LAKE WANAKA – FOR BETTER OR WORSE?

PLANNING FOR THE FUTURE

SEMINAR HOSTED BY THE GUARDIANS OF LAKE WANAKA

LAKE WANAKA CENTRE   12 MARCH 2013

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Introduction
The Guardians of Lake Wanaka are appointed by the Minister of Conservation under the Lake Wanaka Preservation Act. Their role is to advise on "***preserving, as far as possible, the water levels of the lake and its shoreline in their natural state, and maintaining and, as far as possible, improving the quality of water in the lake".***

Following a successful workshop session in 2010, at which representatives of agencies with an interest in the lake were invited to exchange information on current activities and programs, the Guardians felt that a further seminar, featuring presentations from scientists and others with specialist knowledge and experience in maintaining lake quality, would be valuable in answering the basic questions essential to the fulfilment of the Guardians' role

- What is the present quality of the lake?
- Is it appropriate? Is it stable? Is it declining?
- How can we judge?
- Is action required to maintain or improve the quality?

A one day seminar was held on 12 March 2013, with presentations from scientists from Waikato and Otago universities and NIWA, as well as specialists from the District and Regional Councils, and representatives of the local resident and farming communities.

The Guardians are very grateful for the outstanding contribution made by the scientists who shared their knowledge of Lake Wanaka and of investigation and management of other lakes. They not only contributed their time and expertise, but generously provided for their own attendance at the seminar.

Intended Outcomes
The expectation of the seminar was to provide for:
- Sharing information on programs, research, monitoring and control efforts currently in place in New Zealand and beyond and reviewing relevance to Lake Wanaka
- Identifying areas where further research, improved monitoring or specific control programs could benefit Lake Wanaka, and other deep water lakes.
- Establishing priorities, identifying appropriate allocation of responsibilities and possible sources of funding where new or expanded initiatives or programs are seen as desirable.
- Identifying mechanisms to further co-operation and optimum follow-up

Themes of the Seminar
All the presentations reinforced strong themes:
- That the quality of Lake Wanaka (and other deep water Southern Lakes) is greatly valued locally, nationally and internationally
- That Lake Wanaka is currently in a good condition, but this condition has been changing over recent years
- That in order to know how significant changes are, it is essential to have good data.
  Good data is essential to good science. Good science is essential to good outcomes
- That it is critical to address any concerns regarding lake deterioration before major problems occur, rather than trying to mount a recovery operation.

Case studies of Lake Taupo and the Rotorua Lakes were very valuable in providing examples of the cost and difficulty of recovery operations, as well as examples of co-operative planning and management, with strong community input.

Where to from here?

Protecting the quality of Lake Wanaka for future generations will depend on:

- the establishment of community endorsed goals
- extensive and continuous monitoring
- co-operative oversight, involving all relevant agencies

There was a high level of support from all agencies and community groups participating at the seminar.

The Guardians have collated these proceedings for publication as a basis for advancing future efforts.

Helen Tait

Chair, Guardians of Lake Wanaka

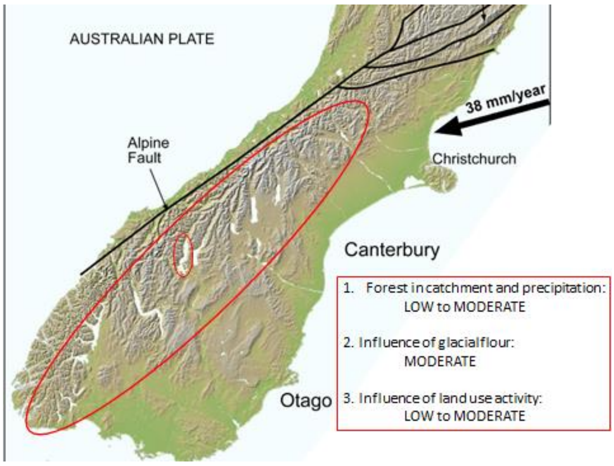
Seminar Programme – Contents

Lake Wanaka – Past, Present and Future
Dr Marc Schallenberg, Research Fellow, Zoology Dept., University of Otago
With input from Tina Bayer, PhD Student

Otago University work with Lake Wanaka started with some recordings taken in 1994 and 2002 by students undertaking comparative studies. It was not until 2008, with ORC funding for a PhD study of land use impacts on the lake, that the lake was studied in a more intensive way.

Marc Schallenberg's background was growing up in Toronto, on Lake Ontario, and spending time on the surrounding freshwater lakes and streams, which led to his interest in freshwater ecology. After his PhD he came to a position at NIWA, and then to Otago University, where he has undertaken research, including work with colleagues at the Cawthron Inst. and NIWA. His scope has included over 70 lakes from Northland to the Campbell Islands, allowing him to place the study of any individual lake into a broader context – ecological (his prime focus) as well as economic, recreational and cultural.

The origin of Lake Wanaka is in the clashing of the Australaisian and Pacific tectonic plates, which pushed up the mountain spine of the South Island. The "roaring forties" location means that there is heavy precipitation from winds bringing moisture from the Tasman sea. Millennia of glaciation retreating and advancing have created an archipelago of lakes, all similar in draining to the south-east of the Southern Alps, fed by both rainwater and melting snow. They can be characterised as the "Southern Great Lakes" of New Zealand. There are advantages in studying the lakes as a group.



Lake Wanaka is in the middle of the archipelago, which has the following features at play: a vegetation gradient in the catchment from native forest in the headwaters through to open landscape with Tussock in Otago. In the Waitaki catchment there is an impact of glacial flour from the highest glaciers in the country. In terms of influences on Wanaka precipitation is in the low to moderate range, there is a little glacial flour, but nothing like the Waitaki lakes, land use intensity is low to moderate, but increasing. The lake can be seen as pristine, but is on the cusp of change.

Background specifics: Wanaka is a deep lake, at 311 m. one of the deepest in New Zealand; it is a large lake (180sq. kms), with a large catchment area (2590 sq. kms), and a large volume of water (33 cub. kms). The residence time (the time taken for the total volume of water to replace itself) is long at 5 – 6 years, meaning that the water stays for long periods, giving rise to some of the lake's characteristics – its clear water, and low nutrients, relative to other lakes.

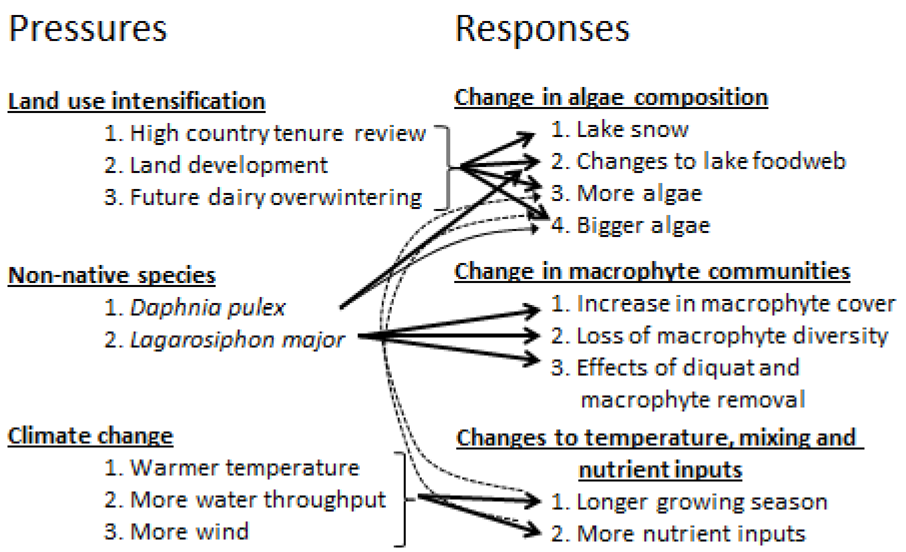
Values of Lake Wanaka include:
Natural values:

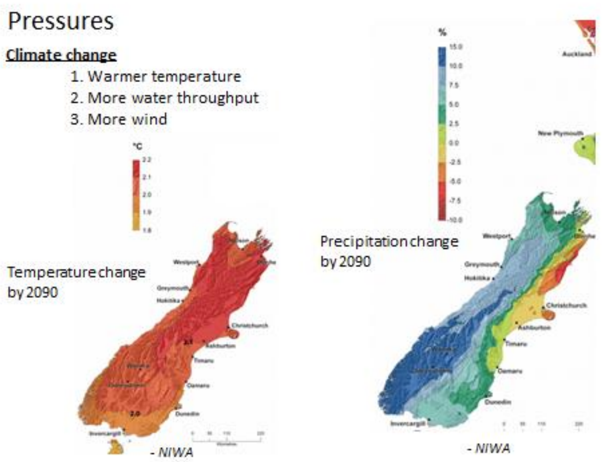
- Scenic beauty – the lake defines the region
- Relatively clean, clear water through self purification due to the long residence time
- Biodiversity

Economic values:

- Drinking water
- Recreation
- Salmonid fishery and commercial fishing activities
- Tourism
- Provides clean water to downstream communities

Pressures facing lake Wanaka include land use change, increased presence of non-native species, and climate change. This diagram shows the interaction between pressures and responses.



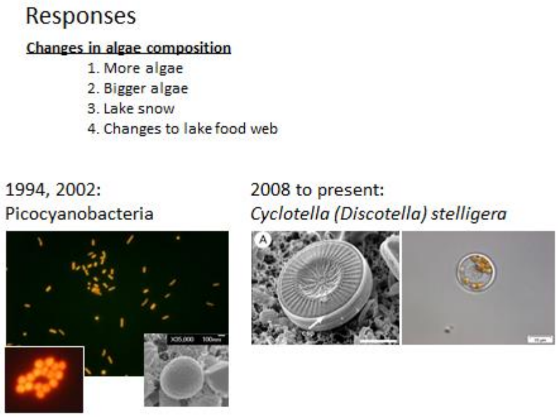


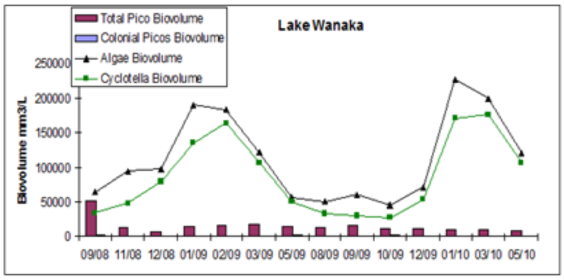
Land use intensification will be dealt with in Amy Weaver's presentation.

Climate change projections show that the lake can be expected to become warmer and subject to higher precipitation. There are already signals that there is more water flowing through the lake.

Responses:
There has been a shift in the composition of the dominant algae in the lake. In 1994 and 2002 student research found the dominance of Picocyanobacteria – the smallest organisms on the planet. Picocyanobacteria dominate low nutrient systems, and are the dominant plankton in the oceans. By 2008 they had been largely replaced by diatomaceous species like Cyclotella, commonly found in

"lake snow", so the microbial biomass has moved from an extremely small organism to a somewhat larger organism. These larger and more plentiful organisms have an effect on the food web in the lake, and a key question is whether they are a biological indicator of the effects of changes in climate and land use.



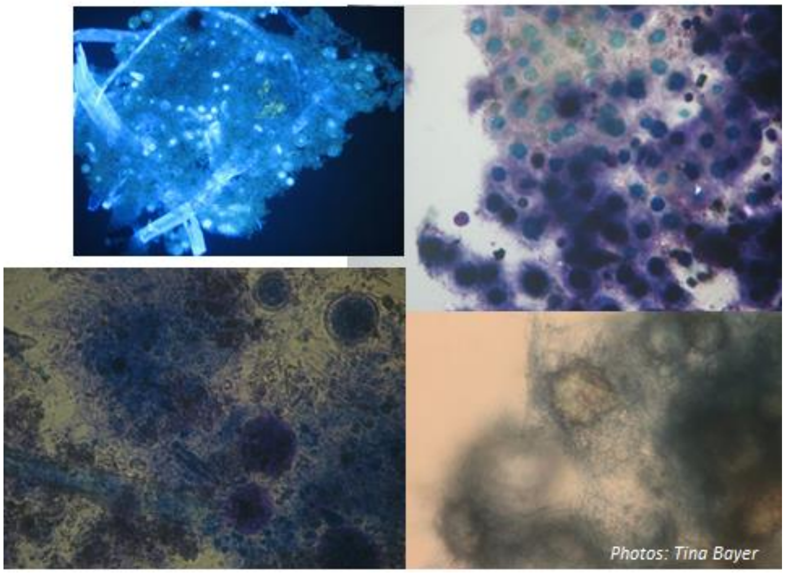


Dominance of *Cyclotella* sp. in Lake Wanaka phytoplankton. Algae biovolume refers to total algae including *Cyclotella*. 'Picos' refers to picocyanobacteria. [data from Tina Bayer, University of Otago PhD student].

Tina Bayer's work shows the total volume and dominance of algae, including Cyclotella, and the move from dominance of Picocaynobacteria to dominance of Cylclotella, particularly during summer periods. There does seem to be evidence of a link between Cyclotella and lake snow.

There is a short video on lake snow posted on UTube by the University of Otago, http://www.youtube.com/watch?v=94xs81d6w9Q which led to contact by staff from the Seattle Water Utility, who had a problem with lake snow in their drinking water supply – identified as being associated with cyclotella. They had taken photographs of the cyclotella, showing the long strings of polysaccharides, which were acting like a glue in the lake. This seemed very similar to the effect observed in Lake Wanaka.

It is not a common effect. Of the 70 lakes observed in New Zealand, it has only been found in Lake Wanaka, but has been observed elsewhere, such as Lake Constance in Europe and Mono and Youngs Lakes in the USA. It has been a cause of considerable concern to Wanaka residents and lake users. Microscopy photographs of Lake Wanaka samples show a high degree of similarity to the Seattle samples



Evidence for *Cyclotella* as cause of Lake Snow in Lake Wanaka

- *Cyclotella stelligera* dominant in Lake Wanaka since we first identified it in 2008 Prior to that (e.g. 1994, 2002), it was not important in the lake. Transition to dominant phytoplankton in Lake Wanaka could have occurred at the time when lake snow first appeared in 2003 (according to local fishermen)
- *Cyclotella* major constituent of lake snow in Lake Wanaka as in Lake Constance and in Lake Youngs
- *Cyclotella* in both Lake Youngs and Lake Wanaka produce transparent polysaccharide threads
- *Cyclotella stelligera* not found in Lakes Wakatipu or Hawea
- *Cyclotella* in Lake Wanaka bloom just before the typical time of year when clogging of water filters is reported (usually in March)

Lake Snow – Possible Causes

Potential Causal Factor	Likelihood: Sole Cause of Problem	Likelihood: Contributor to Problem
1. *Cyclotella* production		
1a. from nutrient inputs	Possible	Probable
1b. from *Daphnia* grazing	Possible	Probable
1c. *Cyclotella stelligera* is new introduction to Lake Wanaka	Possible	Unlikely
2. *Lagarosiphon* die offs	Unlikely	Possible
3. Diquat (gel matrix)	Unlikely	Possible
4. *Didymo* stalks		
4a. from inflowing rivers	Unlikely	Unlikely
4b. from growth in lake	Unlikely	Unlikely

QLDC (2011)

In 2011 a study was conducted in association with QLDC looking at factors in the existence of lake snow in the water supply. This chart examines possible causes and contributing factors, with cyclotella at the head of the list as the most likely contributing cause.

Pressures Continued - Invasive Species in the Lake

Dr Carolyn Burns of Otago University has conducted a study of d***aphnia pulex*** and d***aphnia carinata***, and the different environmental conditions which they prefer. The findings are that daphnia pulex definitely seems to prefer warmer temperatures, it does reach greater densities, and it therefore has a greater grazing pressure on the algae in the lakes and could additionally be selecting different algae. These studies are at an early stage, but could be an important element of the pressures and responses in Lake Wanaka.

Lagarosiphon has been a big issue for the lake and there have been efforts to control the invasion. (See later paper). This is another factor which shouldn't be forgotten.

Pressures Continued – Climate Change

Responses

<u>Changes to lake temperature, mixing and nutrient inputs</u>

1. Longer growing season
2. More nutrient inputs

Climate predictions (Ministry of the Environment, 2008):

- Mean air temperature: +1°C by 2040, and +2°C by 2090
- Higher rainfall in spring and winter, but a decrease (or no change) in summer. Annual +7% by 2040 and +12% by 2090
- Increase in strong westerly winds
- Decreased seasonal snow cover
- Increased frequency of high temperatures and extreme daily rainfalls

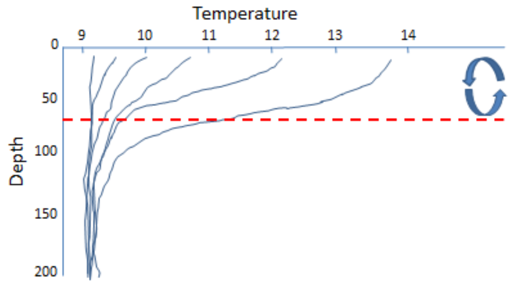
These changes will have a direct influence on the lake itself, as well as on the catchment. There will be more rainfall and run-off, bringing more materials into the lake, as well as a likely increase in wind-blown dust down the braided river valleys, which could potentially also add nutrients to the lake.

The question is raised as to whether these climate change effects could already be having an effect on the type of algae in the lake and the growing dominance of ***Cyclotella.*** Data collected by the Otago Regional Council, and provided by Rachel Ozanne, covers the period from 1994 to almost the present day. The temperature has been taken when water samples have been collected 5 or 6 times a year. Although discreet rather than continuous readings, the records do show an increase in winter temperatures over that time, in line with the prediction by climate scientists that it is winter and night-time temperatures which will respond most to climate change. Evidence from other lakes is that ***Cyclotella*** is linked to warming.

Climate Change and Lake Composition

In the winter the lake temperature tends to be constant at all depths, but as the lake warms in the summer the warmer water is more buoyant and sits on the surface of the colder water, requiring more and more energy to mix the warm water down. This increases both the temperature and the level of light in the algal environment driving the increase of the algae.

Impacts of climate on lake temperature profiles



This was the focus of Tina Bayer's PhD research.

Impacts of climate on lake temperature profiles

Scenario A: no change in wind

- Shallower, longer thermal stratification
- Warmer lake

Scenario B: up to 10% increase in wind

- Deeper mixing, but still longer stratification
- Warmer lake

She took a complex model, developed by Professor David Hamilton of Waikato University, to take the NIWA climate change predictions and draw some conclusions about lake mixing. The study examines two scenarios: a change in temperature, with wind levels remaining the same, or with a 10% increase in wind. Both scenarios provide a longer growing season for the algae, with more available light. This, coupled with a likely increase in nutrients also leading to increased development of algae raises the question as to what is the next stage after ***Cyclotella,*** continuing the growth trend.

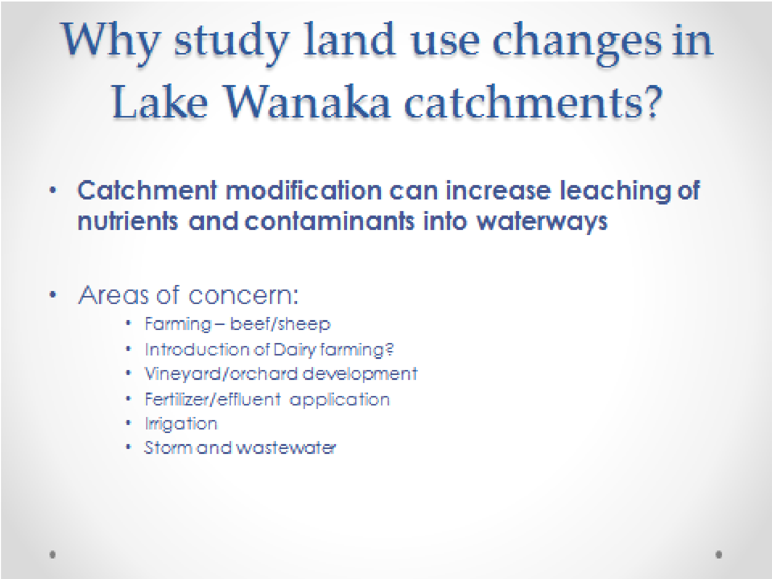
Conclusion

Overall the factors examined in studying pressures and responses indicate a need for more data and further study. Some issues requiring further exploration will be raised in later papers.

Acknowledgements:

1. University of Otago
2. Prof. Carolyn Burns
3. Students (Tina, Amy, Michelle, Lisa)
4. NIWA and the Ministry of Science and Innovation
5. Otago Regional Council (J. Threlfall, R. Ozanne)
6. Queenstown Lakes District Council (G. Essenberg, M. Heather)
7. Guardians of Lake Wanaka (Helen Tait)
8. People of Wanaka

Land-water Interactions in the Lake Wanaka Catchment
Amy Weaver, PhD Candidate, Zoology Dept., University of Otago
Supervisors: Dr Marc Schallenberg, & Prof. Carolyn Burns



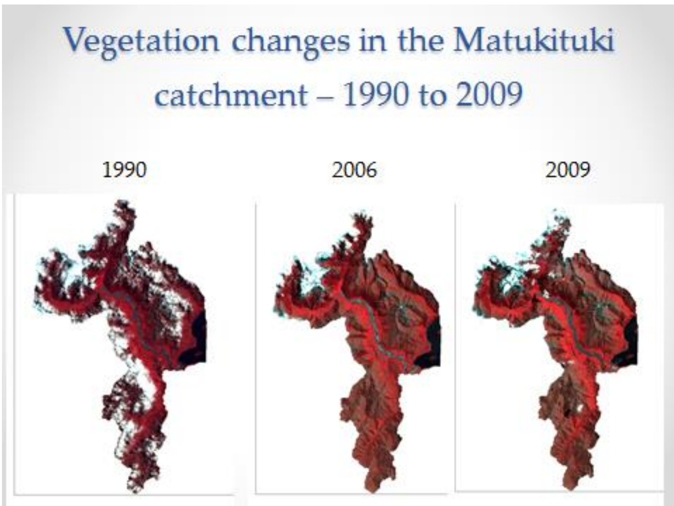
The purpose of Amy's study is to discover whether changing land use patterns are causing an increase in nutrients entering the lake, and, if so, whether this increase is having an adverse effect on the lake.
The study monitored 9 streams, representing a gradient of land use. In particular the Matukituki streams were monitored to assess the material being carried into the lake and the distance into the lake.
The second part of the study examines the cycling in the lake and the extent to which nutrients entering the lake are taken up by micro-organisms.
The third part of the study examines the relationship between nutrient build-up and the formation of "lake snow", the slimy substance which has caused concern to fishermen by clogging their lines, and has caused problems with clogging water supply systems.
Considerable data has been collected and is still being analysed to provide information on:

- Changes in vegetation
- Visible changes in the landscape over 20 years (via remote sensing)
- A stream study – focusing on nutrients and organic material
- The relationship between nutrient input and "lake snow"

The following presentation focuses on the latter two elements: the stream study and the formation of "lake snow"

Known Historic and Prehistoric Changes to the Catchment

By the end of the last glacial period the area around the lake was predominantly grass and shrubland, which was taken over around 7,500 years ago by evergreen forest – lasting until around 600 years ago, when repeated fires destroyed the forest communities, and they were replaced by grassland.
With the arrival of European settlers grasslands were favoured for livestock grazing, and remaining forests removed by milling.

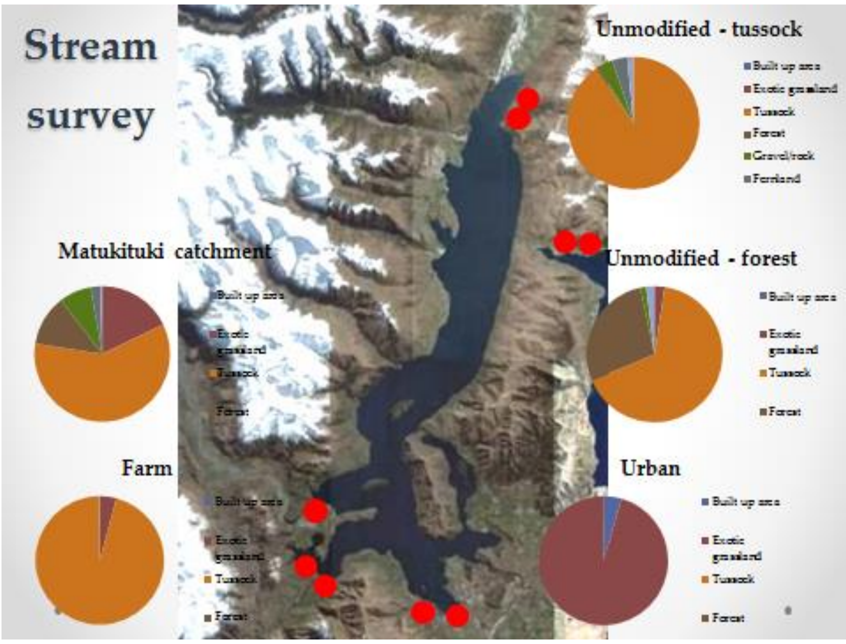


The land use continues to change, as shown through remote sensing imagery. The images show the Matukituki catchment with the red areas showing an increase in the greenness of the catchment, representing a change from tussock to exotic grassland, or the application of fertiliser.

This is important to study as human modification of the catchment can result in increased volumes of nutrients leaching through the soils into the streams and through sub-surface flow. The application of fertiliser can also increase the nutrient level and potential for leaching.

In urban areas there can also be increased nutrient run-off through storm-water with increased hard surface areas, and potentially an effect from the disposal of waste-water – all with the potential to affect rivers and streams. When these rivers and streams run off into a deep lake the effects of increased nutrients may be buffered, perhaps showing initially only in shallow bays, but experience with other large lakes, such as Lake Tahoe, or even Lake Taupo in New Zealand, shows that the increase can cause degradation over time.

What is Being Carried Into Lake Wanaka? And is There a Difference in What is Being Carried from Modified or Unmodified Catchments?



In 2009/10 and 2011/12 a survey of 9 streams was carried out, attempting to sample a gradient of land use types. It was difficult to identify a full range of land use types around Lake Wanaka, most being characterised by tussock grasslands. The least modified were streams flowing into Lake Hawea. The largest body of water sampled was the Matukituki, which is glacially fed, and was reviewed separately.

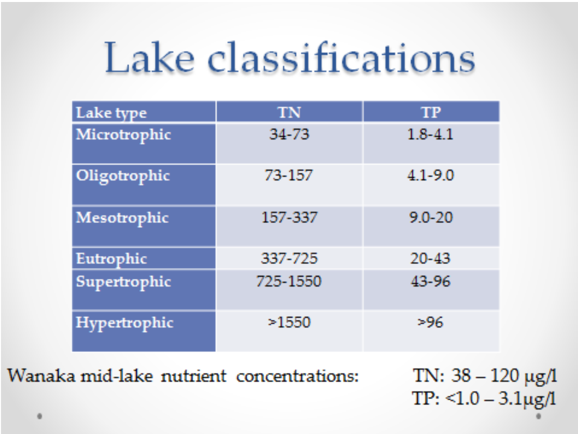
Diagram shows the gradient of land use of the study streams

The study measured temperature, dissolved oxygen levels, pH, and flow rate, as well as water samples to assess nutrient concentrate, including dissolved phosphorus, total nitrogen, total phosphorus, and dissolved organic carbon. At each sampling time NIWA climate data was noted. Percentage catchment cover in each case has been assessed from 2002 GIS data, but this is currently being updated to a later set of data.

The State of Lake Wanaka During the Sampling Period

Lake classification shows the range from a ***Microtrophic*** lake – typified by good water quality, and clarity to a ***Hypertrophic*** lake, with high levels of nutrients and organisms in the water – "sick" lakes. Wanaka during the study was characterised by ***Microtrophic*** to ***Oligotrophic*** levels, in terms of levels of nitrogen and phosphorus. Water clarity was good, with visibility down to 7 to 10 metres.

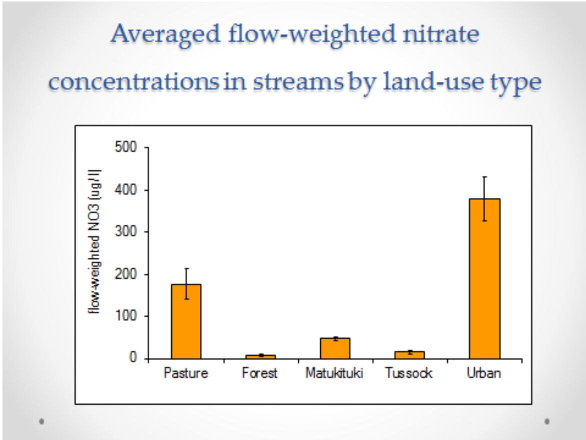
However, when the lake measures were compared with the stream samples, higher concentrations of nitrogen could be seen, depending on the level of modification.

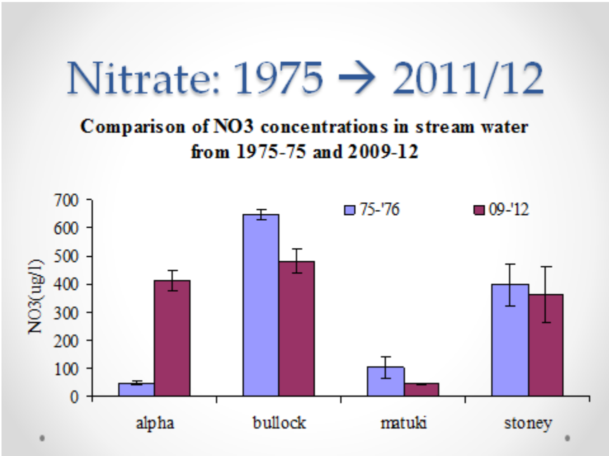


Lake classifications

Lake type	TN	TP
Microtrophic	34-73	1.8-4.1
Oligotrophic	73-157	4.1-9.0
Mesotrophic	157-337	9.0-20
Eutrophic	337-725	20-43
Supertrophic	725-1550	43-96
Hypertrophic	>1550	>96

Wanaka mid-lake nutrient concentrations: TN: 38 – 120 µg/l TP: <1.0 – 3.1µg/l





Overall study results can be compared with a study conducted in 1975/76 by the Guardians of Lake Wanaka. Four of the streams were common to both studies. Three of the streams show minor increase in nitrate levels from 1975 to the present day, but the Alpha Burn shows a difference too significant to be a difference in sampling techniques.

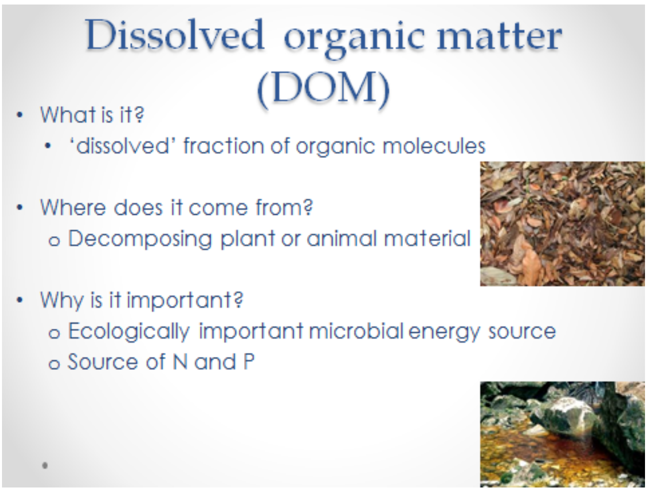
Phosphorus concentrations were more variable – generally low, but with occasional spikes, in both modified and unmodified catchments.

Dissolved Organic Material

In addition to nitrate levels, levels of dissolved organic matter can be an important indicator of lake health – important because it is a source of energy for bacteria, and in being broken down by bacteria can release nitrogen and phosphorus.

Levels can be changed through changes in drainage in the catchment.

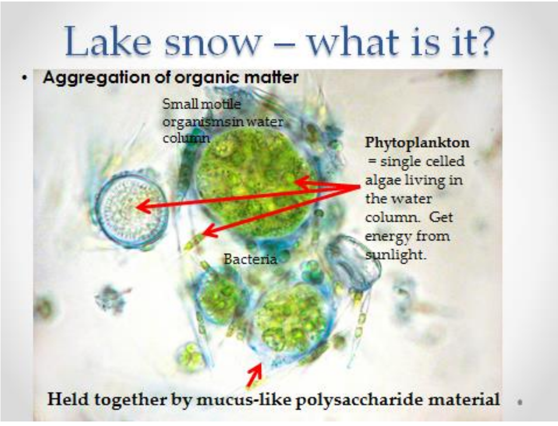
Results were similar to the nitrogen measures – higher in modified than unmodified catchments. It was interesting to note that forested catchments were not significantly higher than other unmodified catchments.

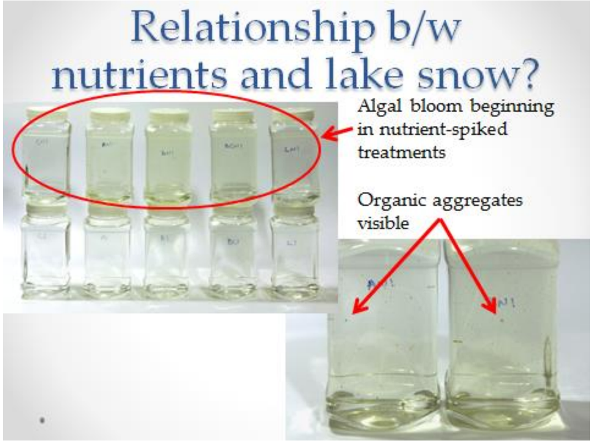


Overall a 30% variance was recorded in dissolved organic material, controlling for soil moisture

Impacts on the Lake

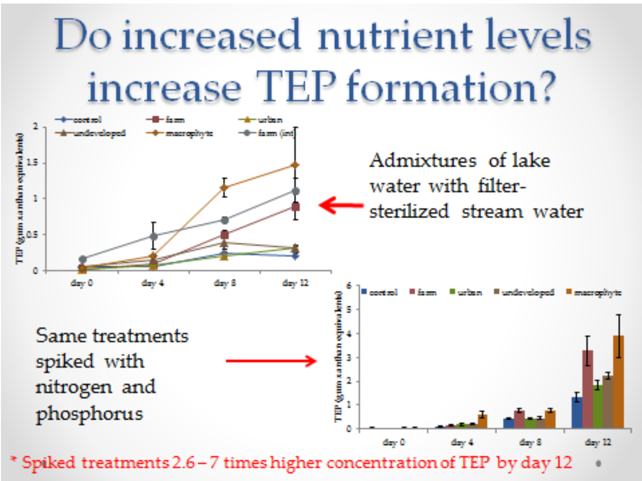
Impacts are difficult to assess because of the buffering effect of the lake size, but the study's interest was in examining the possible impacts on the formation of "lake snow" - which is the clumping together of microscopic bacteria and algae, together with a mucus-like polysaccharide material. It is often noticed during algal blooms, and is possibly caused by cells trying to get rid of excess energy. The clumps can get big enough to be seen with the naked eye.





In order to assess effects, stream water, from 3 different tributaries around the lake, was mixed with lake water: Alpha Burn – which drains a farmed catchment, Bullock Creek – to represent an urban catchment and Boundary Creek – to represent a tussock dominated catchment. Lake water was used as a control.

To assess whether decaying aquatic plants could be a source of the mucus-like material, fronds of lagarosiphon were left to leach out in a water and mixed with lake water.



Results overall showed an increase in TEP levels , which were 2.5 times higher when the experiment was repeated with water "spiked" with higher concentrations of nutrients.

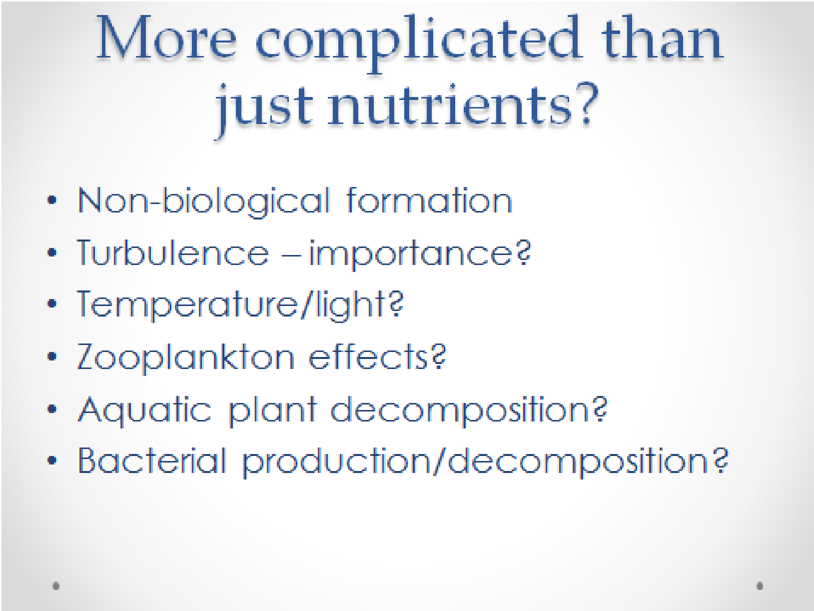
Assessment has not yet been undertaken as to the dominant form of algae, or whether the dominance changes during the build-up of nutrient levels.

The lake is of course a much more complicated environment with a wider range of variables than in the laboratory experiments, and further study is needed.

One area of interest is in the relationship between the polysaccharide build-up and the decaying of aquatic plants, particularly, for example after the spraying of the lagarosiphon beds. This could be analysed in the field before and after a spraying event, with a parallel controlled experiment controlling for light etc. There is the possibility of a nutrient pulse into the lake, which could create a bloom.

Further Study is Needed Both in the Field and in the Laboratory

There are numerous additional factors to be included in the studies over time:



Influences on the Lake: Current practices and observation of effects

1. Nichola Evans, QLDC 3 Waters Service Engineer

Nichola Evans has responsibility for 3 waters operational & maintenance services in Wanaka, including the control of stormwater – the release of water into the lake, and water supply – the taking of water from the lake. QLDC responsibility is not for maintaining or monitoring the quality of water in the lake, but for controlling what goes in, by way of stormwater, and making use of the water extracted for water supply.

Stormwater

3 Waters efforts deal primarily with the stormwater as it comes off the roads, by way of catch pits and mud tanks, where a syphon system and regular cleaning out deals with grit, which has been applied to roads in winter and oil residue.

The work is conducted within the ORC water plan rules for discharge of stormwater. The proposed Plan Change 60 will have an impact on how stormwater is discharged.

Additional development in Wanaka increases the impervious area, which in turn increases run-off, but infrastructure is set up in advance of development, so additional discharge is handled by the existing reticulation system.

Wastewater

The QLDC system discharges through Project Pure – which is tertiary treated and discharged sub-surface about 10 Kms downstream from Wanaka. The project has been set up within ORC consent requirements. QLDC also owns the Glendhu Bay campground where wastewater treatment has also recently been upgraded to tertiary treatment.

Water Supply

QLDC has consents for two water intakes – western, near Rippon, and another near the outlet. The daily take for the water supply is approximately 0.2% of the lake outlet flow.

Concern has been expressed regarding the algae which blocks filters in Wanaka during summer months. Complaints have been recorded and monitored since 2008, and seem to relate to problems throughout the system, rather than being confined to any particular area. The algae causes no public health concerns, and QLDC works within drinking water standards.

In May 2011 a report by MWH was published, examining algae issues – possible causes and proposed responses. Samples were monitored from 4 optional intake points around the lake. A micro filtration plant option was considered and trialled, but the cost of $6.3m was considered excessive for full implementation, based on community feedback to the Council Long Term Plan. There was 26% support for the project which would require a 6.8% increase on rates.

Intakes are regularly monitored and cleaned. A backwash is being installed on the western intake to reduce algae at that point. Continued monitoring of complaints and issues is in place.

2. Jonathon Wallis, High Country Farmer

Jonathon Wallis expressed appreciation of the seminar as a means of being proactive in safeguarding the values of the lake. He lives at and manages Minaret Station, on the western shores of the lake. The station accounts for some 26% of the lake shoreline. His brief for the seminar is to discuss present and predicted farming practices influencing the catchment area. He emphasised that he is not an elected representative of the local farming community, and therefore is presenting his own views, but believes that these views are generally held by others in the farming community.

It is important in examining farming in the area to maintain it in its context. Pastoral farming in the area is relatively unique. Farming is going through a significant time, with animals and people being required to work harder for less. The adage that farmers buy retail and sell wholesale has never been more true. Farming is increasingly being driven by factors beyond the farm gate. The public have heightened awareness and views regarding animal welfare and the environment.

Farming in the catchment is predominantly pastoral, with a small amount of cropping, mostly in the form of winter forage. Of approximately 150kms of shoreline of Lake Wanaka, two thirds is adjacent to pastoral land, but only a small proportion of this has direct access to the lake, as the majority of the marginal strip is fenced. While pastoral land makes up a significant proportion of the shoreline, it is a small proportion of the total catchment, the vast amount of which is land with perpetual conservation mechanisms in place, and unlikely to see any form of development, except perhaps increased recreational use.

Another point to note is that the majority of the pastoral land in the catchment is outside the area of the orographic rainfall. The higher the rainfall, the less the pastoral use, moving towards the mountains and the increased areas of conservation control.

The history of farming in the area dates back some 150 years, and has been through the typical exploitation, degradation then restoration and now conservation phases seen throughout rural New Zealand. This is typical of human nature in many areas – to exploit resources until awareness builds that they will not last forever, and a realisation of the importance of sustainability is developed, and practices of restoration and conservation are adopted. Farmers are very aware of the importance of resources and the effects on them, including the lake.

While there have been changes in land use, the changes in farming practices have not constituted intensification of land use as such, but can be classified as extensive to semi-intensive. It is important to note that this is unlikely to change, given the physical and climatic constraints, economic realities, and the tenure of the catchment.

Marc Schallenberg mentioned tenure review. The illustration shown was Mt Nicholas Station on Lake Wakitipu, which has not been through tenure review. The snow fence line, which shows a marked influence on the landscape, was put in place in the early 1900s, and the majority of the development on that property occurred through the land development scheme, which occurred in the late 1960s – emphasising that development in the high country has been going on for a long time. Tenure review in itself is not an intensification of land use, but an opportunity for the public and farmers to reassess whether the current tenure is the most suitable. Tenure by pastoral lease is not an encumbrance on development in itself, the constraints on development are present regardless of the form of tenure. Tenure review has seen about a 65/35 split, as properties are assessed, but has in fact shown a decrease in the number of animals farmed per farm. There have been changes in land use, but not necessarily intensification.

It is worth discussing fertiliser use – which in the catchment is minimal relative to industry standards. Use of less soluble, more natural fertilisers is a common theme, and the use of nitrogen fertilisers is relatively limited. The bulk of pastoral farming relies on set stock grazing, as opposed to rotational grazing, meaning that nutrient run-off by overland flow is unlikely to occur. The emphasis must therefore be placed on streams and rivers, and is likely to occur during high rainfall events, irrespective of the mitigation measures put in place. The vast majority of nutrients which enter the lake have nothing to do with human input, resulting from natural weathering and sedimentation of the parent material. This is not to suggest that focus on what cannot be controlled should be any excuse for not dealing with the aspects which can be controlled. Farmers are very aware of impacts, and of reviewing practices to deal with them – eg not placing silage pits close to the lake, installation of protective fencing etc. This has been undertaken alongside central and regional government initiatives.

In planning for any future responses it is important to build on facts and good science, and not on emotional responses. It is very disappointing that funding to date has not been available for the proposed monitoring buoy, as information is fundamental to appropriate action, and can provide a clear context. While we can learn from experience elsewhere, it is essential to understand the specific situation of Lake Wanaka, as that is our concern.

Summing up on farming aspects, it is important to emphasise that farmers are acutely aware of their role in the environment, and the level of public interest in that role, that they are malleable to change, and that they are quick to take up new technology. All these influences mean that there will be continuing change from past and present practices, which need to be informed by sound knowledge of impacts and effects. The local farming community will be keen to remain in touch with the Guardians and with future efforts to provide fuller information.

3. Graham Dickson, President, Wanaka Residents' Association

The issue of lake water quality has been of concern to the Residents' Association for quite some time. The Association was party to the proposal for a monitoring buoy and was disappointed that it did not proceed.

Wanaka is a resort town, and Lake Wanaka is the reason for its existence. It is important visually, as the centrepiece in the landscape, and is used for a variety of recreational purposes. The primary reasons for living in Wanaka are tourism, recreation, or as a retirement location, augmented by the requirement for a range of support services. The lake is also central to the existence of holiday homes and visitor accommodation. It is critical as the only logical source of drinking water for the town, and any problems such as toxic algal blooms would have a devastating effect.

The concern of local people is that they have seen changes in the lake over recent years. This has included lagarosiphon, lake snow and the fouling of fishing lines, didymo, and infestations of algae clogging the town's water supply. At public meetings, the evidence is that at least 50% of residents experience this problem. The fact that there is not a higher level of complaints is because people feel that nothing will be done.

Changes are of concern. Residents are aware of changes in North Island lakes, severe in the case of shallower lakes like Rotorua, but even Lake Taupo, which is a cold deep water lake more similar to Lake Wanaka has had problems which have led to major efforts to change and control land use. It is important to avoid reaching a major problem situation. Big lakes take a long time to go bad, but they also take a very long time to recover.

The Association is aware of changes in land use round the lake which may have effects which will take a long time to reverse. These include new subdivisions, establishment of golf courses and recreational resorts, intensification of farming (the installation of the first centre pivot irrigator in Dublin Bay was noted), and increased lake use. There are concerns about the effects on the lake ecosystem, and also concerns about the needs of communities further down the river, and protecting the quality of their water.

The Association believes that there should be a sensible precautionary approach aimed at identifying problems before they become serious. They believe that the following questions need to be answered:

1. Is the lake water currently satisfactory?
2. Are there trends and issues which could cause problems in the future?
3. Are there issues which require action now?
4. Do we have enough information to answer the first three questions?

The general response to these questions seems to be that current water quality appears satisfactory, that there probably are trends and issues which can cause problems in the future, and which require action now, but that we need sound information on which to determine these actions. It is important to have data about what is occurring in the lake, both at the surface and at depth, as a basis for good decisions which can be fully justified.

Discussion

Explanation of the earlier proposal for a monitoring buoy:
These have been developed in the North Island. A surface buoy has a string of sensors down to a considerable depth, giving continuous recording on a range of variables. At the moment all that is being done is infrequent spot monitoring, mostly at surface level. New technology developments allow for an increasing range of variables to be measured, and now provides for continuous reading throughout the column, rather than requiring duplication of individual sensors. There was a comment that lakes tend to "go bad" from the bottom up – and therefore data from deep levels is essential, rather than just surface monitoring.

The point was made that after the initial capital cost, there is a very low on-going cost of maintenance of the buoys, and that it is therefore a very valuable source of data over time on such areas as effects of climate change.

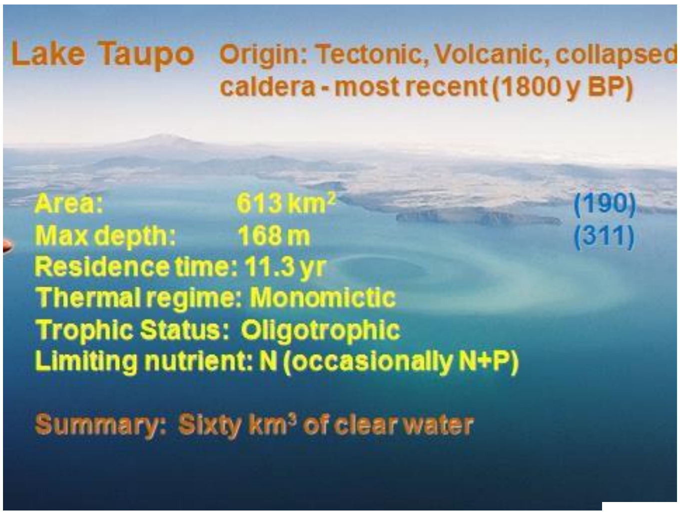
Importance of monitoring vegetation and other changes in the catchment area:
It is also important to gather and assess the significance of information on changes in vegetation and other aspects of the catchment over time. Data is available, but is not collected and reviewed in a systematic way.

Capacity for more intensive farming in the future:
(Reference to the earlier mention of a pivot irrigator). Pivot irrigation may simply provide, as in the area cited, for more efficient irrigation of an area which is already irrigated. The earlier reference to the unique nature of farming in the area is recognition of the climatic and physical factors which cannot be controlled, as well as the economic limitations of being at a great distance from commercial centres eg Ag lime can be bought in Canterbury for $20 per tonne and applied for $10 per tonne. In the Wanaka catchment the delivery cost is $90 per tonne, plus another $90 to have it picked up and applied by air. Technology may make changes, but the relativity will remain. Using Minaret Station as an example, in 1990 it was carrying around 2000 stock units, and is now carrying around 30,000, but in a context of set rather than rotational grazing, and with the majority of waterways fenced off. Water standards will be controlled by the new provisions currently under consultation, which are the highest in the country.
In comparison with the North Island lakes, which have potential for intensified farming in the catchment areas, the Wanaka catchment already has the majority of viable land for farming already in production.

To understand what future effects might be, it is important to have a clearer understanding of, for example fertiliser application. It has been assessed as minimal by industry standards, but what does minimal mean, what changes are occurring over time, and what types of fertiliser are being used? The trend is to use less soluble products less often, to make use of the natural rainfall and weathering process.

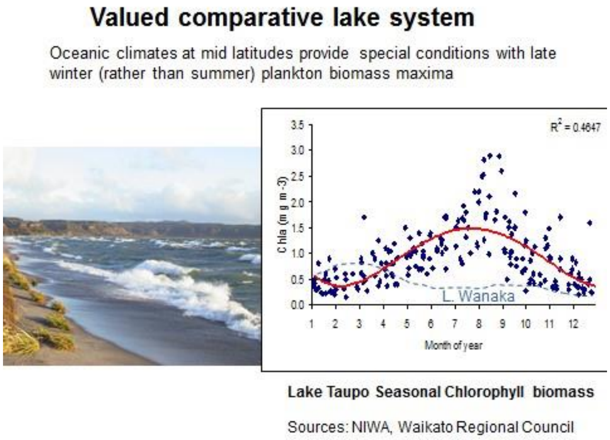
Case Study 1. Decision Framework for the Management of Lake Taupo

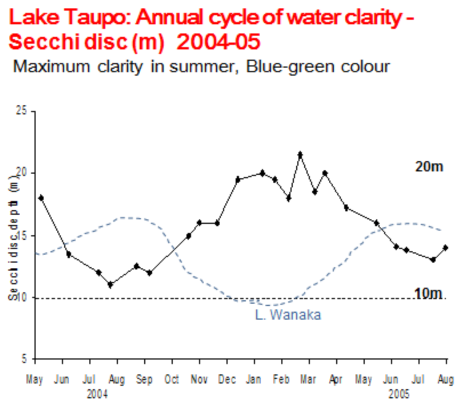
Dr Clive Howard-Williams, Chief Scientist, Fresh Water and Estuaries, NIWA



Lake Taupo is four times larger in area than Lake Wanaka, though less in depth. The residence time (time to replace the water in the lake) is over twice that of Lake Wanaka – giving some indication of the time expected to see, or achieve, changes. It is oligotrophic, and the limiting nutrient is nitrogen, with the surrounding volcanic soils giving rise to significant levels of phosphorus. The total of 60 cubic kms (compared to 30 in Lake Wanaka) is a very large body of water to maintain in a clear state, and over time.

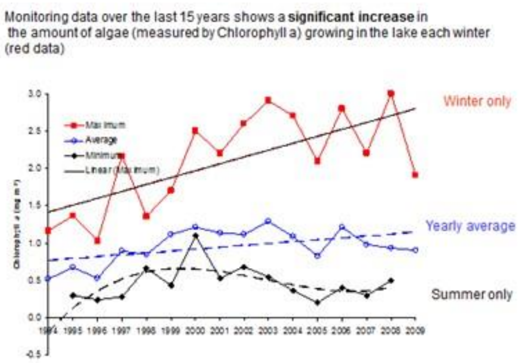
In Lake Taupo there is a winter phytoplankton bloom, with a much higher level of algae.

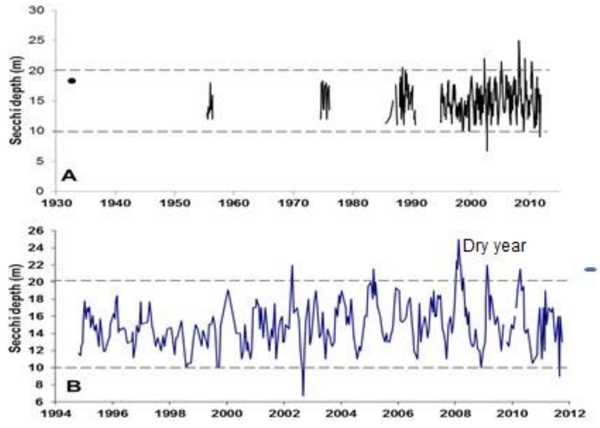




Because there is less activity on the lake in the winter, there is less awareness of the algal bloom compared to Wanaka where the highest algal levels are experienced in the summer when there are more people on the lake.

Because of its iconic status, Lake Taupo started to become a focus of concern from the mid 1980s. It was difficult to gather information about long term trends. The importance of clear information over time cannot be over-emphasised. There were some early warning signals of deterioration in Lake Taupo, with an increase in urban development adjacent to the lake giving rise to some areas of algae in swimming areas for example, but out in the middle of the lake it was much more difficult to discern the trends. The chart shows the variability between winter and summer, and the importance of long term data to highlight trends.



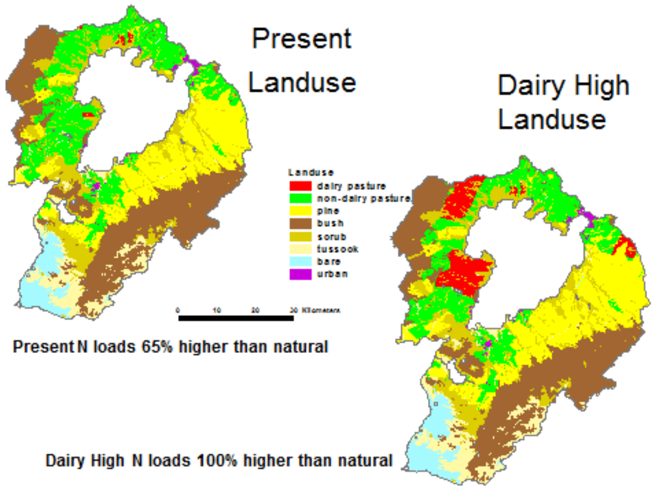


Water clarity as measured by Secchi depth.

In 2003 there were the first significant causes of concern, with warnings on swimming areas due to algal bloom. Water clarity measurements show an alarming reduction in measured clarity in 2003, at the time of the algal bloom, with subsequent improvements shown through to the level indicated at the right of the chart, showing the latest measurement back to about the best the lake has been.

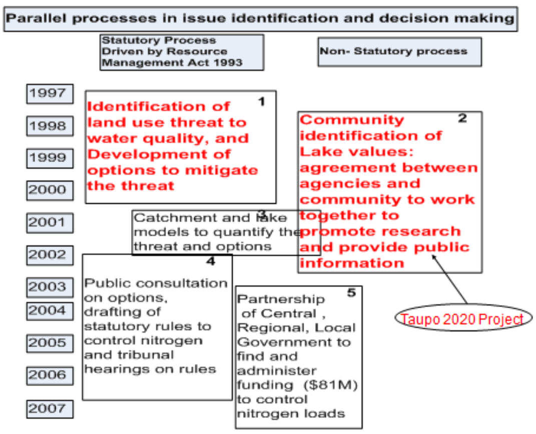
The other scientific early warning trend which was noted was the greater depletion rate of oxygen. As previously noted, it is not always evident from the surface of changing status, and measurement at depth is essential. Lake Wanaka at this stage has a very low oxygen depletion rate, indicating a healthy state at the moment, but it is the trands overall which add up. Because of the long residence time, it is too late for action once effects are clear at surface level.

In 1999 there were some proposals for a substantial increase in allocation of land in the Taupo catchment to dairy use (red on the map) which would have almost doubled the increase of nitrogen going into the lake above natural levels. In general pine forest or undeveloped land leeches about 2kg of nitrogen per year, sheep and beef farming about 7kg, and dairy farming 25kg +



There are some 56 inflows into Lake Taupo which are monitored by the regional council. Porous volcanic land structure means that many of the aquifers are deep and have a long holding time for the water, adding to the difficulty in discerning trends.

The Processes Undertaken in Reviewing Lake Quality and Control



In the late 1990s the substantial threat from intensification of land use in a sensitive catchment was recognised. This led to the establishment of the Taupo 2020 project by the Ministry for the Environment. This was a two year community consultation process, consulting with the widest possible range of community groups, businesses and iwi. It generated a substantial amount of published material – pamphlets on lake weed, lake clarity, algae etc. leading to increased public awareness. It also resulted in a range of scientific and monitoring agendas to be put in place.

The key thing which came out of the Taupo 2020 consultation was an agreed set of values, which could also be relevant to the Lake Wanaka situation. A desire for clear water was the over-riding value, which in turn would achieve a number of the other values. The focus of effort was therefore concentrated on the regulation and controls required to maintain clear water, and a key element of that was recognised as a need to minimise nitrogen levels.

Community based environmental values from ***Taupo 2020*** **project** consultation

1. **Clear water, high quality inflowing water**
2. High biodiversity
3. Maori cultural values (trad. food harvest)
4. Good trout fishing
5. Recreational opportunities
6. Safe drinking water
7. Safe swimming
8. Weed-free lake
9. Lakeshore reserves, Outstanding scenery
10. Wilderness areas, Geological features

Nitrogen is the key

Models:

1. Catchment-based nutrient load model GLEAMSHELL *(Eliott and Stroud 2001)*: provides nutrient inputs from all sub-catchments to:
2. Combined 1-D CWR Lake hydrodynamic model - DYRESM coupled with the CWR Lake ecosystem model - CAEDYM *(Hamilton and Schladow 1997)*, modified by *Spigel et al. 2001*

Modelling Scenarios for N loads:

	tonnes N/yr
Pre-development land cover	728
Present land cover	1200
Moderate dairy increase (Dairy - med)	1370
Large dairy increase (Dairy - high)	1450

To progress understanding of actions which could achieve the desired values, the Ministry for the Environment, the Waikato Regional Council and Dairy NZ (then called Dairy Insight) funded the development of lake models – catchment models, water quality models, physical models etc. The catchment model was key in showing what the effect would be if the planned changes in land use were put in place, with a large increase in dairy use in the catchment resulting in a substantial increase in nitrogen load per year into the lake – to double the pre-development levels.

Overall the models showed that there would be long response times – 20 to 30 years for conservative variables, and up to 5 years for biological and oxygen processes. Projections, based on the model of the high dairy option indicated that by 2020 the following effects could be expected:

- 21% increase in nitrogen
- 47% increase in algae
- The transparency of the lake would be reduced by 2.5m
- There would be a change in lake colour from blue-green to green

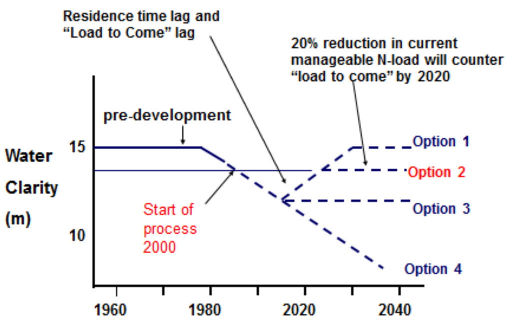
All effects which were counter to the values derived through the consultation process.

As a result of all the information from modelling, and early warning signs of changes occurring, Environment Waikato put out an issues and options paper which examined four options

Environment Waikato ***"Issues and options for managing water quality in Lake Taupo"***

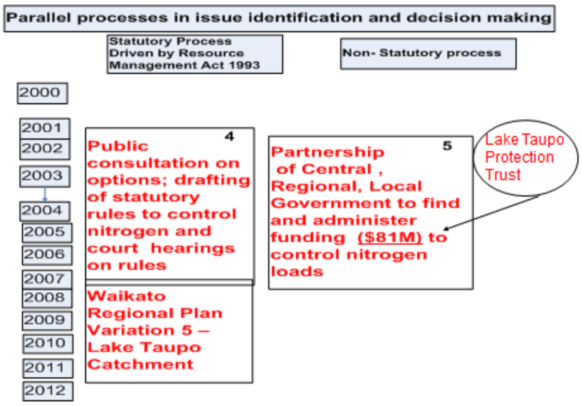
Four management options:

1. Return to pre-development (pre 1980s);
2. **Maintain current (2000 AD) water quality by reducing manageable nutrient load by 20% due to 'load to come'**
3. Maintain current nutrient load recognising that load to come: water quality will deteriorate and stabilise at a "lower" quality;
4. Do nothing: lake will continue to deteriorate over time and loads continue to increase.



Lake Taupo nutrient management options

The recommendation was to adopt option 2 – to maintain the current water quality by reducing the nutrient load by 20%. This would require the authority to promulgate regulations aimed at reducing the level of nitrogen from the catchment by 80 tonnes from the 2000 level.



Consultation & Regulation

By 2002 public consultation on the options was commenced, with the required regulations drafted for discussion. The regulations went to a regional council hearing in 2006. The decisions were appealed and went to the Environment Court, as variation 5 to the Waikato regional plan, and were confirmed in 2011

Variation 5 to the Waikato Regional Plan (RPV5)

Confirmation by Environment Court on 17 June 2011

- **ID Lake Taupo as an outstanding water body on Waikato region**
- **Cap N outputs from land in the catchment (NDAs)**
- **Reduce N from landuse activities and wastewater by 20%**
- **Review N reduction target**
- **Ensure that phosphorus discharges do not get to adverse levels (ie manage N+P)**
- **Public fund to share costs of reducing N from rural land (Lake Taupo Protection Fund)**
- **Permit N trading through transfer of NDAs**

Funding

At the same time the government stepped in, with the establishment of a Lake Taupo Protection Trust and a contribution to the fund to be administered by that trust. (45% of the $81m over 15 years). The fund is applied to incentives to change land use and to purchase land.

Lake Taupo Protection Trust

A Charitable Trust set up under the Local Government Act (2002) and formed with a fund of $81.5 million over 15 years to help protect the water quality of Lake Taupo. Reviewed after 5 years.

Ministry for the Environment	*45% - Taxpayer*
Environment Waikato	*33% - Regional Ratepayer*
Taupo District Council	*22% - Local Ratepayer*

Role of LTPT in protecting the water quality of Lake Taupo:

- Initial Benchmarking (with Regional Council) of nitrogen discharge allowances (NDAs)
- Purchasing N (20 %)
- Facilitating N reduction with land owners
- Supporting research and the technology transfer to reduce N
- Facilitating joint ventures or partnerships to achieve Trust objectives
- Sourcing additional funding (Charitable Trust)
- Monitoring and reporting on Trust performance

Current Process (RPV5)

1. Capping of current nutrient loads

- Identify nitrogen loads from farms: Nutrient budget for every farm (OVERSEER Model)
- Allocate a statutory nutrient load (NDA) to each farm (and forest) based on current loads (nutrient capping)

2. Reduce loads by 20% (Lake Taupo Protection Fund)

- Purchase dairy farms
- Encourage conversion to low nitrogen-loss land use
- Convert farms to forestry
- Change livestock farming to biomass/biofuel production
- Purchase and conversion of farms for reserves

Outcomes

The present process is a combination of the framework provided by the regulations in Regional Plan Variation 5 plus the ability of the Lake Taupo Protection Trust to provide incentives to achieve the initiatives required.

Nitrogen loads for each farm were identified, using the OVERSEER model, which has been controversial, in that it set allowances at the current levels, and makes no recognition of subsequent activity, such as the introduction of wetlands or other mitigation measures.

Nitrogen levels were capped, but nitrogen trading is allowed to encourage changes in land use.

Farmers have taken up the challenge of meeting the reduction requirements, and there has been substantial change in management practices.

Farmers were very wary of nitrogen capping regulation, preferring a best practice approach. They are concerned about a precedent approach being applied to other catchments.

Load levels were grandfathered, not averaged – which meant that foresters and others did not have the potential of their land recognised.

There was concern about the wider application of the principals of the variation

On 10 March 2013 the Minstry for the Environment released a paper – Freshwater Reform 2013 and beyond. This contains an article "Managing Under Limits" – which deals with the good management practices being pushed by the farming industry.

Overall what has been achieved was based initially on good sound information, as a basis for comprehensive data modelling, which fed into changed regulations and extensive community consultation.

Discussion

1. (Jonathon Wallis) The ORC proposed water plan incorporates elements of the Waikato plan variation, in the area of nitrogen capping. OVERSEER is a model which was designed in conjunction with AgResearch. Weaknesses are acknowledged, because it was not originally designed for this purpose, but it is one of the better tools available.

   One of the problems in the Upper Clutha is that moving upstream towards the less used land, the rainfall increases. Rainfall has a huge effect on outputs as measured by OVERSEER. This is the topic of further discussion in the review process which the ORC plan is going through.

2. The effect on land values of the Taupo regime was questioned. Dr Howard-Williams was not aware of data on this. Jonathon Wallis advised that this was the subject of a submission by farming interests, as land values dropped substantially – even before the new regime became operative, particular in areas assigned a low cap level, such as forestry.

   In comparison, land values in the Wanaka catchment tend to be influenced by factors other than pastoral production eg aesthetic values.

3. (Marc Schallenberg) Although the research showed that for Lake Taupo it was clear that nitrogen was the main nutrient involved, it is important not to simply make that assumption for Wanaka. Independent data will be required. The geology means that the Wanaka catchment is more balanced, and the variables for modelling in the case of Wanaka would be different.

Case Study 2. Rotorua Lakes and the Value of Monitoring
Prof. David Hamilton, Prof. of Lakes Restoration, University of Waikato

(An introductory comment was made regarding the Chair of Lakes Restoration, occupied by Prof. Hamilton. This chair, plus a number of post-doctoral fellowships, plus funding for PhD programmes are all funded by the Regional Council. This funding attracts complementary funding from central government and the university, to provide total funding of approximately $1m. per annum.)

Prof. Hamilton's presentation focuses on how good monitoring leads to good science, which supports good lake management. It covers the following aspects:

- Monitoring lakes across the globe, and the timescales necessary to perceive trends
- An explanation as to why was nothing done earlier in the Rotorua area
- The importance of leverage
- Supporting innovations in monitoring
- Some comments regarding the future

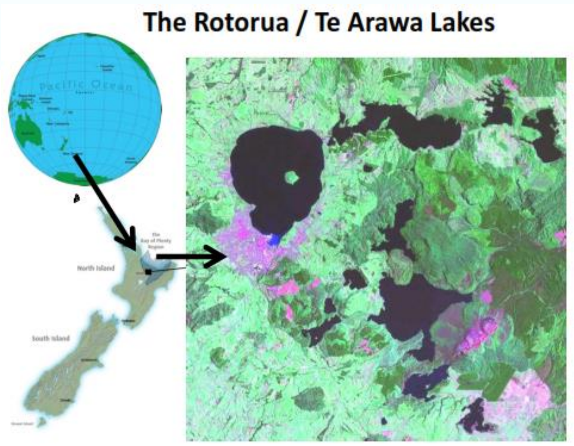
Lake Tahoe in the US provides an example of a deep-water lake which is affected by activities from a wide area – even by dust storms in China. Monitoring data recorded over an extended period was able to show the degradation effects and provide a basis for introducing clean air legislation in order to protect the lake from further deterioration.

Lake Mendota, Wisconsin, USA, is one of the most studied lakes in the world. Records over 142 years were required to show that the annual ice cover has gone down from 120 days to 90 days.

Lake Taihu in China has very good long term data, showing that, from about 1950 it has gone from a clear water lake with abundant fish resources to 2007 when it was showing substantial deterioration – a cause of concern as it is the source of drinking water for around 7 million people.

All of these show the importance of long term monitoring, as short term variation from year to year can mask trends.

Rotorua Lakes



These are culturally very significant, and this has been a major driver in achieving action on lake restoration. At the time when ownership of the lake beds was returned to Te Arawa in 2004, it was pointed out how much deterioration there had been during the time since they had gone into Crown ownership in 1922.

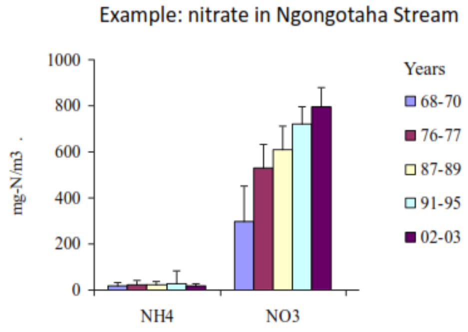
They are an amazing set of lakes, made particularly interesting because of the geothermal activity in the area.

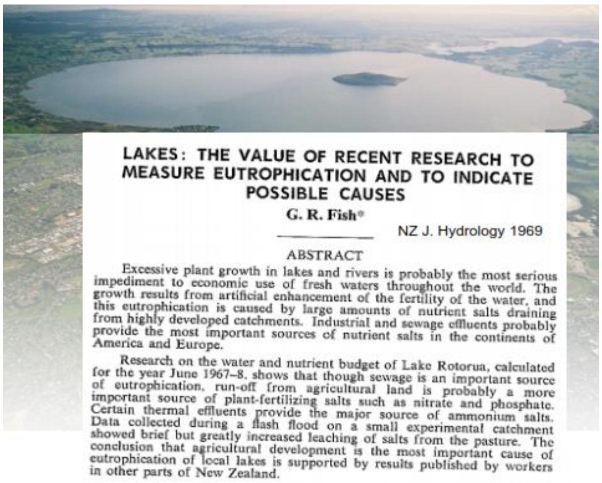
Lake Rotorua is around 80sq.kms – less than half the size of Wanaka, and relatively shallow with an average depth of around 10m. It previously had treated waste water discharging into the lake, until 1991, when it was discharged to land. Less than 10% of the original waste water load now travel through ground water leaching to the waterways.

Nitrogen Run-off

The Kaituna catchment scheme was designed to restore riparian vegetation, and this along with the change in waste water treatment was designed to reduce degradation. However there was still considerable nitrogen run-off with intensification of land use. The trend in the Ngongotaha stream was replicated in 9 of the 10 streams running into the lake.

At a local scale: Effects of land use change and agricultural intensification on stream nitrate conc.





LAKES: THE VALUE OF RECENT RESEARCH TO MEASURE EUTROPHICATION AND TO INDICATE POSSIBLE CAUSES

G. R. Fish*

NZ J. Hydrology 1969

ABSTRACT

Excessive plant growth in lakes and rivers is probably the most serious impediment to economic use of fresh waters throughout the world. The growth results from artificial enhancement of the fertility of the water, and this eutrophication is caused by large amounts of nutrient salts draining from highly developed catchments. Industrial and sewage effluents probably provide the most important sources of nutrient salts in the continents of America and Europe.

Research on the water and nutrient budget of Lake Rotorua, calculated for the year June 1967–8, shows that though sewage is an important source of eutrophication, run-off from agricultural land is probably a more important source of plant-fertilizing salts such as nitrate and phosphate. Certain thermal effluents provide the major source of ammonium salts. Data collected during a flash flood on a small experimental catchment showed brief but greatly increased leaching of salts from the pasture. The conclusion that agricultural development is the most important cause of eutrophication of local lakes is supported by results published by workers in other parts of New Zealand.

Knowledge and Action

It is interesting to note that as far back as 1969 a paper by Geoff Fish identified agricultural run-off as the major cause of increased levels of nitrogen.

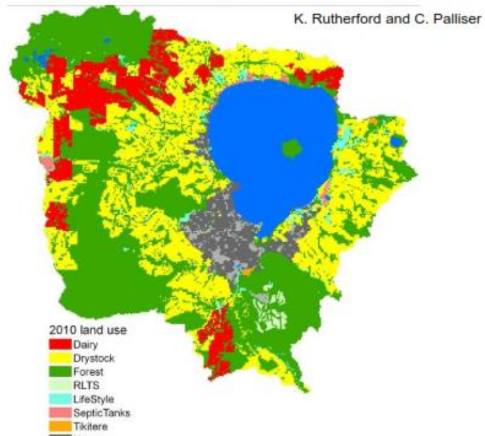
A recent PhD study has been started to examine the relationship between what was known scientifically and the follow-up with enactment of regulations and other responses

Land Use

The map shows land use in the catchment as in 2010, as a result of natural development rather than through any policies or regulations, but leading to a situation where it may be difficult to change land use to protect the lakes.

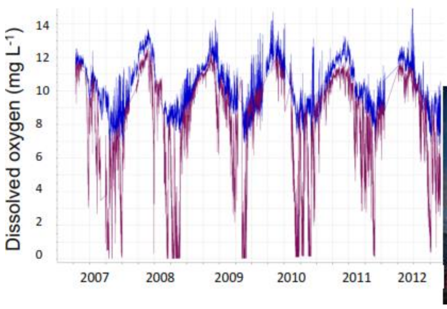
By 2010 there were roughly 25 dairy farms in the catchment.

Regional changes in land use: Lake Rotorua



Oxygen Levels at Surface and Depth

Lake Rotorua
Surface and bottom dissolved oxygen, 2007 to 2012



The chart shows the surface reading (blue line) which shows the seasonal lack of oxygen, and the red line, which shows the reading at depth. The readings were taken with the use of a deep water buoy, which has been in continuous use for about 5 years.

Each time the bottom line reaches zero it indicates a chemical reaction of huge releases of nutrients - an equivalent of almost the whole nutrient load of the catchment being released from the sediments.

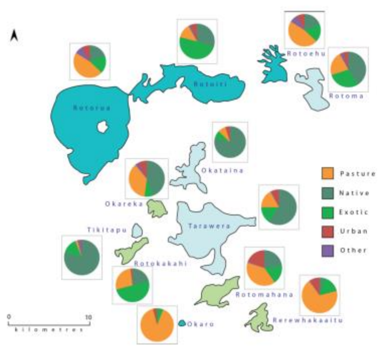
It shows seasonal lack of oxygen fairly clearly until 2011. At that time the change was interpreted as being indicative of a windy summer. As a result the lake was mixing a lot and not showing the usual loss of oxygen. 2012 has been one of the hottest, and certainly the driest summers ever experienced, but interestingly shows a similar pattern of oxygen loss.

It is for this kind of data that continuous recording is particularly important. It would be quite impossible to get "snapshot" recordings of activity and oxygen levels at depth with a random recording method, or even with good sampling, for example monthly.

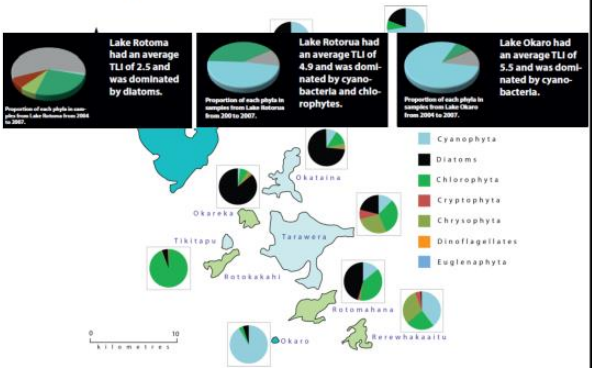
Variation in Land Use

An interesting feature of the Rotorua lakes catchment is the variation in land use for different lakes eg Okaro with almost totally pastoral land use, Okataina, with almost totally native vegetation.
Similarly, there are a variety of algal groups within the lakes, which reflected the type of surrounding land use. Eg Okaro has more than 75% blue-green algae.

Land use around Rotorua lakes

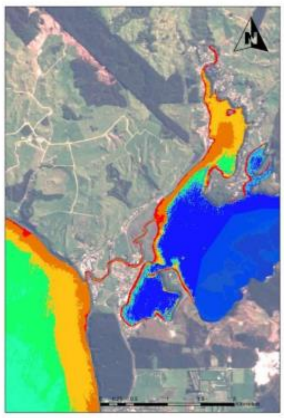


Phytoplankton composition in lakes



Rotoma, which is generally the lake with the highest quality water, is dominated by diatom algae, while Okaro for example is dominated by cyano bacteria – the level of which appears generally related to the level of total phosphorus, the tropic state, and the level of pastoral use in the catchment.

Rotoiti, which had been considered the "jewel in the crown," by 2003/04 had some very severe algal blooms. It was considered was that the water from Rotorua, going through the Ohau Channel to Rotoiti was the cause of the problem, and that improvement could be achieved by diverting the water from Lake Rotorua directly through into the Kaituna River. Substantial modelling was undertaken as a basis for the diversion design.
The satellite image shows the effect of the $10m. wall.



Satellite/aerial views of diversion wall, Lake Rotoiti

Implementation of options depends on good science underpinning decisions. A Rotorua Lakes' Technical Advisory Group of about 10 scientists meets about 3 monthly to review options for implementation.
Regulations and policies flow from good information and well-founded recommendations. Eg the use of the chemical zeolite to lock up some of the phosphorus in the lake, and the introduction of wetland areas and detention dams adjacent to lakes to trap sediment and prevent nutrients going into the lake.

A masters student has been working on the effects of detention bunds, intended to pool water for 2 or 3 days, so that there is potentially still productive pasture, but much of the sediment will be prevented from reaching the lakes.

Another project has been destratification – basically aeration in order to create mixing.   Two aerators are installed in Lake Rotoehu, and effects have been intensively monitored.

Weed harvesting has been trialled to deal particularly with hornwort, and is removing large quantities, not just of hornwort, but also of nitrogen and phosphorus.

Over $100m. is going in to sewage reticulation in the Rotorua lakeside communities.

"End of pipe": What can be done downstream for lakes?[1]

Action	How does it work?	Example of costs	+	-
Sediment capping/ phosphorus inactivation	Chemicals like 'alum' can lock up nutrients in lakes	Lake Okaro (30 ha) modified zeolite application[2] c. $75 000 p.a. over 3 years[3] Lake Rotorua alum dosing $1M p.a.	•Proven effective overseas[4]	•Culturally sensitive •Toxicity issues •Repeated applications required •Extensive consenting process
Dredging	Removes nutrients in bottom sediments	Expensive although costs will vary considerably depending on circumstances	•Proven effective overseas[5]	•Expensive •Disposal issues •Adverse environmental effects •Can fail[5]
Oxygenation/ destratification	Air/O_2 pumped to the bottom of lakes can reduce nutrient releases and increase lake health	Destratification trial in lake Rotoehu (790 ha): $524 000[6]	•No chemicals •Low level of intervention •Potential for rapid results	•Ongoing operational costs
Hypolimnetic withdrawal	Removes poor quality water at the bottom of stratified lakes	•Limited application so far in NZ but proven to be "low cost" in Europe and USA[7].	•Proven effective overseas[7]	•Potential downstream effects •Not suitable for all lakes
Weed harvesting	Removes nutrients locked up in excess weed growth	Hornwort harvesting in Lake Rotoehu (790 ha): $52 800 p.a[8]. ⇒$22/kg N and $165/kg P	•Co-benefits	•Ongoing operational costs •Limited efficacy on its own
Biomanipulation	Modification of food webs can enhance perceived water quality, e.g. reduce algae	Limited application so far in NZ for eutrophication control	•Potential for long term benefits without engineering interventions[9]	•Risk of unpredictable adverse ecological effects •Disastrous record of biological introductions in NZ
Inflow diversion	Diverts nutrient-rich lake inflows downstream	Ohau Channel wall in Lake Rotoiti (124 ha): $10 million[10]	•Potential for immediate benefits	•Adverse downstream effects

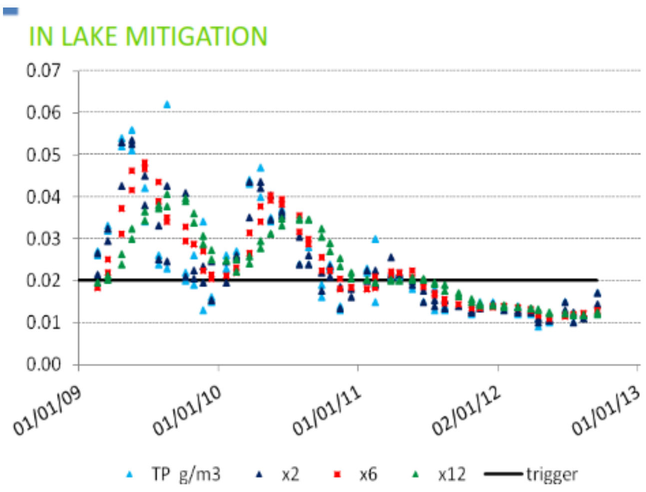
The range of costs in the chart shows how expensive the range of remediation efforts can be.

The cost of phosphorus applied at the top of the catchment is about 20 – 30 cents per kg.

To remove the equivalent amount at the bottom of the catchment in lake remediation efforts may be $250 per kg.   The more that can be kept at the top of the catchment, and kept on the land the better, because of the very high cost of remedial treatments lower down.

Remedial Actions

The chart shows the beneficial effects of a range of remedial actions in Lake Rotorua. Based on concerns generated by earlier data, a target level of 0.02 parts per million was identified, and has now been achieved, and has allowed the lake to become a recreational playground again.



Lakes Restoration Chair, Waikato University

The establishment of the Lake Restoration Chair in 2002 has generated a great deal of leverage and co-benefits. Internationally and nationally, it has provided a focus for the range of research which has underpinned the ability to take action.

There is a complementary value in the existence of the technical advisory group, with scientists from NIWA, other universities, SION, as well as consultants and council staff

Discussion

Funding sources for the range of actions such as the bunds, aerators etc. were queried. It came from a variety of sources – primarily the regional council, but augmented by targeted central government funding, predominantly the Ministry for the Environment, and the Ministry of Health for the lakeside sewage reticulation (approx. $105m.)

A key issue for Lake Wanaka is the desire not to let things get to anything like the state of the Rotorua lakes. It is a major quandary for government, in terms of supporting initiatives, that they wish to support both the development of agricultural production, which is so important to the country, and at the same time to protect the quality of lakes.

The efficacy of riparian planting was questioned. While there has been a great deal of riparian planting, this highlights the difference between phosphorus and nitrogen, which leaches underground through the porous volcanic soils. The greatest inflow is nearly 3 cub.m. per sec. It is also an issue that, while it is practical to fence streams on flat land, such as in Canterbury, in the sloping areas higher in the Rotorua catchment, it is not a practical reality. Maximising good farming practice and the uptake of new technologies will be a key. The range of actions shown on the table is backed up by a whole range of other initiatives developed in conjunction with AgResearch and others.

(Comment from Jonathon Wallis). It is fortunate in the Wanaka area that there is a high acceptance of the importance of goo land management practice, and a recognition that water protection is not just an encumbrance on the land which lowers the land value. It is recognised that there is an intrinsic value in sustainable land management. It is important to recognise those things which cannot be controlled, such as climate change.

Farmers are noting higher, less frequent, rainfall – even though the average has remained the same. This makes nutrient run-off harder to control. Wanaka has some areas of shallows, and areas of pastoral land which is close to the water table, which make it different to Wakatipu. There are many challenges, and sound science is essential in developing the response to those challenges.

Marc Schallenberg questioned whether, in relation to the Rotoiti diversion wall, there was much debate about sending the polluted water directly into the Kaituna Stream. The Kaituna Makatu system was substantially modified in the 1960s by engineering works, primarily for flood control, and because of development in the lower catchment. That was the initial action which alienated iwi in the area.

There was extensive modelling done around the effects of the diversion – showing that water spent a maximum of two or three days in the Makatu system and the increase in nutrients was minimal, but it was recognised as inefficient to be sending the nutrients out to the coastal zone. Sewage and meatworks discharge contributed as much to the Kaituna system as was being diverted through from Rotorua. At the moment, because Rotorua has improved so much, there has also been an improvement in the Kaituna system, but there is potentially another massive clean-up required in that water system taking into account the waste water and meat works discharges.

A numerical measure of the improvement in Rotorua compared to when it was at its worst. This can be answered in terms of the target level of 4.2. This was exceeded about the late 1960s or early 1970s, reaching a level of around 4.9 at its peak, and coming down to a level in the last year of 4.1. The quality of the water monitoring was good enough that it was possible to look back to a time when quality was acceptable, not at pre-European levels, but acceptable as an aim.

The impact of tourist development was questioned eg Treble Cone with up to 1000 visitors per day and minimal treatment plants, golf courses and subdivisions with increasing fertiliser run-off. Comparison made with the Lake Tarawera catchment, with 323 properties, to spend around $13m. to reticulate the waste water away from Lake Tarawera. (Roughly $31,000 per household, spread over 20 or so years.)

Monitoring and Control

1. QLDC District Plan Process – Leigh Overton, Wanaka Ward Councillor, and Chair QLDC Strategy Committee

Water quality is specifically a regional council issue, so the influence of the district plan is limited. It sets the consenting regime for jetties and moorings and indicates where jetski and boating activities should occur and where they shouldn't.

The district plan defines the lake as part of the "outstanding natural landscape" classification, within the rural general zone. Residential subdivision within the rural general area, adjacent to the lake, is a discretionary activity.

The RMA requires the revision of parts of the district plan, which are 10 years old. The aim is not to start again from scratch, but to try to make the plan simpler, to remove inconsistencies and to fix errors, as well as updating the plan to reflect latest national guidelines, and ensuring alignment with council and community strategies.

The process for the district plan review involves consultation with those affected by each topic selected for review. This is then brought back to the Council's Strategy Committee to be work-shopped. A Section 32 report, which sets out the arguments for and against proposed elements under review, is then prepared by council planners, reported back to the Strategy Committee, then put up on the Council website for public review, before final adoption in October 2013.

The process may be affected by the Ministry for the Environment discussion paper on the future of the Resource Management Act. All or part of the Council process may be put on hold, depending on the timetable of the RMA review process.

Discussion

(Jonathon Wallis) From a farming point of view, it is not correct to say that the regional council assumes full responsibility for water quality. The District Council is responsible for the consenting of many aspects of land use, such as vegetation, location of buildings, effluent disposal etc. In any consent process, specially regarding a change of activity in the Rural General Zone, issues of water quality play a significant part in what is considered.

(Graham Dickson) While submissions can be made by concerned parties relating to water quality impacts of consent applications, the problem for the Council is that there are no recognised standards to judge against as to what can be put into the lake. The shortfall in the process is that there is not an objective as to what sort of lake quality we are trying to achieve. Between the District Council and the Regional Council, it would be advantageous to have some clear statements as to what is to be achieved.

2. ORC Water Plan. Rachel Ozanne, Water Quality Scientist, Otago Regional Council

What the proposed plan change 6A is trying to achieve:

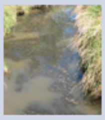
It aims to maintain good water quality and improve it where necessary, whilst meeting the requirements of the National Policy Statement for Freshwater Management.

What will be the plan's change of focus:

It addresses non-point source discharges to water in rural areas i.e. contaminants coming out of drains, and from runoff and leaching.

Characteristics of good quality water

Characteristic	Description	Contaminant effect
Clarity 	When standing in knee-deep water, the bed is easily and clearly seen.	Sediment reduces the clarity of water, and has an adverse effect on aquatic habitats.
Colour 	Water colour is not altered by contamination. rivers have natural colour such as tannin-stain or snow melt	A change in colour can be indicative of contamination by sediment or organic matter, linked to potentially high concentrations of DRP, NNN, ammoniacal nitrogen or E coli.

Characteristic	Description	Contaminant effect
Sediment 	Riffles and runs free of obvious mud and silt deposits. Walking across a riffle or run should not produce an obvious plume. Some rivers are naturally high in sediment	Sediment affects the colour of water, and has an adverse effect on aquatic habitats, and can result in high concentrations of phosphorous, and allow *E. coli* to persist.
Smell 	Water is odourless.	Smell can be indicative of contamination, from a source high in ammoniacal nitrogen or *E. coli* or the decay of excessive amounts of organic matter - which limits people's opportunity to appreciate water

Characteristic	Description	Contaminant effect
Algae 	Healthy levels of algae: • Do not cover more than 30% of the bed. • Strands are less than 20 mm in length. • No slime on the surface of the water.	Excessive nitrogen and phosphorous contribute to algal growth which has an adverse effect on native fish habitat, amenity and recreation values, and angling opportunities.
Bank appearance 	Functioning riparian margins: • Vegetation is healthy • Banks are stable. • No obvious livestock disturbance.	Healthy riparian margins mitigate sediment and nutrient discharges.

In preparing for the plan change, efforts were made to define good water quality. This was done through a consultation process throughout Otago. It was clear that the number one requirement by the community was clarity. This and other characteristics were given definitions as a basis for the plans goals.

Upper Clutha Rivers Compared to Targets

Only two of the rivers in the Upper Clutha have been regularly monitored to provide these figures – the Dart and the Matukituki at West Wanaka. The standards proposed represent a stringent control eg the asterisked values are lower than those proposed in the New Zealand Periphyton guidelines

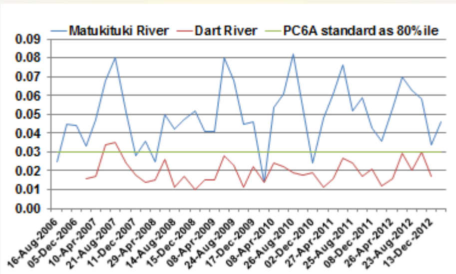
Current state of upper Clutha rivers relative to proposed targets (based on SOE data 2006 to 2010)

Site Name	Nitrite Nitrate Nitrogen (80%ile)	Ammoniacal Nitrogen (80%ile)	Dissolved Reactive Phosphorus (80%ile)	E.Coli (80%ile)
Schedule 15	*0.03	0.01	*0.005	10
Dart at The Hillocks	0.027	0.009	0.0045	5
Matukituki at West Wanaka	0.073	0.01	0.005	19.2

* value more stringent than that proposed by Biggs *et al.* (2000).

Otago Regional Council www.orc.govt.nz

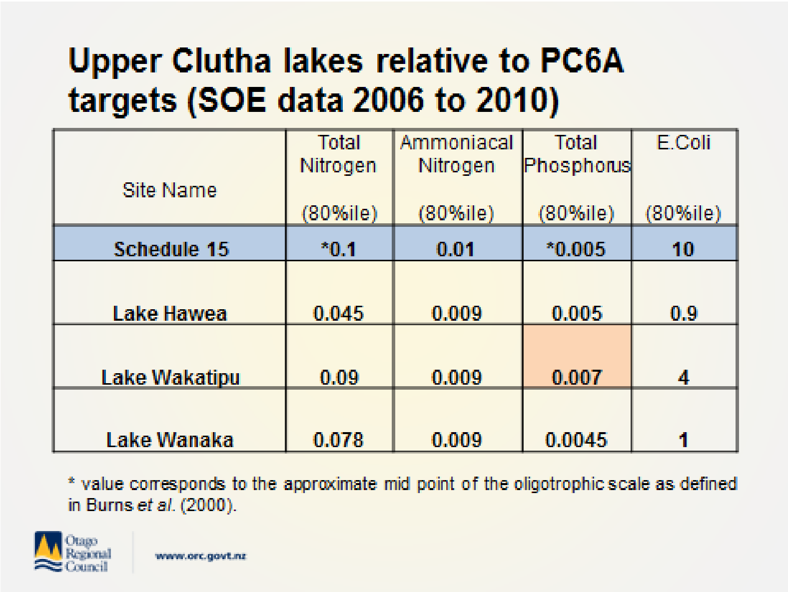
Nitrite Nitrate Nitrogen Matukituki and Dart Rivers – relative to proposed standard



Otago Regional Council www.orc.govt.nz

Currently for nitrite-nitrate nitrogen the Matukituki is more than double the standard – indicating that there is work to be done there.

The E. coli count also exceeds the proposed standard, but is well within the safe swimming guidelines.



Upper Clutha lakes relative to PC6A targets (SOE data 2006 to 2010)

Site Name	Total Nitrogen (80%ile)	Ammoniacal Nitrogen (80%ile)	Total Phosphorus (80%ile)	E.Coli (80%ile)
Schedule 15	*0.1	0.01	*0.005	10
Lake Hawea	0.045	0.009	0.005	0.9
Lake Wakatipu	0.09	0.009	0.007	4
Lake Wanaka	0.078	0.009	0.0045	1

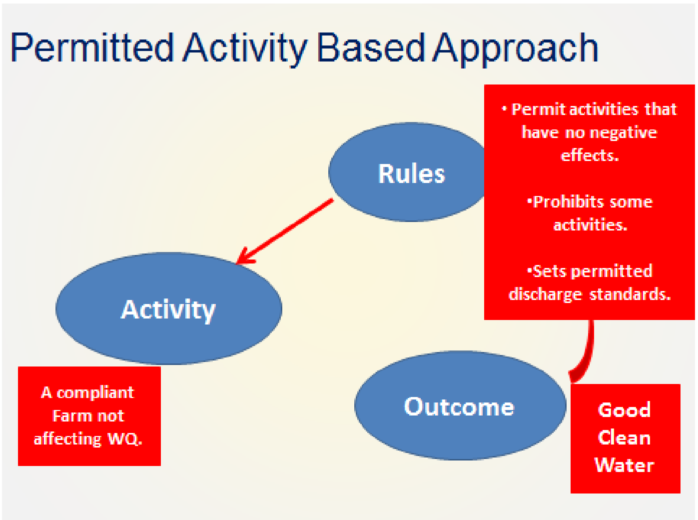
* value corresponds to the approximate mid point of the oligotrophic scale as defined in Burns *et al.* (2000).

Otago Regional Council www.orc.govt.nz

Standards for Lakes
The standards for lakes are expressed slightly differently – setting total nitrogen and total phosphorus.

Lake Wanaka currently meets all the guidelines (as recorded at the outlet).

Implications for Farming in the Wanaka Catchment
The plan opts for a permitted activity approach.
The ***Outcome*** of good clean water is established. Rules setting what is permitted and what is prohibited in order to achieve the outcome are developed, and the desired outcome is farming activity which does not affect water quality.



Prohibited Activities
A strong component of the proposed plan is to define and prohibit activities which can be expected to impede the achievement of the desired outcomes. Discharge standards are set for water as it leaves a property.
(Schedule 16 of Proposed Plan)
These are recorded against median flow or below, in order not to penalise discharge during periods of high rainfall.

Conclusions

1. Plan change 6A policies are effects focused and informed by science.
2. The discharge standards are stringent and will, if consistently applied, maintain the values of Lake Wanaka.
3. They are not prescriptive for the landowner, but allowed within the framework of defined outcomes
4. This approach reduces consenting and monitoring costs to the ORC, but will rely more heavily on compliance.

Discussion

(Chair) Given the information earlier in the day about the huge investment of other regional councils, where does the ORC level of concern regarding the quality of deep water lakes sit relative to concerns regarding other Otago waterways?

The funding of the PhD programmes indicates that lake quality is given a priority by the ORC. It is anticipated that environmental monitoring will continue much as it has been in the past, and that compliance monitoring may have to be increased. Compliance monitoring will be on a catchment by catchment basis, plus response to complaints and spot checking.

(Clive Howard-Williams) It was questioned whether the groundwater nitrogen level shown is set for the Wanaka Catchment or more widely. It was clarified that the level of 10kg. per hectare is for sensitive and upper catchment areas, and that elsewhere the level set is 30kg.

(Jonathon Wallis) When the plan was notified farmers expressed the concern that there was a lack of information on which to base the arbitrary levels. Funding has since been provided to set up a range of testing points to provide more comprehensive data.

(David Hamilton) The source of reference against which standards have been set was questioned. This was set from data over recent years (2006 – 2010) – not going back to an earlier more pristine standard.

(Marc Schallenberg) Questioned the decision to ignore the discharge levels in times of high flow.
It is understood that even high quality rivers and streams will have high nutrient run-off in heavy flood, but the concern is that most of the impacts on water quality will occur in floods, when the standards will not apply. It is intended that this will be addressed through the specification of prohibited activities, which are those which would be expected to have the greatest impact in flood times.

(Graham Dickson) The proposed plan sets out to control the level of nutrients going into a river eg the groundwater nitrogen limit of 10kg per hectare, but the effect on the river will depend on the landform and rainfall eg three times the rainfall in an area will lead to 1/3 of the concentration in the stream. The measure may work well for a river with a short retention time before flowing out to sea, but for Lake Wanaka, with inflows from a range of sources, the critical factor is to understand whether or not the level of nutrients is being built up in the lake. The Lake Taupo example sought to measure and control the total inflow from the whole catchment.

The plan change sets low limits for the Wanaka catchment in an effort to achieve the desired lake standards, but doesn't set whole of catchment limits. A problem with doing this in the Taupo catchment has been the limitations of the OVERSEER model. Investment is required to develop more satisfactory means of measuring and setting standards to provide better data.

The Condition of Lake Wanaka as Indicated by Aquatic Plants

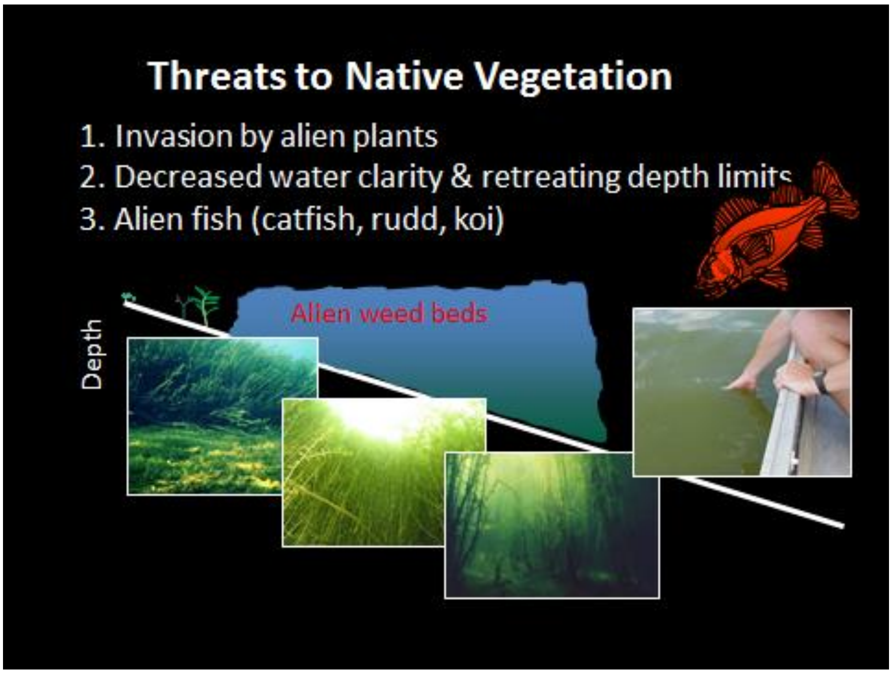
Dr John Clayton, Principal Scientist,
National Institute of Water and Atmospheric Research

SIZE	LAKE	Sq.km	Depth (m)	DEPTH	LAKE	Depth (m)	sq.km
1	Taupo	616	186	1	Hauroko	462	68
2	Te Anau	347	417	2	Manapouri	444	143
3	Wakatipu	291	380	3	Te Anau	417	347
4	Wanaka	180	311	4	Wakatipu	380	291
5	Pukaki	179	70	5	Wanaka	311	180
6	Manapouri	143	444	14	Waikaremoana (NI)	248	56
9	Rotorua (NI)	80	44		Coleridge	200	33
12	Hauroko	68	462		Taupo	186	616
14	Waikaremoana (NI)	56	248		Pukaki	70	179
15	Coleridge	33	200		Rotorua (NI)	44	80

Hauroko, Manapouri, Te Anau, Wakatipu - in top 35 deepest lakes in world

Aquatic plants can provide a very good indication of the quality of a waterbody. In studying plants in lakes most of the effort tends to be related to management needs, and there is a real lack of information, particularly on geographically isolated lakes. Less than 10% (350) of the lakes over 1 hectare in size (3850) have been studied.

The chart shows comparative size and depth of some lakes of relevance in comparison to Lake Wanaka (4th biggest and 5th deepest).

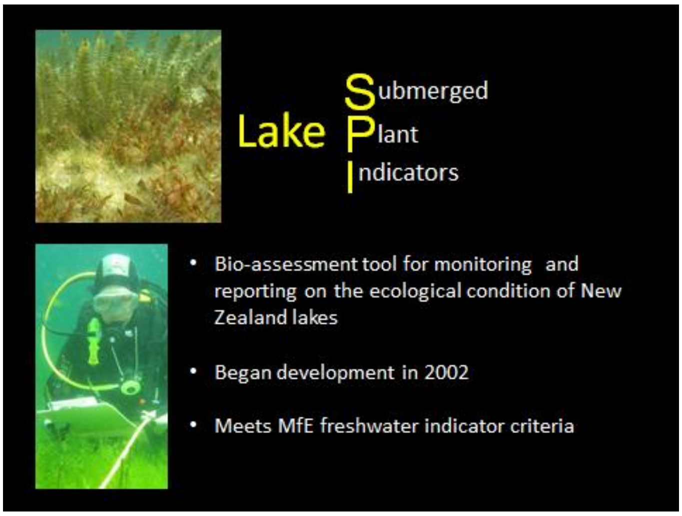


In a healthy lake there will be a range of aquatic native vegetation types at varying depths.

When **alien plants** are introduced – often through boating and other recreational activities, they build up a bed of weed growth which displaces native vegetation particulalry in the 1-10m depth range. Alien plants often grow taller and denser than any native plants, so they are easily overcome.

Decreasing water clarity also has a strong effect on plants which need light to thrive. Lack of water clarity causes deep water plants to retract to a shallower depth. Thus the depth to which water plants grow gives information on the clarity of water.

Alien Fish can also cause damage to aquatic plants. For example, catfish and koi carp trawl through lake sediment often leaving a deserted landscape. Perch, Rudd and Tench have been stocked in a range of New Zealand lakes for recreational fishers, but they are not desirable in lakes with conservation values.



LakeSPI or Lake Submerged Plant Indicators, is a management tool that uses information from the plants growing within a lake to indicate its overall condition.

LakeSPI survey's focus on the margins of a lake where aquatic plants are mostly found. Other benefits of using plants as indicators is that they are easy to observe because of their size, they are rooted (so aren't able to swim away) and they are able to reflect changes in lake condition over time.

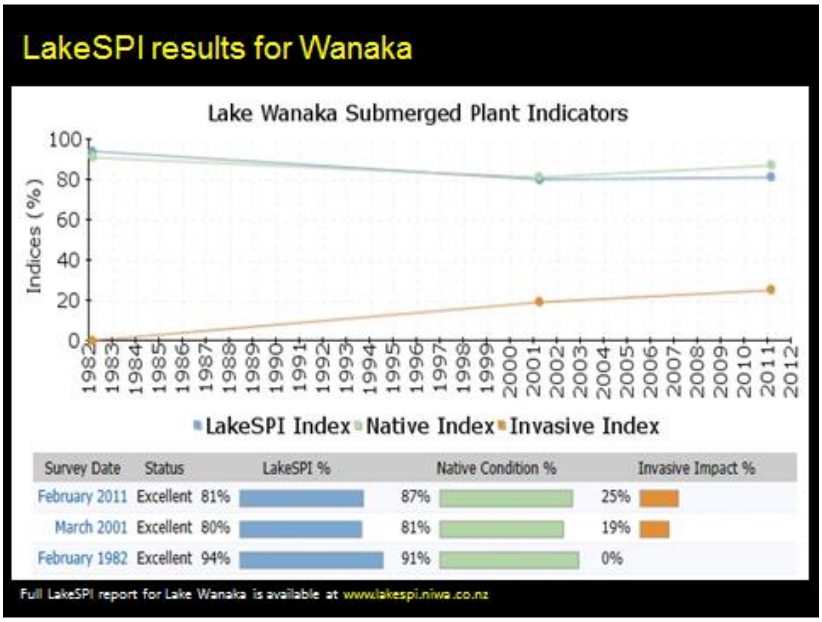
The underlying principles of LakeSPI are:

- Maximum depth of plant growth relates closely to water clarity
- Native species and high native biodiversity are seen as desirable in a lake
- Increased impacts from invading species signal worsening conditions

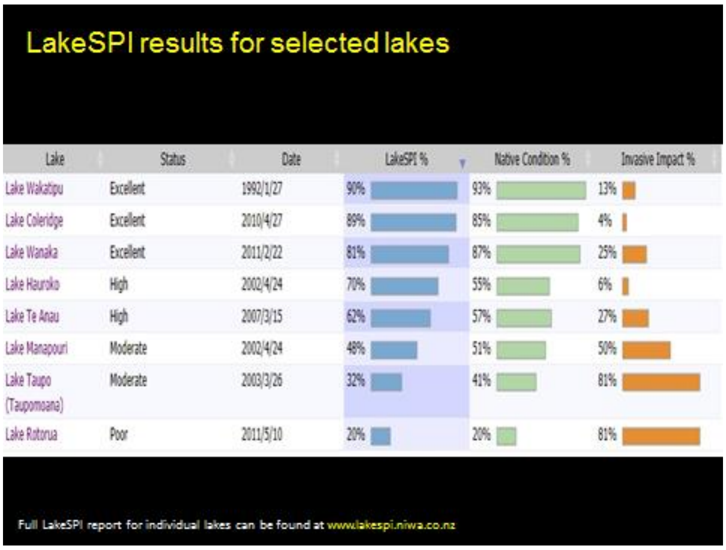
Thus the LakeSPI assessment tool can be used to:

- Describe ecological condition
- Assess changes over time
- Compare lakes of contrasting depth & type (by using a percentage of a maximum score)
- Rank the state of lakes on regional or national level
- Prioritise lake management actions (e.g., for surveillance or protection)
- Assess catchment & management initiatives
- Contribute towards national & regional reporting

This chart shows the LakeSPI scores for Lake Wanaka, dropping only slightly from 1982 when aquatic plants were first described in the lake, but still regarded as in excellent condition.



An important trend to note is the increase in invasive species compared to 1982, however this trend has been largely contained by on-going crown funded control works on lagarosiphon.



LakeSPI results for selected lakes

Lake	Status	Date	LakeSPI %	Native Condition %	Invasive Impact %
Lake Wakatipu	Excellent	1992/1/27	90%	93%	13%
Lake Coleridge	Excellent	2010/4/27	89%	85%	4%
Lake Wanaka	Excellent	2011/2/22	81%	87%	25%
Lake Hauroko	High	2002/4/24	70%	55%	6%
Lake Te Anau	High	2007/3/15	62%	57%	27%
Lake Manapouri	Moderate	2002/4/24	48%	51%	50%
Lake Taupo (Taupomoana)	Moderate	2003/3/26	32%	41%	81%
Lake Rotorua	Poor	2011/5/10	20%	20%	81%

Full LakeSPI report for individual lakes can be found at www.lakespi.niwa.co.nz

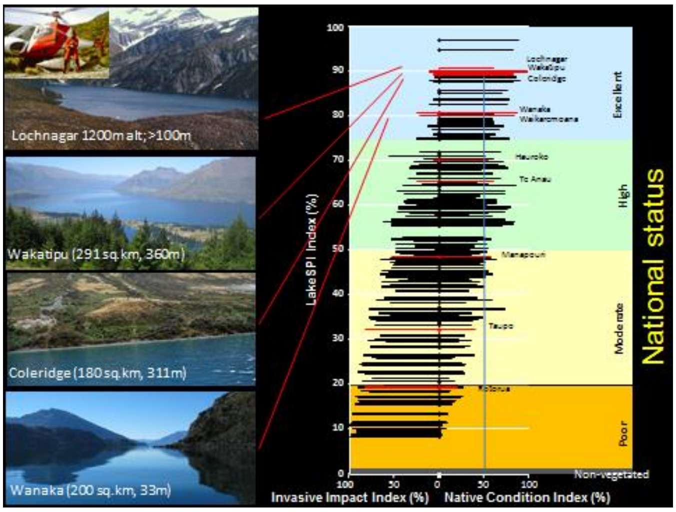
Wanaka Relative to Other Lakes

This comparison with other lakes (that have LakeSPI results available) shows Wanaka ranked as one of the top 3 lakes in New Zealand along with Wakatipu and Coleridge, all classified as being in 'excellent' condition — relative to the best they could be.

For interest only, it also shows Lake Taupo (preliminary LakeSPI result only) to be sitting around 32% ('moderate' condition) and Rotorua at 20% ('poor'condition) based on the submerged plant information recorded for each lake.

Ranking lake condition

This national status graph shows the position of Lake Wanaka (indicated here in red) next to all other lakes in New Zealand where LakeSPI information is available (>250 lakes). Lakes are classified depending on their LakeSPI scores as being in an excellent, high, moderate, poor or non-vegetated condition.



Deep Water Bryophytes

These are not included in the LakeSPI method, mainly because they are rarely found and they grow too deep for safe diving assessment and sampling. In the LakeSPI methodology anything below 20m scores the maximum score for this parameter, as this already indicates a lake with very good water clarity. They are being mentioned here however because they are an important and special feature of Wanaka's native biodiversity!

The first New Zealand record for deep mosses and liverworts (i.e., bryophytes) was at Sunshine Bay in Lake Whakitipu in 1979. Deep water brypohytes had been reported overseas, so this first record from Lake Wakatipu led to speculation that perhaps other New Zealand may contain them too. Subsequently we carried out more extensive studies during the 1980s, with deep dives in many clear water North and South Island lakes. Only a few South Island lakes were found to contain the deep water bryophytes, which can include around 40 species of liverworts and mosses. Globally there are only around 25-30 lakes that are reported to contain bryopyhtes at depths greater than 10m.

Brypoytes tolerate low light and low temperatures, and are very vulnerable to siltation and disturbance (inflows, currents and steep gradients).

The only North Island lake where deep water bryophytes have been discovered is Lake Tama, in Tongariro National Park, which is only 8m deep, but has bryophytes growing across the bottom of the lake.

In the South Island, they grow down to 70m, which is very difficult to assess by diving. Bryophytes form a complete carpet across the bottom of the lakes in areas where there is no slumping and where there is a more moderate gradient. They will also grow over rocks and on top of silt, without needing to attach to anything.

The underwater pictures above show Lake Wanaka in March 2013. This site (entrance to Roys Bay) had not been dived since 1982, but still retained a full cover of bryophytes from around 25 – 35m.

South Island	Depth range (50+m)	Score	Frequency	Score	Cover	Score	Rank	LakeSPI	RISK
Coleridge (507m Alt; 200m Deep)	(35) 50-60 (70)	5	High	5	High	5	15	Ex 90%	High
Wakatipu (310m Alt; 380m Deep)	(35) 40-50 (60)	5	High	5	High	5	15	Ex 89%	Low
Wanaka (300m Alt; 311m Deep)	(25) 30- 40 (45)	5	Med	3	High	5	13	Ex 81%	Med
Lochnagar (1200m ; >100m Deep)	30-57	5	Low	1	Med	3	9	Ex 92%	Low
	Depth range (30+)								
Hawea (348m Alt; 392m Deep)	35	3	Low	1	Low	1	5		
Tennyson	30	3	Low	1	Low	1	5		
Sumner	32 (?)	0	?	0	?	0	0		
	Depth range (10+)								
Rotoiti/Rotoroa (Nelson) (460m)	22	1	Low	1	Low	1	3		
Ohau	22	1	Low	1	Low	1	3		
Manapouri/Te Anau	14-17	1	Med	3	Low	1	5		
Monowai/Hauroko	19-22	1	Low/med	2	Low	1	4		
Alta (1506m Alt)	12	1	Low	1	Low	1	3		
North Island									
Upper Tama (Tong NP) 1314m	8m bottom	1	High	5	High	5	11		
Taupo/Waikaremoana	Nil (Koura)	0	Nil	0	Nil	0	0		
Overseas									
Tahoe (USA)	125m (less now)								
Crater (USA)	30-80m (140)								
Geneva (Switzerand)	65m (now absent)								

National and International Comparison of Bryophytes

Three renowned deep international lakes (Tahoe, Crater and Geneva) all used to have bryophytes growing down to significant depths, but all have now either gone (Geneva) or retracted.

In the North Island there are no deep water bryophytes in Lakes Taupo or Waikaremoana. This is believed to be because of grazing from fresh water crayfish.

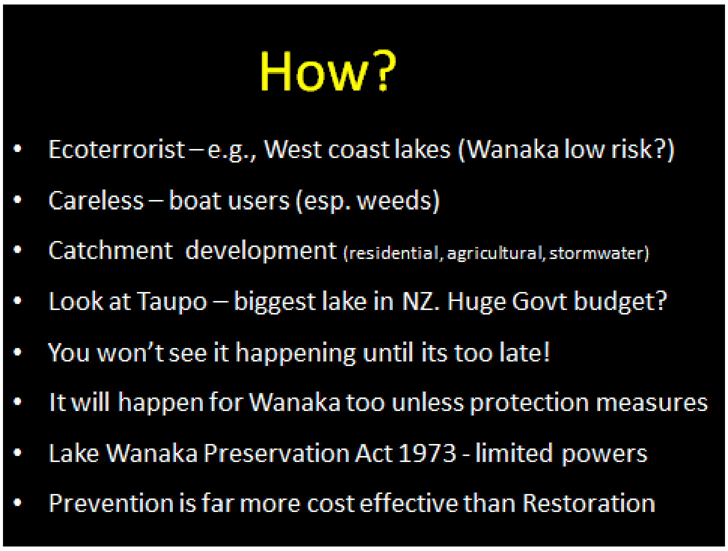
The South Island lakes on the chart which are not highlighted have only occasional isolated sprigs with a low cover.

The table above ranks lakes only on bryophyte factors using depth range, cover and frequency. There are only four lakes (highlighted) which score highly for both coverage and depth. This additional component of plant community structure is a useful factor to consider in addition to any LakeSPI classification.

In the case of Wanaka, surveying of bryophytes has been limited by lack of resources and time, but based on existing bryophyte information from yesterday, Lake Wanaka would be ranked third for condition as indicated by aquatic plants. The 'risk' status added to the table are a subjective assessment only. For example, Lake Coleridge is 'high risk' because hydro diversion works are likely to create escalating turbidity, while Lake Wanaka is rated a 'medium risk' because of the potential for change in the catchment.

What are the Risks to Lake Wanaka?

- **Increasing sediment** – catchment development and climate change can lead to increased sediment input. For example, flood events in the Matukituki River have an effect well beyond just the arm it flows into. Turbid water decreases water clarity.
- **Increasing nutrients –** changes in catchment activities such as an increase in agriculture can also lead to decreasing water clarity and increased algal growth.
- **Pest plants** – hornwort is a major risk. This species is National Interest Pest Species for the South Island only and all known SI sites have been eradicated under government (MPI) legislation.
- **Pest fish –** any exotic fish (exception made for trout!) is undesirable in a heritage lake such as Wanaka.



Ways in Which Risks May Eventuate
There are examples on the West Coast liberation of exotic fish concurrent with exotic weeds such as lagarosiphon. Deep lakes are probably only a low risk for deliberate release of exotic fish.

Weeds are readily transferred by boat users. Lake users should be continually educated on how to prevent the spread of invasive weed species. Check, clean and dry message.

General development in the catchment can be expected to continue.

There is a real risk that problems can occur but not be recognised until it is too late. Lake Taupo provides an example of the huge cost required to install controls once problems are recognised.

The current regulatory and protection framework for Lake Wanaka may need review.

Discussion
The level of adoption of the LakeSPI tool was queried. It has been adopted by most of the regional councils, and there is now quite a good data set for comparisons throughout the country. It is aligned with Ministry for the Environment, State of Environment record monitoring objectives, and has their endorsement.

It has the advantages of being a quick and cost effective (eg annual checks) option for lake monitoring.

The difference between Hawea and Wanaka was queried. The 20m water fluctuation in Hawea is because of hydro electricity use, making the top 20m a desert zone.

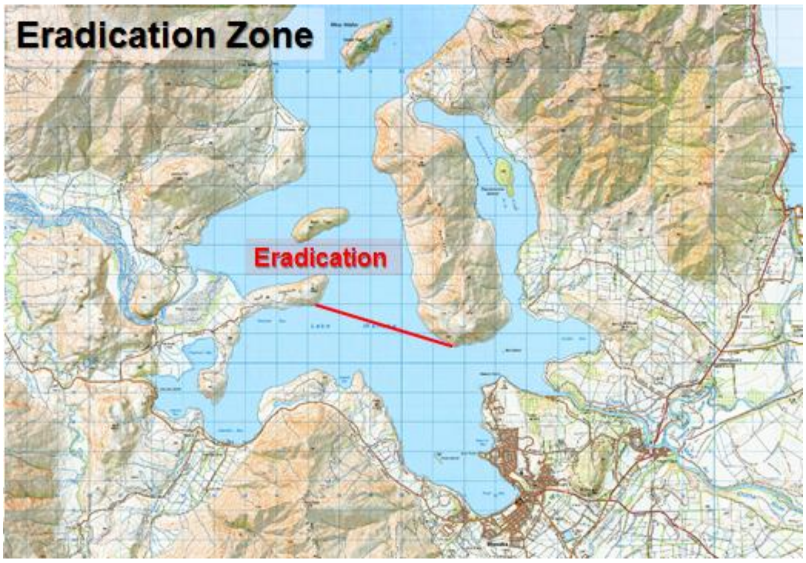
The risk referred to from river inflows into Wanaka was questioned. Given that the rivers have been flowing since the glaciers retreated the risk which is perceived is seen as increased due to human modification, particularly round the developed areas of Roys Bay and Glendhu Bay.

The Lake Wanaka Lagarosiphon Control Programme
Marcus Girvan, Biosecurity Consultant, Boffa Miskell,
Biosecurity service providers to Land Information New Zealand

The Lagarosiphon control programme was established, with government funding, as a response to community concern. It is administered through LINZ, based on their responsibility for the bed of the lake. It is overseen by a control committee convened by LINZ, and representing LINZ, the Department of Conservation, the Guardians of Lake Wanaka, QLDC and ORC, with NIWA as scientific advisor. Boffa manages the operational aspects of the programme and makes recommendations to the committee twice annually regarding the programme.

The 10 year management plan was approved in 2005 and has the following objectives:

- Protect indigenous biodiversity
- Maintain natural heritage values
- Maintain and improve amenity values
- Minimise risk of inter and intra-lake spread
- Minimise risk of further accidental introductions



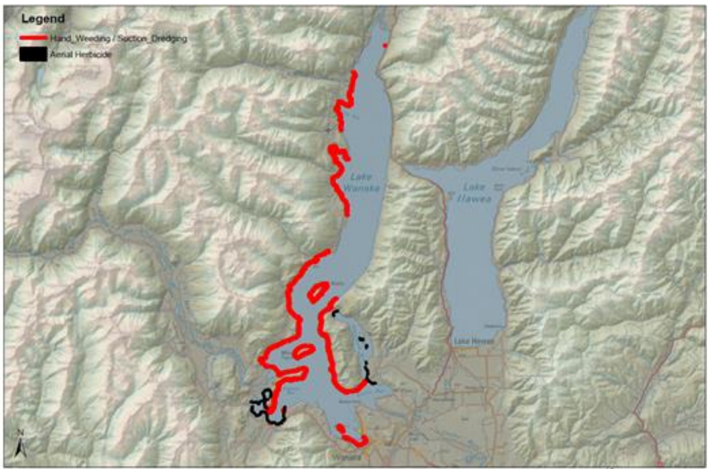
The map shows the agreed containment line, which was established in 2003, and has moved further south since then.

The north of the lake is now largely clear of the weed, and in the southern part of the lake there is a containment programme in place, with a combination of aerial and boat applied herbicide, suction dredging and hand weeding, with the latter two accounting for the majority of the work.

Control in 2011-12, showing the GPS tracking of the control works undertaken.

The red line is suction dredging and hand weeding, and the black is spraying.

Huge progress has been made, especially beyond the containment line, where now only a few catch-bags of odd plants are removed in a season.



Lake Wanaka Lagarosiphon Control Works 2011/12

Discussion

The future of the programme beyond 10 years was questioned. David Mole (LINZ) indicated that the funding of the programme is now included in LINZ base line funding. It will need to be evaluated and reviewed at the end of the present programme and a continuing programme basis established and agreed.

There was a question to John Clayton as to how bad the lagarosiphon problem had become in relation to invasive weed problems generally and how much better it is now. After several years of no lagarosiphon control from 2001 - 2003, alarm bells started ringing over the escalating spread of weed beds. This led to a Lagarosiphon Workshop in 2003, followed by a Memorandum of Understanding between key agencies in August 2004 and the development of a draft 10 Year Lagarosiphon Management Plan in October 2004.

There is a perception issue that observers do not see a problem until it is really bad, so as lagarosiphon is brought under control and a smaller mass is being weeded out, this can lead to complacency.

The monitoring of pesticide residues was questioned. Diquat has been used every year since 1959 in the Rotorua lakes. Sampling and analysis of lake sediments and biota have revealed no measurable residues or deleterious impacts. Often one of the main differences found between treated and untreated sites is the re-establishment of native vegetation once weed beds have been largely cleared.

There was a comment from Steve Trainor, a diver present in the public gallery that he was concerned that the impression might be that there is no longer a significant presence of lagarosiphon, whereas it is still present in significant quantities. This was confirmed by John Clayton, who noted particularly the area around the marina, which is a main point of public interface with the lake. He gave an explanation of the weighted evaluation mechanism designed to determine best value for funds expended.

The question was asked as to whether plant decay following herbicide treatment could contribute to development of algae and lake snow. This was considered unlikely because the treated volume of the lake is so small and the appearance of lake snow appears too widespread, rather than being concentrated in treated areas such as Paddock Bay. Also Lagarosiphon is just a tiny proportion of the natural seasonal decomposition of vegetation in the lake.. The establishment of an exotic water flea (Daphnia) in Lake Wanaka was suggested as a more likely mechanism for the decline in small water borne algae, allowing a change in dominance to large celled cyclotella algae, which are associated with lake snow formation.

Summary and Discussion Session - Presenters and Guardians

The final session attempted to focus on what should be done, and by whom, for the future health and protection of Lake Wanaka.

In the first instance the Guardians are seeking advice on what they can and should do as Guardians, but the discussion needs to be much wider – to answer the question as to how all interested in the lake should work to co-ordinate the efforts of responsible agencies.

Written Recommendation from the Floor (Don Robertson, former Chief Scientist, NIWA):
Members of the public attending the seminar had been invited to submit written questions or issues to be covered. The following was submitted, and later expanded:

It is quite clear that current monitoring and research are totally inadequate for monitoring the future values and quality of Lake Wanaka.

It should therefore be a recommendation to the Minister that the Guardians be asked to seek funding from QLDC, ORC, DoC, LINZ etc. for a high level scientific report to address the question:

"What spatial and temporal sampling and what parameters and processes need to be measured to produce credible models to inform policy and management decisions for maintaining and/or improving the quality of Lake Wanaka (and other Southern lakes)? "

This report should include:

- ***advice on the development of a framework for community consultation on lake values and definition of quality;***
- ***advice on appropriate sampling regimes for biological monitoring (e.g. lake bed vegetation, benthic and water column biodiversity, species mix, biosecurity);***
- ***lake hydrological monitoring (including lake and catchment nutrient levels and flows, and advice on number and placement of deep water monitoring buoys);***
- ***and the adequacy (or not) of existing levels of monitoring;***
- ***advice on lake(s) management policies, governance and implementation.***

Comments on this recommendation and other issues raised during the day were sought from presenters and Guardians.

The discussion was framed with a request to take what we already know about Lake Wanaka, and, drawing on the experience from elsewhere presented through the seminar, determine what are the things we need to know to make conclusions about the present quality of the lake and likely future directions?

It has been a clear and consistent theme throughout the day that more information is required. There needs to be better information about the relationship between the lake and the rivers which flow into it, and the lake and the land use in the catchment, both to inform a proposed initial comprehensive report, but also on an on-going basis, to ensure continuity of management.

Key indices can be determined from experience elsewhere. Who should most appropriately be involved?

Technical Advisory Committee
The Technical Advisory Committee, set up in relation to the Rotorua lakes, provides a very good model. It is funded by the Regional Council, which covers meeting attendance costs. It was initially set up as a result of an initiative of the Ministry for the Environment, to provide for oversight of government investment in lakes restoration. Those involved feel that it has been very useful – providing for input from the scientific community in the university, research agencies, and regulatory agencies. That particular committee has some financial strength because of the government money flowing through to the Lakes Restoration funding, but this is not essential to the value of the committee.

Discussion and working through proposals by a committee such as this can provide robust answers to the questions as to what needs to be measured and how.

A strong Technical Advisory Committee provides a link between ensuring that valid data is collected, appropriate recommendations made, and that there is the required level of credibility to generate response actions from the relevant agencies (who should be contributing to the membership of the committee).

Values and Quality
The first step may be to define the values to be preserved and enhanced.
Marc Schallenberg in his presentation proposed a set of values. These need to be cemented through community consultation. Otherwise it would be possible to have a tool which might control some factors in the lake, but not the ones necessarily which are of concern to the community.

1. Define and agree values
2. Determine what needs to be known to measure whether the values are being achieved
3. Measure and monitor over time
4. Relevant agencies to take action based on the information from the monitoring

In the example of the Rotorua lakes where this has been done, individual values have been agreed for individual lakes.

The Lake Wanaka Preservation Act refers to maintaining and enhancing "quality", but does not define quality. Should this be a first step for the Guardians, to work with the community to agree a definition of quality and a set of values for Lake Wanaka? The Regional Council developed a set of values, and undertook wide consultation in relation to the Regional Water Plan. This consultation was not specific to Lake Wanaka, or to specific lake values, but was general to the region. However, it could provide a very useful starting point.

Out of this, and other previous consultation processes, eg Wanaka 2020, and the consultation around the District Plan, there should be some existing statements which can be built on. It was suggested that the Lake Wanaka Preservation Act gives the Guardians a mandate to produce a statement as to what they consider quality to be, for public comment, rather than starting from scratch with public consultation. It is sometimes easier to agree on what is NOT quality.

Availability of funding to undertake the actions to achieve and maintain quality needs to be borne in mind from the beginning. There is no point in reaching highly idealistic definitions of quality if there is no possibility of funding to achieve the desired values.

There was general agreement from the Guardians present, and community representatives, that it could be a useful first step for the Guardians to prepare a statement of values, and attempt a definition of quality, to go out for public consultation.

Looking at a next step of establishing a Technical Advisory Committee on the Rotorua Lakes model, it was questioned whether the Otago Regional Council would be willing to take a leadership role comparable to the Bay of Plenty Regional Council role – partly because Lake Wanaka, and the Southern Lakes generally, have not been seen as a source of concern. If the Guardians could set up a framework for a technical advisory group, would there be support from the relevant agencies?

It was suggested that there might need to be initial work undertaken on data collection, involving university staff and others, to raise the profile and awareness of lake needs and changes, and to provide an impetus for more structured management.

The Need for Information

Starting at that end of the equation, what should be the starting point with data collection and use?

The North Island lake examples started with a clear recognition that there was a problem. In the case of Wanaka, there is community concern, but not enough knowledge to confirm how significant the problem is

It is fundamental that there are changes occurring. Locals are aware of the changes and concerned about such signs as "lake snow". The most important practical starting point is to clarify what needs to be known to determine the severity and significance of those changes. Then, if there is not funding available to address all the issues, at least there is a basis for prioritising the funding which is available.

A key step will be to record the nutrient levels in the lake, as a basis for determining what the effects of changes in the environment might be. The tool needs to provide a model of how the lake works, with its balance of inputs and outputs. First the indices need to be determined.

Monitoring Buoys

It was questioned how critical the decisions are as to exactly what parametres are to be monitored before commissioning and installing buoys. Key points:

- The vital importance of long term data (eg the Rotorua monitors 12 lakes monthly)
- The main measures are fairly standard. There may be particular add-ons defined, but base measures are generally widely standardised.
- Inflows need to be monitored to determine what is a reference condition and what is changing over time
- Constant monitoring through use of continuously recording buoys allows assessment of the significance of variations – are they temporary "spikes" or meaningful trends indicating changes in lake health.

Current cost per buoy is $65 - $70k. The big change now in technology is the ability to record in profile over the length of the buoy line. This also reduces maintenance costs, as the previous chain of sensors is not required.

Previous approaches to the Central Lakes Trust for funding had failed. Other possible funding sources were canvassed. These included the idea of commercial sponsorship, Contact Energy, the Parliamentary Commissioner for the Environment, Ngai Tahu, specialist trusts, ORC obligations under the national Water Quality Statement. Starting with some initial data and a management framework would also provide a basis for engaging farmers and other economic interests

It was suggested that the Guardians might petition the ORC for monthly in-lake monitoring of both lakes Wanaka and Wakatipu as a minimum, which would involve some cost to the ORC, but that the community itself might support funding for a buoy, or buoys, which would be a tangible symbol of attention to the lake, and in itself a means of raising awareness. The possible mechanism of a Lake Wanaka Trust (or Southern Lakes Trust) was discussed – perhaps as a basis for attracting partnering government funding.

Monitoring Underwater Vegetation levels
In addition to water monitoring, another useful source of data would be to install lake bed monitors to record the level of underwater vegetation, as the vegetation tends to cut off in a clear line, which may move up or down over time, indicating changes in water quality, invasive plants etc. This could be incorporated into the NIWA Lake SPI programme if funding could be generated. In 1974, with central government MAF funding, 50 sites round the lake were monitored, providing the only useful historical data. Since then, there has only been spot checking of a handful of sites – without funding being provided for the survey work.

Framework Report
It was questioned whether the range of initiatives discussed addressed the initial recommendation from Don Robertson. He felt that they did not, as the initiatives had a danger of being too piecemeal. Funding for the sort of initiatives proposed required the credibility of a major overview report, conducted by scientists of recognised standing. A sound research plan is required "up front". His second question was whether the Guardians would seek funding for a report which would answer many of the other questions raised, and provide a clear path for future action. He did not believe that the quantum of funding would be very large.

A Technical Advisory Committee would come further down the track, once a course of action had been identified and supported with sound scientific argument.

Recommendations for Actions/Topics to be Considered by the Guardians
The following recommendations were drawn together from the discussion. These were not in any way formally endorsed by the meeting, but all forwarded to the Guardians for their consideration. They are not mutually exclusive, and the best course of action may be a combination of the recommendations:

- **Lobby the ORC to conduct monthly (minimum) monitoring of Lake Wanaka and Lake Wakatipu**
- **(Re)investigate sources of funding for the provision of deep water monitoring buoys**
- **Seek funding for a high level scientific report to provide a clear and credible basis for future action, funding, and support.**
- **Develop and consult on a framework of values and definition of quality**
- **Request a costing from John Clayton and NIWA for a lake bed vegetation monitoring programme**

Record of Seminar Follow-up Discussion and Decisions

(Following a meeting of the Guardians of Lake Wanaka held 13 May 2013)

At their first meeting following the March seminar, the Guardians discussed the information and guidance obtained through the seminar.

Seminar Proceedings

It was agreed that the content of the seminar had been very useful, and that a full record should be published. This will be posted on the Department of Conservation website, available for downloading, and hard copies will be sent to participants, media, and relevant agencies.

Key Messages for Guardians' Attention

It was felt that the Guardians' focus should be on the key messages from the seminar:

- Lake Wanaka appears currently in good condition, but changes over recent years have been noted and cause concern
- There is insufficient data from which to determine what is happening to lake quality
- More extensive and consistently collected data will provide a basis for scientific analysis, which in turn can guide future actions to ensure the best outcomes
- Experience elsewhere emphasises that early action is critical, as remediation is expensive and difficult
- The case studies presented emphasise the importance of drawing on good scientific advice and having the commitment of relevant agencies to achieve best outcomes

Guardians' Focus

There was some discussion as to whether future action should focus only Lake Wanaka, or on a wider group of Southern lakes. It was agreed that while the issues for Lake Wanaka are similar to those for other Southern lakes, the Guardians' mandate relates specifically to Lake Wanaka. Focus on a wider grouping may attract greater "buy-in" from funding and regulatory agencies, and seems appropriate to put forward, in the interest of the whole area, but it will be important for the Guardians to retain focus on their mandate within a wider group.

Seminar Recommendations

The specific recommendations which had been noted in the summary of the seminar concluding session were reviewed. All were seen to have value, and to be inter-related. It was felt that determining priority for action was a matter of timing and sequence, rather than adoption/rejection.

Lobby the ORC to conduct monthly (minimum) monitoring of Lake Wanaka and Lake Wakatipu

Because of the ORC's responsibilities for water quality, their commitment to scientific review through funding of university programmes and their own research, their existing monitoring programmes, and the follow-up on the amended Water Plan, consultation and co-operation with the Regional Council was seen as a top priority. Choice of next steps may depend on the Council's focus and commitment. An early meeting with ORC representatives is to be sought.

(Re)investigate sources of funding for the provision of deep water monitoring buoys

Meetings with Central Lakes Trust representatives have been held, and the Trust will be kept informed of further actions and progress. It was felt that an approach to the Trust and other potential funding agencies could be appropriate further down the track, once the commitment of the ORC and others is explored, a programme of future actions determined and costed, and possible responsibilities assigned.

Seek funding for a high level scientific report to provide a clear and credible basis for future action, funding, and support

While the value of an overview report, as recommended by Don Robertson is clear, the Guardians felt that, even without such a report, the vital importance of monitoring and data review is already apparent . It was felt that the seminar itself provided some of the credibility sought from such a review. The desirability of a review, as well as the value of an on-going Technical Advisory Group, as in the Rotorua situation, will be further discussed with the ORC and others, as part of planning for future actions. It can be further developed at the same time as support for monitoring is advanced.

Develop and consult on a framework of values and definition of quality

As was noted in the seminar discussion session, there are a number of models on which to base a values statement and quality definition. These include the recent consultation undertaken by the ORC as a basis for the revised Water Plan, and the documents developed for the Lake Taupo and Rotorua Lakes programmes. It was felt that the Guardians have a mandate to develop these statements to be fed in to a further planning and action framework, but they do not have to be completed and adopted prior to other actions. There is a clear enough understanding of the value of what is to be preserved, and the risks perceived for responses to be developed.

Request a costing from John Clayton and NIWA for a lake bed vegetation monitoring programme

This was seen as a valuable complement to any water quality monitoring, and it was agreed that a costing should be sought.