standards will give direction and certainty to water users and provide for cumulative effects to be considered in order to address the water quality of Lake Hayes. Consideration will also need to be given to Appendix 3, which promotes an effluent standard for on-site sewage disposal (for example septic tanks).

4.5.3 Provision for the review of conditions on current resource consents issued under the Resource Management Act to ensure they meet any prescribed standards.

Explanation
This mechanism may be necessary given the current level of phosphorus loading into Lake Hayes.

4.5.4 The control of the use of fertilisers, pesticides and herbicides.

Explanation
There is a need to ensure that vegetated margins, which are performing a role in trapping nutrients are not affected by accidental or intended use of herbicide. If pesticides and herbicides are used according to manufactures directions then human safety is assured. Provisions exist under the Pesticides Regulations for prosecution if spray damages non target plants, and if negligent use can be demonstrated. These controls may be sufficient without the need for further regulation. To improve the trophic status of Lake Hayes phosphorus inputs into the lake must be reduced. It is particularly important that riparian margins do not receive fertiliser application, as their close proximity to water bodies and likely saturated soils will aid the flow of phosphorus into both surface and groundwater.

4.6 Regulatory matters recommended for consideration in the Queenstown Lakes District Plan

4.6.1 Consideration of the on-site disposal guidelines and standards outlined in Appendix 3, consistent with any regional plan.

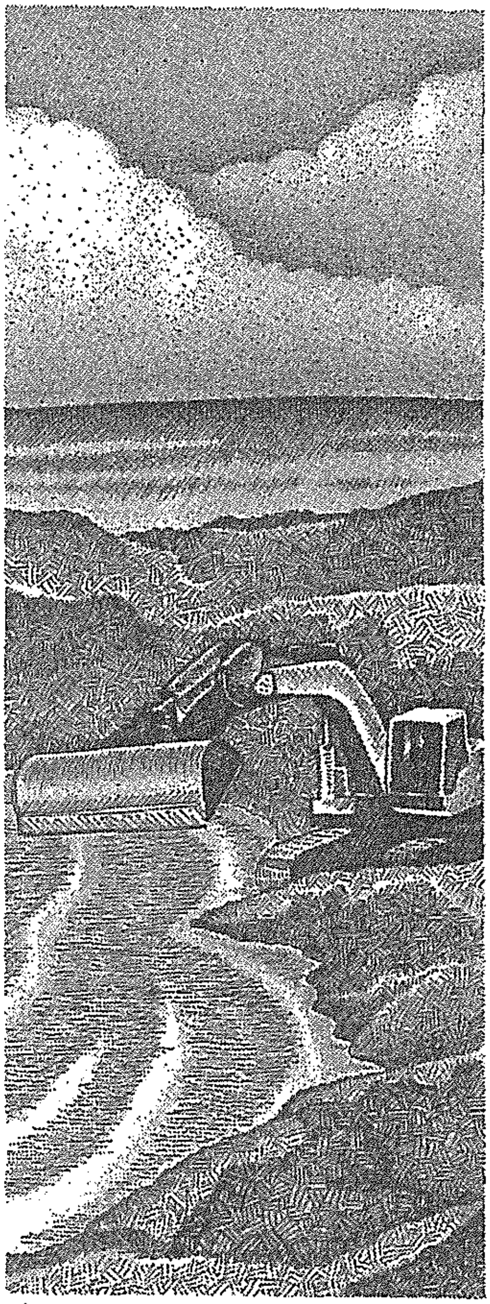
Explanation
On-site disposal guidelines for effluent quality are shown in Appendix 3. This mechanism is considered the most effective as the installation of the septic tank and its operating requirements can be dealt with in conjunction with the building consent. Where septic tanks currently do not meet the standard of effluent discharge required, the land holder is given the option of upgrading, or having the septic tank emptied regularly through a service agreement. This may be the best mechanism for households which are not regularly occupied, but where the septic tank system is currently inadequate.

4.6.2 *Requiring the connection of new subdivision areas and areas of* development into reticulated sewerage systems.

Explanation

New subdivision proposals, unless adequate provisions are made to deal with associated sewage discharges, could result in increased phosphorus loadings into Lake Hayes. Requiring the connection to a reticulated sewerage system, at the time of considering the subdivision application, will ensure that the potential impact of increased sewage discharges on the eutrophic state of the lake is taken into account.

5. The Taking, Use, Damming and Diversion of Water



5.1 Introduction

Water is used for a wide variety of functions in the Lake Hayes catchment. Some of these uses include fish ponds, snow making, public water supply, wildlife and tourism ventures, mining and irrigation. Pressure on the water resource is likely to increase with the expected growth in the area. The catchment can experience water shortages, in both summer and winter months, making the efficient and effective management of water quantity in the catchment extremely important. Water quantity will also affect water quality in tributaries and Lake Hayes. Lake Hayes itself is favoured for recreational use and the tributaries have important wildlife and fishery values.

Management of water use is necessary to sustain the potential of the lake to meet the needs of future generations. The need for further drinking water supply, irrigation, recreational use and fishing of the water resource in the Lake Hayes catchment can be foreseen.

Large scale drainage works and willow clearance were carried out in the Lake Hayes catchment in 1961. Between 80 and 120 hectares of land was drained in the upper half of Mill Creek resulting in an increase in productive land, but with the associated loss of wetlands. To improve the water quality of Lake Hayes, the benefits and methods of clearing drainage channels and the rate of flow of water through the catchment needs to be reassessed. This section of the strategy deals with how the taking, use, damming and diversion of water should be managed to achieve the objective to improve the water quality of Lake Hayes.

5.2 Issues

5.2.1 The quantity of water flowing in Mill Creek affects the quantity of nutrient entering the lake and the lake's rate of flushing.

Explanation

Continuous low flow of Mill Creek will affect the rate of flushing of Lake Hayes and hence potentially lead to a higher concentration of phosphorus in the lake. However since most of the nutrient entering the lake is bound to sediment, flood flows tend to carry more phosphorus. High flows also result in more erosion of the banks and movement of sediment downstream.

There are both water takes and discharges into Mill Creek, mostly for the purposes of land irrigation during the summer months. With an increase in viticulture in the catchment, demands for water from groundwater sources Lake Hayes and Mill Creek may increase. Groundwater takes from the catchment may also affect the amount of surface water available to the area.

5.2.2 The culverts at the outlet of the lake may be of insufficient size to manage high lake levels without causing flooding of adjacent land.

Explanation

It is normal for lake levels to rise at times of high rainfall. However when this occurs nutrients from the surrounding farmland is washed into the lake. It would be of benefit to lake recovery and lake flushing rates to ensure the culverts do not pose an excessive restriction on lake flushing and level control.

5.2.3 Lack of information on the groundwater resource in the Lake Hayes catchment impedes sustainable management of the use of water in the catchment.

Explanation

Groundwater recharges Mill Creek, the lake and the spring at the head of the lake. Increasing pressure to take water in the catchment, including the public water supply the spring provides, requires management agencies to have a better understanding of the capacity of the groundwater resource. In the Wakatipu Basin away from the main rivers, recharge of the groundwater aquifers is very limited and there is a possibility of aquifers giving low yields or becoming exhausted. The ability of the ground to sustain effluent disposal without contaminating ground or surface water is partially dependent on the geology. In coarse gravels, where there are few fine particles to act as a filter, soakage can allow effluent through the ground easily with little treatment. In the Lake Hayes basin the rural residents are mainly obtaining their domestic water supply from aquifers within the same ground deposits which are taking their effluent.

5.2.4 Drainage and flood protection works carried out in the past and their maintenance, increase the rate of flow of water through the Lake Hayes catchment and contribute high phosphorus content sediment to Lake Hayes.

Explanation

Increased rates of flow result in less sediment being able to settle out of the water column, and disturbs highly nutrient enriched sediment, sending it downstream into Lake Hayes.

5.3 Objectives

5.3.1 To ensure that the taking, use, damming and diversion of water in the Lake Hayes catchment does not adversely affect catchment water quantity and quality.

Explanation
The taking, use, damming and diversion of water has the potential to either increase or decrease sediment and nutrient flows into Lake Hayes, depending on how it is carried out and the mitigation mechanisms employed.

5.3.2 To manage drainage channels and flood protection works so they no longer contribute phosphorus and sediment to Lake Hayes.

Explanation
The use and maintenance of drainage channels have been found to contribute approximately 10% of the phosphorus loads to Lake Hayes per year. To improve the water quality of Lake Hayes it is necessary to reduce this form of phosphorus contribution.

5.4 Policies

5.4.1 To minimise obstructions to lake flushing and efficiently manage high lake levels.

Explanation
Structures which restrict the rate at which the lake can clear itself of high inflows are inconsistent with water quality improvement as they exacerbate flooding of adjacent land and increase water residence time.

Obstruction to the outflow of the lake results in higher than normal lake levels over the whole year, and flooding of shoreline margins at times of high rainfall. When shoreline margins are flooded, phosphorus from the land is made available to the lake. Obstruction to outflow also increases lake residence time, which will extend the time it takes the lake to recover under the mechanism of reducing phosphorus inputs.

5.4.2 Through the proposed *Regional Plan: Water,* minimum flows for Mill Creek will be established.

Explanation
Where the Otago Regional Council has a role in managing the use of water in the Lake Hayes catchment, it will ensure that use of water will not result in the lowering of Mill Creek to below its minimum flow.

Minimum flow regimes are mechanisms whereby the needs of instream values are considered alongside the water needs of the community, and the minimum flow is set which reflects a balance between the two.

5.4.3 To ensure the efficient use of water in the catchment.

Explanation
The Queenstown Lakes District including the Lake Hayes catchment is experiencing rapid population growth and rural/urban development. With these changes to land use, crops such as grapes, which require irrigation, are currently and will in the foreseeable future put further pressure on the catchment's water supply. Along with this, there is little information on the capacity of the groundwater resource in the catchment. These factors culminate to requiring a conservative approach to water use.

5.4.4 To adopt a cautious approach to the quantity of groundwater taken in the catchment and to ensure that use of groundwater will not significantly adversely affect the flow rate in tributaries, lake levels, or result in a decline in water quality.

Explanation
Lack of information on the groundwater resource in the Lake Hayes catchment means there is the potential for unsustainable use of groundwater. Since groundwater recharges surface water there is a potential impact on dilution and concentration of phosphorus entering Lake Hayes with over use of groundwater. The spring at the head of Lake Hayes is a groundwater site which is used for a public water supply. The availability of that water source is required for the predicted growth of households in the area, however it should not significantly impact on water available to Lake Hayes. In-lake factors such as residency time (the time a particle of water spends in the lake system) and the requirements of aquatic ecosystems also need to be considered when water is allocated between users.

5.4.5 To reduce water flow rates, and the movement of sediment in catchment tributaries and Mill Creek.

Explanation
High flow rates carry more sediment in the streams and creeks of the catchment and are more likely to cause streambank erosion. When water is slow moving, suspended solids have the chance to settle out through the water column. This is what happens in a wetland. The sediment in the beds of water bodies is disturbed during high flow and released into the lake, making phosphorus available to the lake and for future algal blooms.

5.5 Proposed Otago Regional Council actions

5.5.1 The Otago Regional Council will commission an independent engineering report into the functioning of the culverts at the outlet of Lake Hayes and the functioning of Hayes Creek itself.

Explanation
Past investigations have found that base levels in the outlet channel could be lowered, and this would provide some buffering capacity between the normal lake level and that at which significant flooding occurs. A reduction in lake levels in the order of 20-30cm is considered appropriate. It is estimated that a 1600mm culvert, properly installed under SH6 would reduce persistent high lake levels. Such a culvert would prove slightly less efficient at low lake levels, hence further investigation is required to ascertain how peaks can be reduced, while residence time decreases or remains the same. The gradient of Hayes Creek at the outlet may also be responsible for restrictions to flushing. Obstruction from willow colonisation suggests works on Hayes Creek itself may also be required.

5.5.2 The Otago Regional Council will promote water efficiency mechanisms.

Explanation
The Council will actively promote the efficient and effective use of water in the Lake Hayes catchment, a potentially water short catchment.

5.5.3 The Otago Regional Council will provide for an investigation into groundwater resources in the Lake Hayes catchment.

Explanation
This investigation is needed to obtain information on the quantity and quality of the groundwater resources in the Lake Hayes catchment and

Wakatipu Basin, so that management of the groundwater resource is based on sound technical information and knowledge.

5.5.4 The Otago Regional Council will provide advice on the management and maintenance of stream and drainage channels to ensure any work undertaken is in a way that minimises phosphorus and sediment inputs into the Lakes Hayes catchment.

Explanation
Drainage works carried out in the 1960s increased the amount of production land available and removed the natural nutrient sinks. The works included drainage and stream channels which now form part of the existing system of carrying nutrients to Lake Hayes. Maintenance of the channels needs to be carried out in such a way that phosphorus and sediment inputs into water bodies is minimised. Any maintenance undertaken shall recognise any conditions contained on a consent that has been granted.

Works that are required following a flood can be undertaken provided they meet the requirements of the emergency provisions of the Resource Management Act.

Consultation and advice to land owners will need to be carried out to ensure that the best approach is adopted.

5.5.5 The Otago Regional Council will provide where necessary for a programme of shaping, spreading, grassing and fencing around channels.

Explanation
Spoil created from the clearance of drainage channels has previously been placed on the bank above the water body. This spoil has a high nutrient content, and with rainfall this is displaced back into the water course. Spreading and grassing of the spoil will reduce the likelihood of sediment re-entering the water body.

5.5.6 The Otago Regional Council will investigate the re-establishment of Mill Creek to a meandering form in the sites currently channelled.

Explanation
Mill Creek's natural character was more meandering than its current form. Meandering streams are better for water quality as the flow rate is slower and there is greater provision for sediment deposition. Where possible it would be beneficial from both a water quality and fisheries perspective for Mill Creek to return to its meandering form through the valley. The impact on sedimentation of works required to

recreate a meandering form, and the potential for the meandering form of the creek to contribute greater amounts of phosphorus as a result of increased erosion on the creek bends need to be considered.

5.5.7 To establish a wetland or sediment pond on land occupied by Millbrook Country Club.

Explanation
Millbrook Country Club are in agreement with the establishment of a wetland or sediment pond on part of their land which is being developed as a resort hotel and golf course.

5.6 Regulatory matters recommended for consideration in the *Regional Plan: Water*

5.6.1 Establishing minimum flows for Mill Creek.

Explanation
The development of minimum flows for Mill Creek will be considered within the regulatory framework of the proposed *Regional Plan: Water*.

5.6.2 Controlling the taking and use of water in the Lake Hayes catchment.

Explanation
Section 14 of the Resource Management Act already establishes restrictions relating to the taking, use, damming and diversion of water. In a catchment such as Lake Hayes where rapid growth and land use changes are taking place some form of regulatory control provides the ability to consider and mitigate current and potential adverse effects, so that sustainable management may be achieved. Controlling the use of water in this catchment is also needed to ensure there are adequate quantities of water flowing into the lake to maintain the lakes rate of flushing, dilution of phosphorus and the aquatic ecosystem.

Non utilised irrigation water can have high sediment and nutrient loads where it has flowed over pasture, crops or exposed ground. It is also wasteful to apply irrigation in quantities larger than the assimilative capacity of the crop and soils present. The use of regulation will need to be considered further in the proposed *Regional Plan: Water*.

5.6.3 Controlling the damming and diversion of water.

Explanation

Dams can assist in augmenting natural flows and levels, retaining water during periods of high flows to be released at periods of low flow. They are also required for the creation of wetlands and ponds, which this strategy supports. The damming and diversion of water also needs to consider the potential impact on fish passage.

5.6.4 Controlling the disturbance of bed and banks of Lake Hayes and its tributaries.

Explanation

Section 13 of the Resource Management Act restricts the disturbance, deposition, reclamation and introduction of plants, to the beds of rivers and lakes. In relation to the Lake Hayes catchment, the primary concern of disturbance of the beds and banks of water bodies, is the effect that disturbance may have on sedimentation and channel destabilisation.

6. Appendices

6.1 Appendix 1: Alternative Methods for Improving Water Quality

6.1.1 Diversion of Mill Creek.

The feasibility of this method was explored in 1985. It was found that proposals to divert flows of up to 10m³/s from Mill Creek during times of flood were impractical and very costly. Mechanisms investigated included the channelling of flood flows around the lake into Hayes Creek, diverting flows from Dan O'Connell, Station and McMullens Creeks (tributaries to Mill Creek) into the Shotover River, and channelling flood flows from Mill Creek into the Arrow River catchment. For any of these works it was found that costs would prove high and in two of the cases the works would be highly visually obtrusive.

6.1.2 Clearing the outlet and decreased lake levels.

A preliminary investigation on the fluctuation of Lake Hayes' level and the effect the culvert at the outlet to Lake Hayes may have on this was undertaken in response to long term residents' concern that the level of Lake Hayes had risen between 300 and 500mm since the replacement of the SH6 bridge over Lake Hayes Creek with twin 900mm diameter culverts in the 1960s.

It was found (based on 15 years of once monthly observations) that the range in lake levels fell between RL 327.6 - 328.5m. (RL = reduced level, measured as height above Mean Sea Level.) A desirable range of lake levels from the point of view of farm drainage, from the lakes was considered to be RL 327.6 - 328.1m. It was also estimated that one 1600mm diameter culvert would reduce persistently high lake levels, although it may be slightly less efficient at low lake levels. From the point of lake nutrient reduction, it is detrimental to lake recovery to have adjacent farm land flooded, as with the return of flood water to the lake comes nutrients from the farmland.

Further exploration is needed into this issue of the functioning of the lake outlet, and hence lake flushing and residence time.

6.1.3 Piping of nutrient rich bottom waters.

This involves selectively withdrawing hypolimnetic (bottom) waters, which tend to be the richest at times of lake stratification. This method decreases the residence time (the time a particle of water spends in the lake system) of the hypolimnion. It has been shown to be effective in lakes that are smaller than Lake Hayes and show different stratification patterns. Application of Nurnberg's conclusions to Lake Hayes suggest hypolimnetic withdraw could be used to enhance the rate of depletion of the sediment pool of phosphorus during the anoxic release period (Nurnberg, 1984). Such an approach would gradually reduce hypolimnetic phosphorus concentrations and the sediment pool of available phosphorus for subsequent release. It could not be considered as a technique to achieve immediate cessation of internal phosphorus release and immediate lake recovery. In a programme with external load reduction and hypolimnetic withdrawal, evidence suggests lake recovery would eventually occur more rapidly than with external load reduction alone.

6.1.4 Use of barley straw.

The use of barley straw to clear waters of algae was investigated following suggestions of this method from members of the public. Barley straw does have some application in shallow lakes where it can act in a sieve-like fashion, to capture floating algae. However, following consultation with organisations employing this technology, it was considered to be an ineffective method for a lake the size and depth of Lake Hayes.

6.1.5 Chemical methods of in-lake control.

There are three broad groups of chemical methods available to treat eutrophic lakes. They are herbicides, algal flocculation and nutrient inactivation.

6.1.5.1 Herbicide

Copper sulphate has been the most widely used algicide in New Zealand as it is effective against blue green algae. Its application however is most relevant to water reservoirs for drinking water supplies. Copper sulphate can be toxic to freshwater vertebrates and invertebrates, hence for a lake the size and depth of Lake Hayes the risk of toxicity to the important fishery and wildlife values of the lake is considered too great a risk.

Other herbicides which have been used in New Zealand in the past include Diquat and triazines. Herbicides of this nature tend to be most effective against higher plants than the blue-green algae which is present in Lake Hayes towards the end of summer. New Zealand regulations only permit the use of triazines in irrigation ditches.

6.1.5.2 Algal Flocculation

Flocculation is the process of precipitating out suspended solids from the water column. This is done by dosing the water with a surface spray of chemical compounds. In this way phytoplankton are directly precipitated with the chemical floc, and phosphorus is precipitated from the water column. However, this method is only successful for small lakes, up to 0.6km². Lake Hayes at 2.76km² and with a maximum depth of 33m is too large for this method of treatment.

6.1.5.3 Nutrient Inactivation

Where phosphorus is shown to be the limiting nutrient in phytoplankton growth, lake treatment with alum (aluminium sulphate) to precipitate the phosphorus can produce a reduction in phytoplankton biomass. Application of alum to intermittently stratified lakes such as Lake Hayes has not been as successful as with shallow or constantly stratified lakes. Studies on nutrient inactivation have shown that lake recovery from in-lake controls alone has not been sufficient if phosphorus inputs were not previously reduced.

A full investigation of the use of alum in Lake Hayes was undertaken by Robertson and Royds Garden in 1989. Alum was found to be the preferable method of in-lake controls for Lake Hayes. That document should be referred to for an explanation of the proposed costs and benefits to Lake Hayes of alum technology.

6.1.6 Flushing Lake Hayes with water from the Arrow River.

Flushing a nutrient rich lake with water of lower nutrient concentration will improve the water quality. However, in the case of Lake Hayes it is not certain whether this option could possibly aggravate the situation by upsetting the natural thermal balance of the lake and encouraging mixing of high phosphorus hypolimnetic water with low phosphorus surface water during summer. This method, like that of diverting Mill Creek (see 6.1.1 above) is likely to have high capital costs. The problem of high nutrient loads entering the lake from the Mill Creek catchment would still remain under this method.

6.1.7 Introduction of carp

MAF Fisheries investigated the potential benefits of using silver carp to control eutrophication in Lake Hayes in 1989. It was found that, in terms of long term control, silver carp would not be of benefit, as total nutrient loading to the lake would not change unless the fish were harvested. It was also considered that the amount of phosphorus bound up in fish flesh would be insignificant. It is suggested that silver carp may in fact increase algal biomass by eating the zooplankton which is currently the only control on the algal population. Given the uncertainties of the benefits and evidence that the carp may be a hindrance to improving lake water quality, this option will not form part of the rehabilitation plan.

6.1.8 Hypolimnetic aeration.

An investigation into the viability of hypolimnetic aeration in Lake Hayes was carried out by Robertson and Royds Garden in 1989. The major objective of hypolimnetic aeration is to raise the oxygen content of the hypolimnion without destratifying thermal stratification. Review of hypolimnetic aeration results concluded that the technique is not accepted as a technique with demonstrated effectiveness to substantially reduce internal loading of phosphorus. Although phosphorus in the hypolimnion during aeration can be reduced, the effect is not as great nor as permanent as other techniques such as alum addition, hypolimnetic withdraw (siphoning) or dredging. Investigations of this method in 1989 concluded operating costs would be in the order of an initial cost for materials of $380,000 and a yearly operating cost of $55,000.

6.1.9 Artificial circulation.

The objective of artificial circulation is to aerate the volume of water that is normally the hypolimnion and oxidise substances in the entire water column. In so doing the lake is destratified. Destratification of Lake Hayes should result in a permanently oxic lake, with lowered iron, manganese and ammonium concentrations. The most extensive and recent review of the effectiveness of this technique to date considers artificial circulation to be a technique requiring more research and demonstration. It does not currently appear effective at substantially reducing internal loading of phosphorus. This method was reviewed by Robertson and Royds Garden in 1989 and that review should be referred to for additional information.

6.1.10 Sediment traps and wetlands.

The feasibility of constructing a sediment trap was briefly explored by the Otago Catchment Board in 1985. Initial costings of $100,000 were made for a 4 hectare sediment trap. Wetlands were identified in the Robertson report as possible mechanisms for achieving phosphorus removal by the settling out of sediment. It has been claimed that prior to the draining of the major wetland in the Lake Hayes catchment, dirty Mill Creek floodwaters were not seen in Lake Hayes, implying the wetland was performing a role in settling out sediment. Initial costing of this option was $500,000.

A full investigation into the feasibility of wetlands to achieve improved water quality in Lake Hayes was undertaken by the Otago Regional Council in 1994. The Council commissioned Royds Consulting Limited to undertake the investigation. They found that wetlands store phosphorus in sediment on their beds and did not consider that wetlands could achieve a net removal of phosphorus under this mechanism. Royds found that a water retention time of 15 days would be required to achieve sedimentation of phosphorus. This would give an 80% phosphorus removal rate. Royds also stated that in order to maintain these rates of removal, wetland sediment would need to be periodically dredged and dispersed onto land. The amount of land required to achieve the required retention time was found to be 345 hectares. A total of only 149 hectares was potentially available, and this area was dispersed over 4 sites.

To achieve a 50% removal would have required 138 hectares, which is still more area than was available at any one of the potential sites. The largest site was 93 hectares.

Royds found that constructing wetlands at each of the potential sites would not be satisfactory because even though the total area may be sufficient, it was the flow velocity (retention time) at each site that was important for effective phosphorus removal.

Wetlands as defined in the Royds report required excavation of 1 metre depth to achieve the desirable water depth. Such a design is expensive due to the construction requirements.

Royds therefore found that there were no suitable sites within the Mill Creek catchment for a wetland of sufficient area to ensure a high degree of phosphorus removal. All potential sites were said to require a compromise between the extent of phosphorus removal achievable and the area of wetland physically available. The largest area of land that might be available to form a wetland had the disadvantage of being furthest up the catchment away from Lake Hayes and hence could only intercept up to 40% of the phosphorus load to Lake Hayes.

Royds found that the likely cost of constructing a surface flow wetland, including land purchase, was $155,000/ha. Based on this, the cost of the largest wetland that could be built in the catchment, would be $17 million.

6.1.11 Mill Creek erosion.

In June 1994 the Otago Regional Council re-investigated Mill Creek to identify sources of sediment and identify the cost measures that might prevent or reduce the flow of sediment from Mill Creek into Lake Hayes. The report identified measures to reduce the runoff into water of non-sediment, phosphorus bearing material, particularly dung. The report identified areas within the creek where erosion is currently occurring and where some stabilising of the creek would reduce erosion. It also identified areas which would benefit from the exclusion of stock, and fencing was recommended. The fencing and associated works were costed out at $95,000, including the provision of alternative stock water supply.

6.1.12 Altering land use practices, reducing external phosphorus inputs.

Changes in land use and land use practices correlate highly with the movement of phosphorus off the land and into water bodies in the Lake Hayes catchment. Major estimated inputs of phosphorus into the Lake Hayes catchment were shown in Robertson's 1988 report. This report identified various methods of phosphorus control. In terms of land use practices he identified: reduction in fertiliser application and runoff, reduction in runoff from animal stocking, wetland re-establishment, erosion prevention, and changes in land use, as being necessary to alleviate lake eutrophication. Each of these options is explored in more detail in Robertson's report.

6.2 Appendix 2: Trends From Water Quality Monitoring Data 1983-1994

In relation to Mill Creek:

(1) Mill Creek provides about 80% of the annual external load of phosphorus to Lake Hayes. The proportion has not changed significantly since 1983.

(2) The suspended solids phosphorus content (about 0.2%) is similar under all flow conditions and has not changed significantly since 1983.

(3) The annual phosphorus load is variable and was much higher in 1983-84 than in 1990-94 because of a high incidence of flood events, an above average base flow rate and elevated concentrations of sediment-bound phosphorus.

(4) Base flow annual phosphorus load, and to a lesser degree total annual phosphorus load, correlates well with the annual median total phosphorus and sediment-bound phosphorus concentrations.

(5) pH levels were lower in 1983 than in 1984 and 1990-94, possibly because of an above average mean flow rate and incidence of flood events.

(6) Conductivity, turbidity and inorganic nitrogen levels have not changed significantly since 1983.

In relation to Lake Hayes:

(1) The recent yield of total phosphorus for the Lake Hayes catchment is in the range 10-20kg/km^2/yr making it a low-average exporter of phosphorus.

(2) The annual external load of phosphorus in 1983-84 (2400kg) was much higher than in 1990-93 (400-1000kg), whereas the output in 1983-84 (580kg) was similar to that in 1990-93 (550-700kg). The data support the view that the cycling of phosphorus in the lake is being driven primarily by the internal release of sediment-bound phosphorus.

(3) Phosphorus concentrations in the lake are seasonal and depth dependent. Winter surface phosphorus concentrations and summer reactive phosphorus concentrations in the hypolimnion were significantly lower in 1983-85 than in 1970-71 and 1990-94. During the 1990-94 period total and dissolved reactive phosphorus concentrations remained relatively constant at all depths. It is hypothesised that in 1983 flow rates in Mill Creek were above average, throughput in the lake was elevated and lake residence time lower than normal. This resulted in lower lake phosphorus concentrations following autumn mixing. At stratification the subsequent rate of oxygen depletion would be lower because of a phosphorus concentration related fall in biological activity, the onset of anoxia

delayed, the amount of sediment-bound phosphorus released into the hypolimnion would be reduced, and the resulting phosphorus concentration in the hypolimnion would be lower.

(4) Median dissolved oxygen concentrations in the hypolimnion during summer were <1 g/m^3 in each of the three study periods. There is insufficient information to determine whether the date of onset of anoxia has changed, but it is clear that the hypolimnion is still anoxic during the summer stratification period.

(5) The pH of the lake is seasonal and depth related. The winter pH was about 7.5 in 1983-84 and 8.0 since 1988. During spring and summer the epilimnion becomes increasingly alkaline and the hypolimnion more acidic, probably in response to increased rates of photosynthesis and respiration. Since 1989 the pH of the epilimnion during the summer period has been around 9.0.

(6) The present water quality survey suggests that the water quality of the lake has probably not changed significantly since 1983. Under normal input flow conditions elevated lake phosphorus concentrations continue to provide a nutrient rich environment for algal growth, whilst the absence of any improvement in the anoxic condition of the hypolimnion, combined with high pH levels in the epilimnion during summer stratification constitutes a poor fishery environment.

6.3 Appendix 3: On-Site Disposal Effluent Standard

Because of the soil and drainage characteristics of the Lake Hayes catchment and the location of groundwater and drinking water sources, it is important that future on-site disposal mechanisms achieve an effluent standard that will protect the groundwater resources from phosphorus.

Prior to the granting of a consent for on-site disposal, evidence must be supplied that the engineering of the system will achieve reliable uniform loading of effluent to the full design infiltration surface and in general this will be achieved by pressurised distribution systems incorporating sound principles of hydraulic design.

The effluent discharge from the land disposal field as determined by monitoring should conform with the following criteria, until such time when a regional plan rules otherwise:

(1) Biological Oxygen Demand (BOD) shall not exceed $10g/m^3$ and annual average shall not exceed $5g/m^3$.

(2) Total Suspended Solids shall not exceed $5g/m^3$ and annual average shall not exceed $2g/m^3$.

(3) Total Phosphorus shall not exceed $5g/m^3$ and annual average shall not exceed $1g/m^3$.

(4) Total Nitrogen shall not exceed $20g/m^3$ and annual average shall not exceed $10g/m^3$.

(5) Faecal coliforms shall not exceed 200 per 100mls and annual average shall not exceed 10 per 100mls.

6.4 Appendix 4: Suggested Species for Riparian Management Plantings

Sedges and Grasses

Species		Fringe	Mid	High bank	Characteristics	Soils
Tussock sedges	*Carex* spp	Yes	Yes	No	Excellent for cool conditions and poorly drained sites.	Low fertility, acid soils.
Tussocks (native)	*Chionochloa* spp	Yes	Yes	Yes	Use locally grown stock. *C. rubra* (red tussock) can become the dominant species in poorly drained soils, frost hardy.	Low fertility, moist soils but can withstand drought.
Tussocks (other native)	*Festuca novae-zelandiae*	No	Yes	Yes	Planted at close spacings provides a micro climate for other plantings. Frost hardy and drought tolerant.	Most dry soils.
Toetoe	*Cortaderia* spp	Yes	Yes	Yes	Large coarse grasses up to 5m in height. Frost hardy, mildly drought resistant, ideal nurse crop for establishing native plants. The exotic *C. selloana* and *C. jubata* should be avoided.	Low fertility, moist soils providing an abundant water supply exists.

Appendix 4 (continued): Shrubs and trees

Species		Fringe	Mid	High bank	Characteristics	Soils
Wine-berry	*Aristotelia serrata*	Yes	Yes	No	Suitable for low to mid tier shelter (but not as a windbreak) for more permanent species. Provides rapid canopy, frost hardy.	Most soils except very poorly drained or drought prone.
Flaxes	*Phormium* spp	Yes	Yes	Yes	Excellent stream bank stabiliser and water shade provider. Very tolerant of frost, drought and wind. Provides good shelter for other plantings.	All soils from waterlogged to drought prone. Use locally grown stock.
Olearia	*Olearia* spp (32 species)	No	Yes	Yes	Extremely hardy, easily propagated, will tolerate dry and exposed positions. Ideal nurse crop.	Most soils except poorly drained.
Senecio	*Senecio* spp (23 species of shrub)	No	Yes	Yes	Hardy shrub, easily propagated, ideal for use in soil conservation or revegetation in botanically sensitive areas ie, scenic reserves.	Most soils including peaty and sandy soils.
Koro-miko	*Hebe stricta* and *H salicifolia*	Yes	Yes	No	Shrub to 4-5m ideal for stream side and wet gullies. Fine fibrous root system.	Most soils, not very drought tolerant.
Pitto-sporum	*Pittosporum* spp	No	Yes	Yes	Shrub or small tree. Ideal for understorey plant or nurse crop for taller species. Protect from direct wind.	Well drained, but not drought prone.
Copros-ma	*Coprosma* spp	Yes	Yes	Yes	Up to 5m *C. parviflora* most suited. Frost tolerant but not drought hardy. Ideal understorey for taller species. Plant from locally grown stocks.	Tolerates heavy, wet and infertile soils very well. Most soils and clay.

Broadleaf	*Griselinia littoralis*	No	Yes	Yes	Up to 15m with stout branches, frost tolerant, withstands strong wind except when young. Will not tolerate prolonged drought. Glassy foliage.	Grows well on all but very infertile or gravelly soils.
Cabbage tree	*Cordyline australis*	Yes	Yes	Yes	Up to 12m, sparingly branched, leaf cluster at top, strong tap root.	All soils, from wet swampy ground to dry windy hill slopes.
Kowhai	*Sophora microphylla*	No	Yes	Yes	Attractive hardy small tree.	Well drained fertile soils.
Corokia	*Corokia cotoneaster*	No	Yes	Yes	Shrub up to 3m, extremely frost and drought tolerant and withstands exposure well. Excellent hedging or windbreak plant.	Most soil conditions.

NB: Slow maturing native trees such as Beeches, Kahikatea, Rimu, Matai, Totara etc, and the numerous exotic species are all suitable for interspersed plantings and the long term plan. Existing natives ie, Matagouri, *Carmichaelia* etc, should remain *in situ*.

6.5 Glossary

Terms marked with an * are terms defined by Section 2 of the Resource Management Act 1991.

Access strip	Is a strip of land created by the registration of an easement in accordance with Section 237B for the purpose of allowing public access to or along any river, or lake, or the coast, or to any esplanade reserve, esplanade strip, other reserve, or land owned by the local authority or by the Crown (but excluding all land held for a public work except land held, administered, or managed under the Conservation Act 1987 and the Acts named in the First Schedule to that Act).
Aesthetic Value	A value associated with the visual quality or the appreciation of the inherent visual quality of an element in the built or natural environment.
Anoxia (and anoxic)	A state of being oxygen poor, (cf. oxic state).
BOD	Biochemical Oxygen Demand. Used as a measure of organic pollution. The measured amount of oxygen required by micro-organisms to biologically degrade the organic matter in water.
Catchment	The total area from which a single water body collects surface and subsurface runoff.
Conditions*	In relation to plans and resource consents, includes terms, standards, restrictions, and prohibitions.
Consultation	The communication of a genuine invitation to give advice and a genuine consideration of that advice.
Contaminant*	Includes any substance (including gases, liquids, solids and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy or heat: (a) When discharged into water, changes or is likely to change the physical, chemical or biological condition of water; or (b) When discharged onto or into land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged.

Dam	A structure used or to be used for the damming of any natural water, river, or stream but does not include a flood bank or channel training work.
Discharge*	Includes emit, deposit and allow to escape.
Divert	The act of deflecting or moving a stream or river to another area.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Effect	Section 3 of the Resource Management Act defines the term effect as including: (a) Any positive or adverse effect; and (b) Any temporary or permanent effect; and (c) Any past, present, or future effect; and (d) Any cumulative effect which arises over time or in combination with other effects - regardless of the scale, intensity, duration or frequency of the effect; and also includes - (e) Any potential effect of high probability; and (f) Any potential effect of low probability which has a high potential impact.
Environment*	Includes: (a) Ecosystems and their constituent parts, including people and communities; and (b) All natural and physical resources; and (c) Amenity values; and (d) The social, economic, aesthetic, and cultural conditions which affect the matters stated in paragraphs (a) to (c) of this definition or which are affected by those matters.
Epilimnion (and *epilimnetic*)	The highest stratum (layer) of a stratified lake.
Erosion	The processes of the wearing away of the land surface by natural agents and the transport of the material that results.

Esplanade reserve* A reserve within the meaning of the Reserves Act 1977 -

(a) Which is either -

(i) A local purpose reserve within the meaning of Section 23 of that Act, if vested in the territorial authority under Section 239 of the Act; or

(ii) A reserve vested in the Crown or a regional council under Section 237D; and

(b) Which is vested in the territorial authority, regional council, or the Crown for a purpose set out in Section 229 of the Act.

Esplanade strip* A strip of land created by the registration of an instrument in accordance with Section 232 of the Act for a purpose or purposes set out in Section 229 of the Act.

Eutrophication Process by which water (usually freshwater) becomes rich in nutrients, causing excessive plant growth which kills animal life by deprivation of oxygen.

Fauna All the animal life of a given place or time.

Flora All the plant life of a given place or time.

Flushing Rate The rate at which a body of water completely replenishes itself.

Fresh Water* All water except coastal water and geothermal water.

Groundwater Water that occupies or moves through pores, cavities, cracks and other spaces in crustal rocks.

Habitat The place or type of site where an organism or ecological community naturally occurs.

Hydrology The science of the properties and laws of water, especially its movement on, under and above the land.

Hypolimnion (and hypolimnetic) The lowest stratum (layer) of a stratified lake.

Indigenous Species A native species of New Zealand.

Instream Values	Those uses or values of rivers and streams that are derived from within the river system itself and include those associated with freshwater ecology and recreational, scenic, aesthetic, intrinsic and educational uses.
Intrinsic Values*	In relation to ecosystems, means those aspects of ecosystems and their constituent parts which have value in their own right, including: (a) Their biological and genetic diversity; and (b) The essential characteristics that determine an ecosystem's integrity, form, functioning, and resilience.
Issue	A matter of concern to an area's community regarding activities affecting some aspect of natural and physical resources and the environment of the area.
Kaitiakitanga*	The exercise of guardianship; and, in relation to a resource, includes the ethic of stewardship based on the nature of the resource itself.
Lake*	A body of fresh water which is entirely or nearly surrounded by land.
Land*	Includes land covered by water and the air space above land.
Land Drainage	The act of taking off or diverting water from the land by artificial channels, pipes or other means.
Loess	A homogenous deposit of wind-blown silt.
Mitigate	To make or become less severe or harsh. To moderate.
Natural and Physical Resources*	Includes land, water, air, soil, minerals and energy, all forms of plants and animals (whether native to New Zealand or introduced), and all structures.
Non-point Source Discharge	Runoff or leachate from land, onto or into land, air, a water body or the sea.
Oxia (and oxic)	A situation with oxygen present (cf. an anoxic state).
Phytoplankton	Planktonic plant life, mainly microscopic algae, existing in the water column.
Point Source Discharge	A discharge from a specific and identifiable source, onto or into land, air, a water body or the sea.

Policy	The course of action to achieve the objective.
Resource Consents	A consent to do something which would otherwise contravene any of Sections 9 to 13 of the Resource Management Act 1991. It includes Land Use Consent, Coastal Permit, Subdivision Consent, Water Permit, Discharge Permit.
Riparian Margins	A strip of land adjacent to a water body which is frequently moist, and which generally extends from the perceived change in contour of the flood plain to the water body itself.
River*	A continually or intermittently flowing body of fresh water; and includes a stream and modified watercourse; but does not *include any artificial watercourse (including an irrigation canal,* water supply race, canal for the supply of water for electricity power generation, and farm drainage canal).
Tributary	A stream or river that flows into a water body.
Turbidity	The relative tendency of a water to scatter light. Informally taken as synonymous with "cloudiness" (lack of visual clarity).
Water Body*	Fresh water or geothermal water in a river, lake, stream, pond, wetland, or aquifer, or any part thereof, that is not located within the coastal marine area.
Wetland*	Includes permanently or intermittently wet areas, shallow water, and land margins that support a natural ecosystem of plants and animals that are adapted to wet conditions.

6.6 Maori terms and phrases

Hapu	Subtribe, extended whanau
Hui	Consultative meeting
Iwi	Tribe
Kai Tahu	Descendants of Tahu, the tribe
Kai Tahu whanui	The large family of Kai Tahu
Kaitiaki	Guardians
Kaitiakitanga	Guardianship
Mahika kai	Places where food is procured or produced
Mana	Authority or influence or prestige
Manawhenua	Those with rangatiratanga for a particular area of land or district
Mauri	Life force
Rangatiratanga	Chieftainship or authority
Runanga	Local representative groups or community system of organisation
Taoka	All things highly prized, including treasures, property, a resource or resources or even a person (same as taonga)
Wai	Water
Wairua	Life principal
Whakapapa	Genealogy or family tree
Whanau	Family
Whanui	Large or extended

6.7 Bibliography

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