Session Four : Lake Weed – The Way Forward

SESSION CHAIR – Prof Chad Hewitt, School of Science, Waikato University

POTENTIAL LAKE ROTORUA SCENARIOS

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Max was trained as an analytical chemist and has worked for NIWA (and its predecessor, DSIR) for 50 years, initially in the field of pesticides and forensic analysis and subsequently studying eutrophication in freshwater. For the last 42 years, Max has worked on lakes around most of New Zealand, primarily on Lake Taupo and the restoration of Lake Rotorua, and Lake Horowhenua. He was instrumental in the identification of the hydraulic coupling between Lake Rotorua and Lake Rotoiti, which eventually lead to the installation of the diversion wall. He has used his experience of iron cycling, obtained as a fellow at Edinburgh University and the Lake District in 1980, to help in the understanding of phosphorus interactions across the sediment-water interface in New Zealand lakes. He was awarded an Honorary Doctorate of the University of Waikato in 2010 for his work with lake restoration and the assistance and mentoring of students. Recently Max developed an internationally acclaimed forensic stable isotope technique that enables the identification and apportionment of sediment sources by land use in the catchment and he has extensive knowledge of the linkages between erosion and the impacts of fine sediment in lakes, rivers and estuaries.

ABSTRACT

Lakes need weeds, good ones (native species) not bad (invasive exotic species), although even exotic species are better than no weeds. Without aquatic macrophytes, a lake can become phytoplankton dominated with low clarity and high chlorophyll concentrations, a condition from which it is difficult to recover. The challenge is to manage the macrophytes to the advantage of the lake to obtain the highest practical water quality that is acceptable to lake users, within the financial constraints of a rates-based budget.

Lake Rotorua has sufficient surface area and depth that macrophytes, by themselves, are not likely to control water clarity and phytoplankton growth. However, their management may be a critical factor in the restoration of Lake Rotorua. In this talk I look at potential scenarios associated with managing aquatic macrophytes in Lake Rotorua. With the availability of a weed harvester dedicated to the Te Arawa/Rotorua lakes, there are a number of options that can be applied to Lake Rotorua that would be beneficial to the lake and the people who use the lake. For example, the weed harvester can be used to mow the weed beds to remove part of the nutrient load from the lake and thus improve the lake water quality. The Lake Rotorua Action Plan is looking to reduce the N load on the lake by an additional 50 t y^{-1}. Weed harvesting has the potential to achieve this. Removal of the tops of surface-reaching macrophyte beds around some stream mouths may improve trout fishing for anglers while maintaining the habitat that the trout need in shallow water. Clearance of boat ramps and maintenance of lake access are obvious applications. So is the mowing of the large areas of macrophyte beds adjacent to Rotorua city lake front to reduce plant break-off in wave action and thereby reduce the incidence of macrophytes washing ashore. These are just some of the potential Lake Rotorua scenarios.

TRANSCRIPT

The topic 'Potential Lake Rotorua Scenarios' is based on the study of weeds; undoubtedly, lakes need weeds, but too much weed can cause problems. So aquatic macrophytes/weeds, especially invasive exotic species (or alien species as they have been called) can cause problems. They smother native species, choke waterways and broken pieces wash up on shores after storms. Solutions to weed problems need careful consideration. Some options regard weed control as synonymous with eradication. The words 'spraying' for weed control conjures up an image of total de-vegetation leaving bare sediment. This is undesirable and can result in a lake flipping to a phytoplankton dominated system, with the potential to develop toxic cyanobacterial blooms.

Used correctly, exotic species sensitive to spraying can be eradicated while allowing more tolerant native species to re-establish. The use of Endathol can allow charophytes to re-establish while taking out hornwort.

Weed harvesting is a tool to use for management of lakes and waterways for boat access and recreational activities. However, most exotic weed species can grow down to depths of more than 5 metres; the weed harvester cutting depth is mostly less than 2 metres, so weed harvesting leaves the exotic weed bed intact to continue growing. Weed harvesting can also allow native species to become re-established; studies in Aratiatia Dam have shown native charophytes can re-establish after harvesting.

The consequences of spraying and weed harvesting need to be considered. With spraying, dead plant matter is left in the lake where released nutrients are returned to the water column and this can stimulate phytoplankton growth. The decomposition driven processes from collapsed weed on the lake bed causes anoxia and so legacy nutrients from the sediment are released. If phosphorus is released under these conditions it can stimulate cyanobacteria growth. Leaving cut weed in the lake from weed harvesting has the same issues.

Control or manage?

Clearly management of exotic weed is an option, but management for what? Can we use these tools to re-establish native weed species? Spraying? Yes. Weed harvesting? Yes. Can we use these tools to manage nutrient loads in the lake? Spraying? No. Weed harvesting? Possibly. John Madsen reported in 2000 that, 'Harvesting aquatic weeds is not an effective tool for reducing nutrient loads in a lake.'[1]

How else can these tools be used? First of all the problem must be understood before intervention. **Slide 1** (over) looks at the case study of Lake Horowhenua with a seasonal cyanobacteria bloom problem. **Slide 2** shows that in summer there are cyanobacteria blooms and in winter there is clear water. Cyanobacteria are favoured in their growth if there is excess phosphorus over nitrogen.

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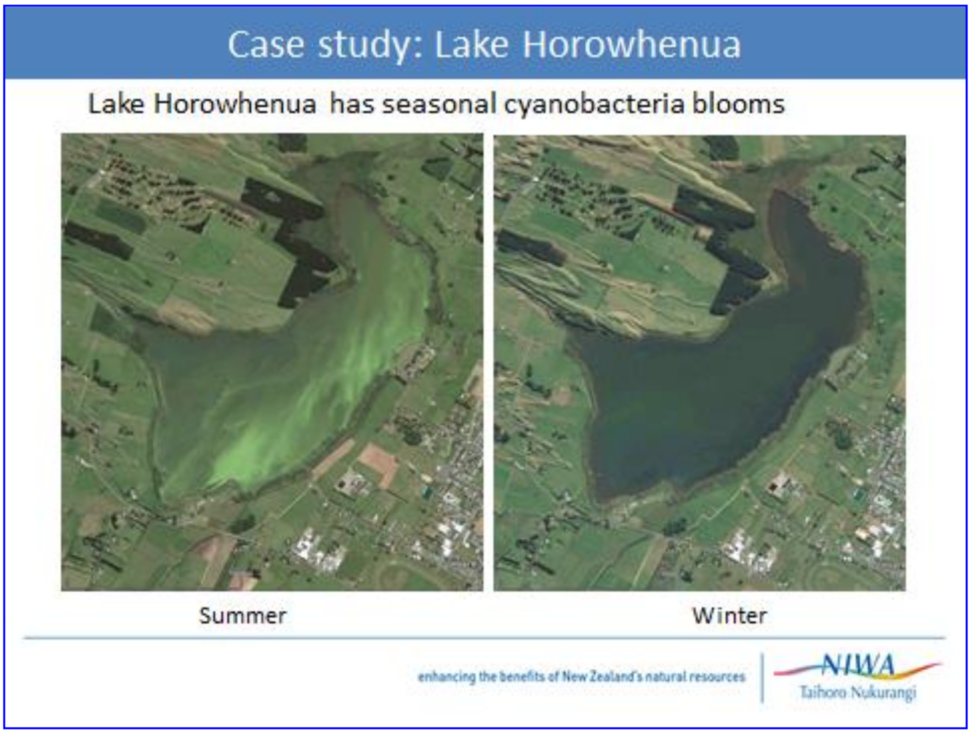
[1] Advantages and disadvantages of Aquatic Plant Management Techniques, *Lakeline* 20 (1):22-34

Slide 1



Case study: Lake Horowhenua

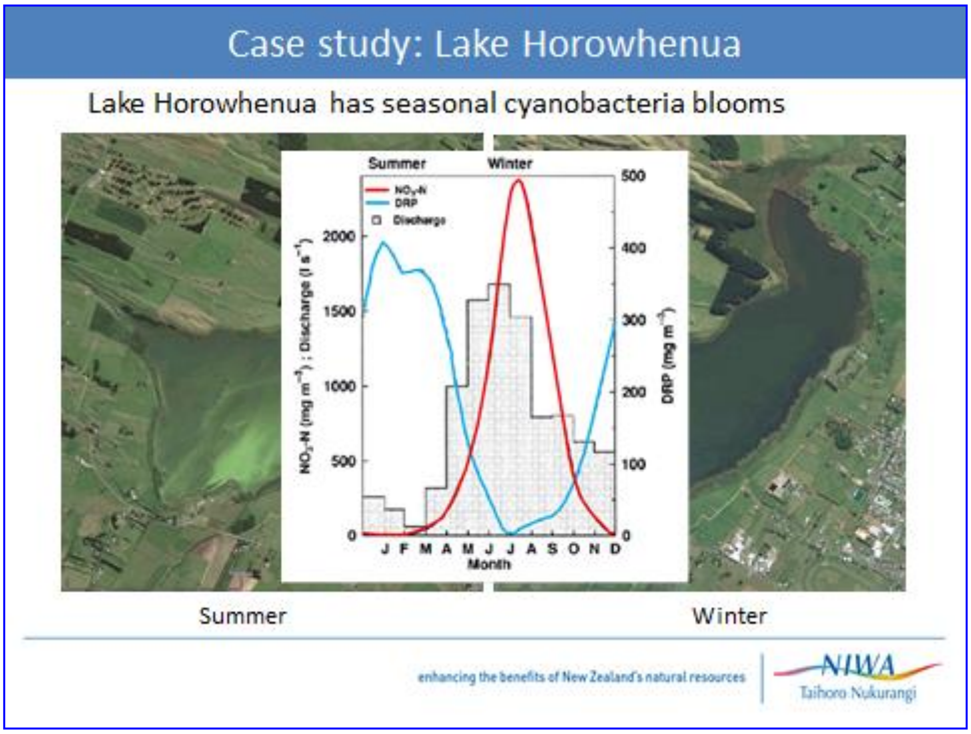
Lake Horowhenua has seasonal cyanobacteria blooms

Summer

Winter

enhancing the benefits of New Zealand's natural resources

Slide 2



Case study: Lake Horowhenua

Lake Horowhenua has seasonal cyanobacteria blooms

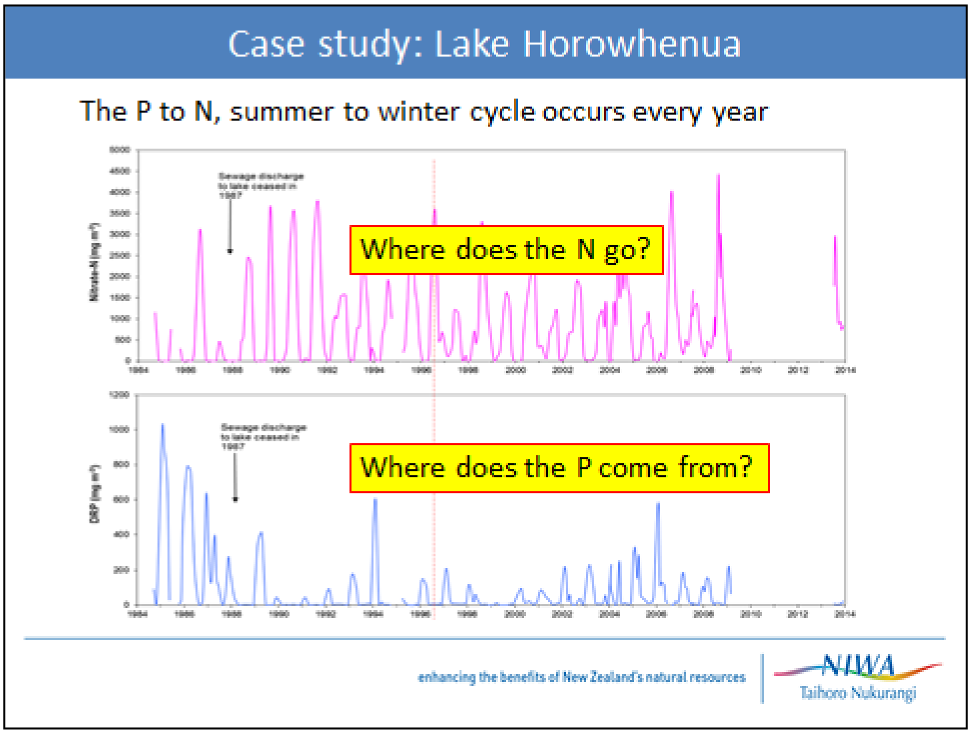
Summer

Winter

enhancing the benefits of New Zealand's natural resources

Slide 3 shows that there is very high phosphorus in summer with no nitrate, but very high nitrogen in winter with no phosphate. This cycle is a summer/winter cycle and occurs every year. In the period from 1985 to today, even after the removal of sewage, nitrogen always appeared in winter and, although less after the sewage removal, phosphorus appeared in summer.

Slide 3



Case study: Lake Horowhenua

The P to N, summer to winter cycle occurs every year

Where does the N go?

Where does the P come from?

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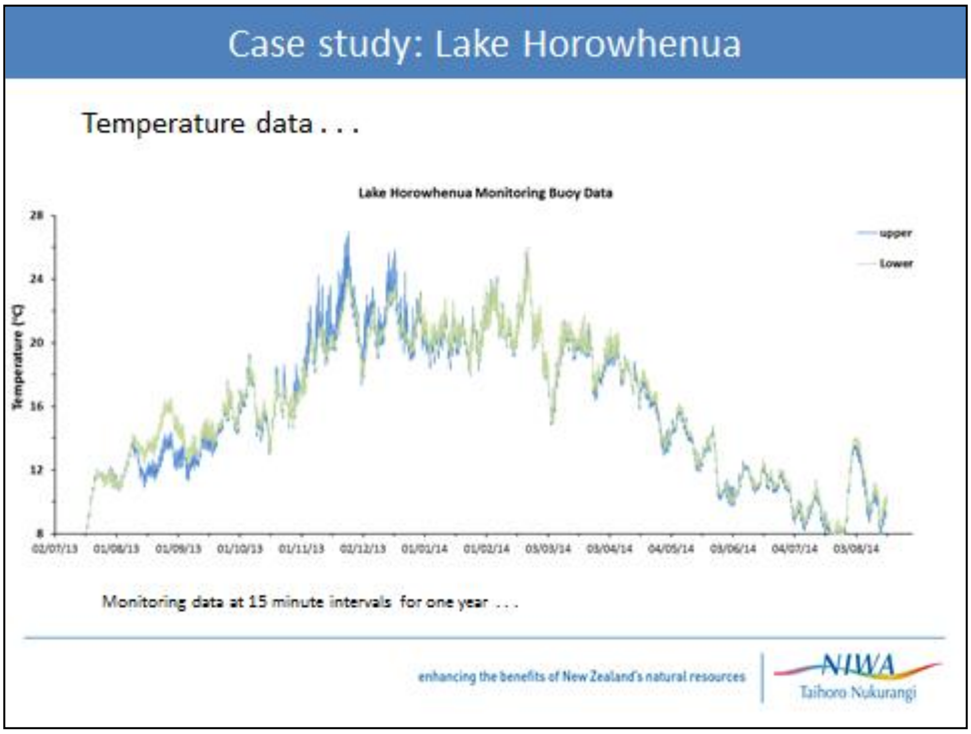
Slide 4



Case study: Lake Horowhenua

Temperature data . . .

Monitoring data at 15 minute intervals for one year . . .

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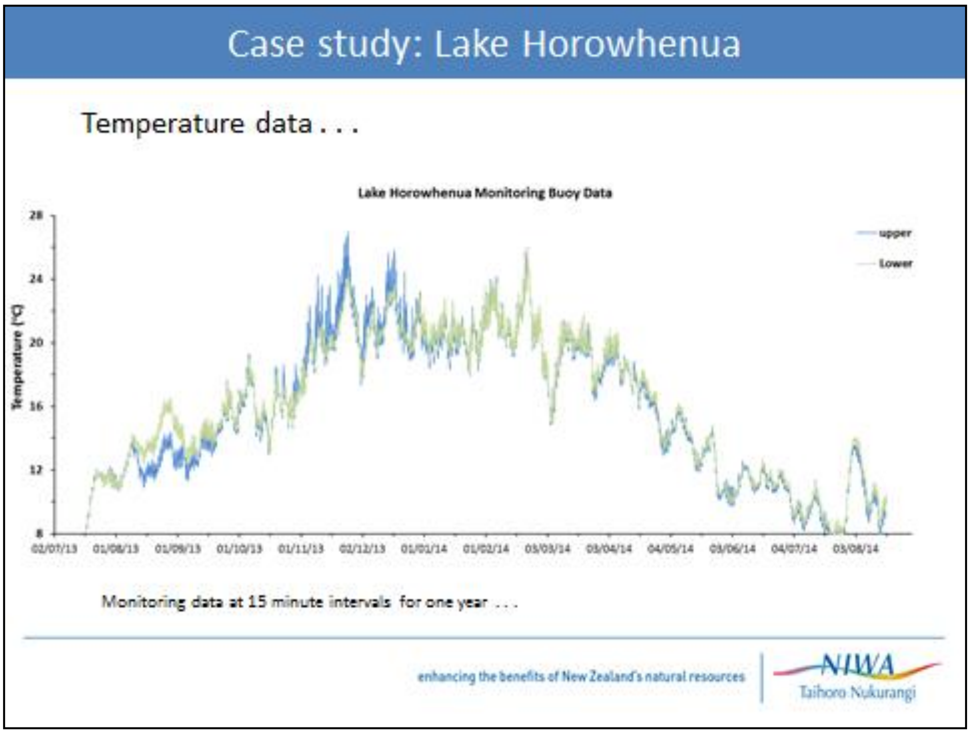
Where does the nitrogen go and where does the phosphorus come from? Normally phosphorus is released in lakes under anoxic conditions. **Slide 4** is the temperature data from a monitoring boy in the lake and shows that there is very little difference between surface and bottom temperatures in the lake. The lake has a maximum depth of just 2 metres so thermal stratification and anoxia would not be expected.

Slide 5 shows the oxygen data as the orange line, with a very short period where oxygen concentrations go very low. That is probably not long enough to establish the amount of phosphorus that is released in this lake in summer.

Slide 5



Case study: Lake Horowhenua

Temperature data . . .

Monitoring data at 15 minute intervals for one year . . .

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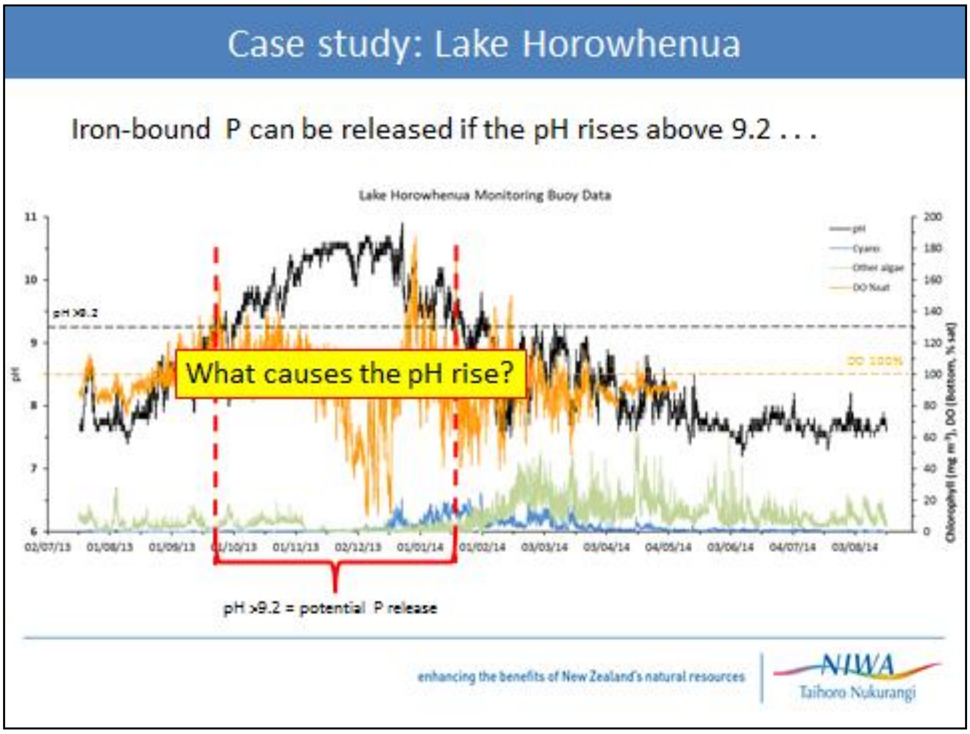
Slide 6 looks at the phosphorus bound into the sediments of the lake by iron and which can be released if the pH rises above 9.2.

Slide 6



Case study: Lake Horowhenua

Iron-bound P can be released if the pH rises above 9.2 . . .

What causes the pH rise?

pH >9.2 = potential P release

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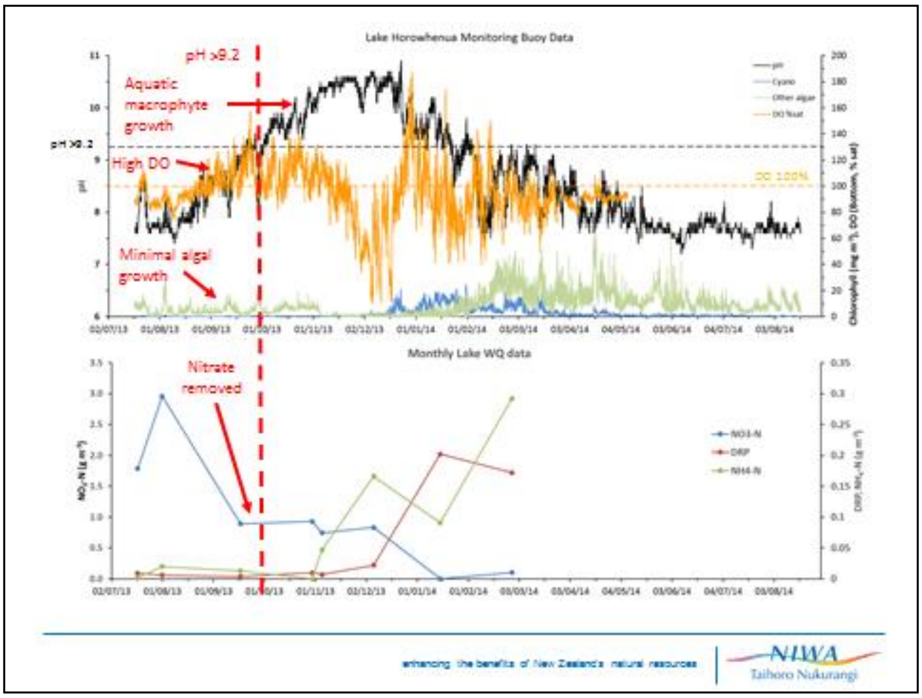
Slide 7


Lake Horowhenua Monitoring Buoy Data

pH >9.2

Aquatic macrophyte growth

High DO

Minimal algal growth

Monthly Lake WQ data

Nitrate removed

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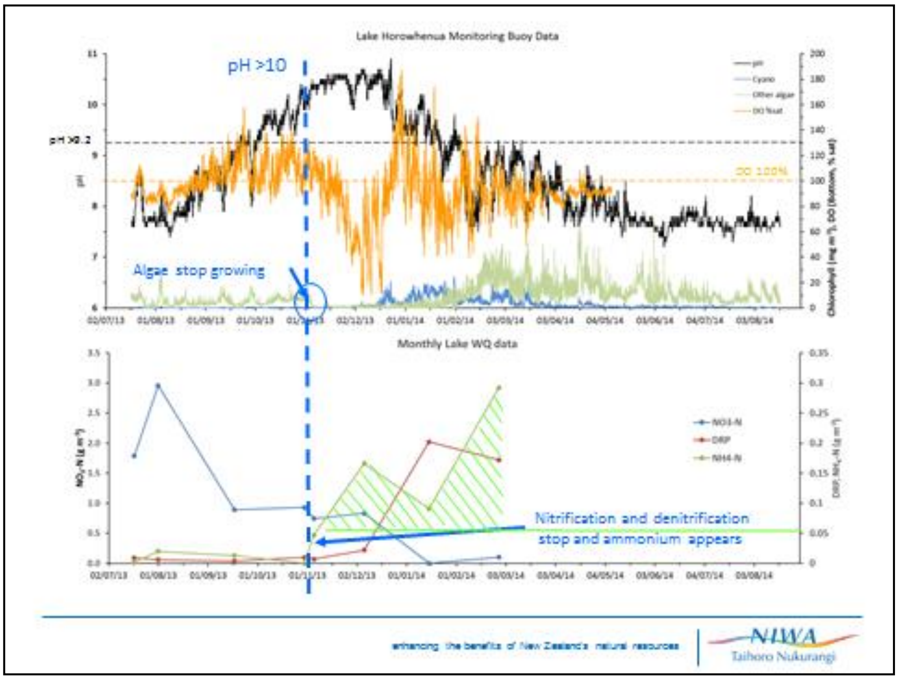
In **Slide 7** it is seen that pH goes above 9.2 for a considerable period of time. During this part of the year there is a potential for phosphorus to be released from the sediment purely by the rise in pH, even if oxygen is present.

What causes the pH to rise? Looking at the whole system, including the nutrients, there is the winter nitrogen period in the lake and then there is the pH effect. When the pH exceeds 9.2 the dissolved oxygen increases; dissolved oxygen becomes greater than 100% and that indicates photosynthesis. The nitrate is removed; that indicates that a plant is removing the nitrogen from the system. Looking at the algal content, as in green algae rather than blue green, it is seen that there is only minimal algal growth, so it cannot be increasing algal biomass that is producing the high pH. The simple answer is that there is aquatic macrophyte growth in the lake and the macrophytes are pushing up the pH.

Slide 8


Lake Horowhenua Monitoring Buoy Data

pH >10

Algae stop growing

Monthly Lake WQ data

Nitrification and denitrification stop and ammonium appears

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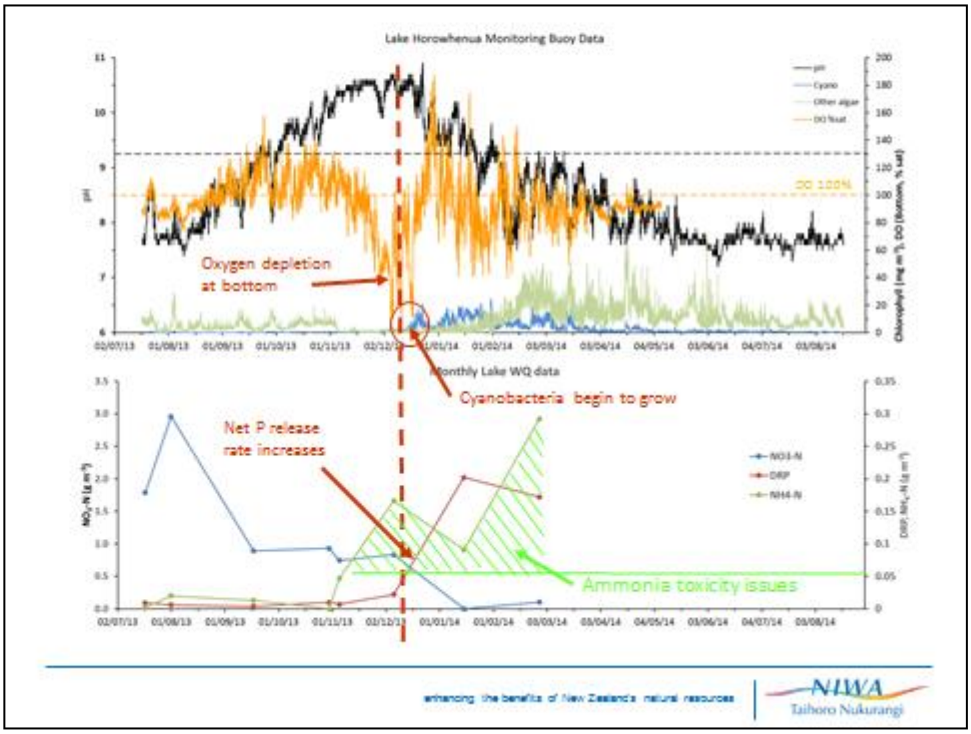
Slide 8 An interesting side issue is that green algae, like most native aquatic plant species can only tolerate a pH of about 8.5 for photosynthesis. Higher than that they start to decline in growth. The pH is greater than 9 and to achieve that requires a bicarbonate adapted plant species. Cyanobacteria, potamogeton and elodea are all in the lake and all have this capability of pushing the pH greater than 9.2. When pH reaches 10 the point where green algae can survive is exceeded and they stop growing.

Slide 9 The point is exceeded where the bacterial conversion of ammonia to nitrate (nitrification) stops and ammonia starts coming out of the sediments. Continuing along that trend or the timeline it is seen that pH has stopped increasing. There is a short period of oxygen depletion at the bottom, net phosphorus release in the sediment is seen and nitrate has decreased. Unfortunately this data is from monthly samples and so the exact time frame may not be accurate. Within the restrictions, it can be said that under these conditions the trigger for cyanobacteria beginning to bloom has been reached.

Slide 9


Lake Horowhenua Monitoring Buoy Data

Oxygen depletion at bottom

Cyanobacteria begin to grow

Monthly Lake WQ data

Net P release rate increases

Ammonia toxicity issues

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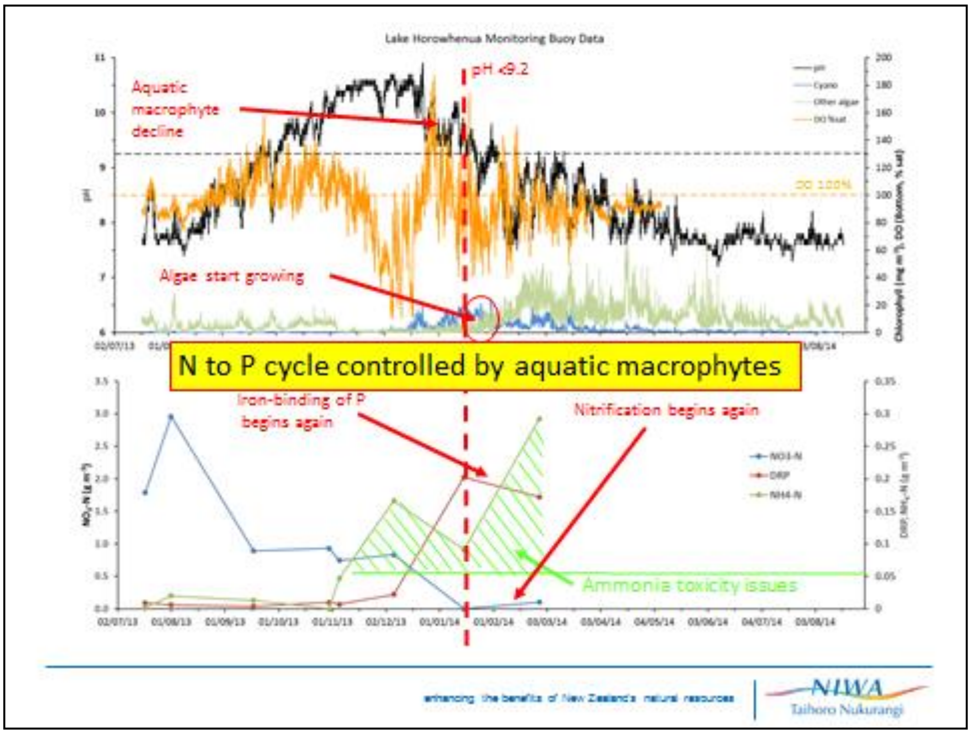
Slide 10 Assuming that this is all driven by macrophytes, the macrophytes are beginning to decline, pH has dropped down to 9.2, the threshold point is reached where green algae can grow again and iron will bind the phosphorus back into the sediments. So a cycle is completed, nitrification begins again because the toxic pH zone is over. Thus the N to P cycle in Lake Horowhenua is controlled by aquatic macrophytes.

The phosphorus in Lake Horowhenua is a legacy from disposal of treated sewage effluent in the early 60's, 70's and 80s. The effluent discharge stopped in 1987 but the water quality has not improved. The phosphorus source to the lake now is associated with the soil erosion from cropping. Land erosion of fine sediment carries phosphorus into the lake where the P can be recycled from the sediment out of the fine particles.

Slide 10



Aquatic macrophyte decline

pH <9.2

Algae start growing

N to P cycle controlled by aquatic macrophytes

Iron-binding of P begins again

Nitrification begins again

Ammonia toxicity issues

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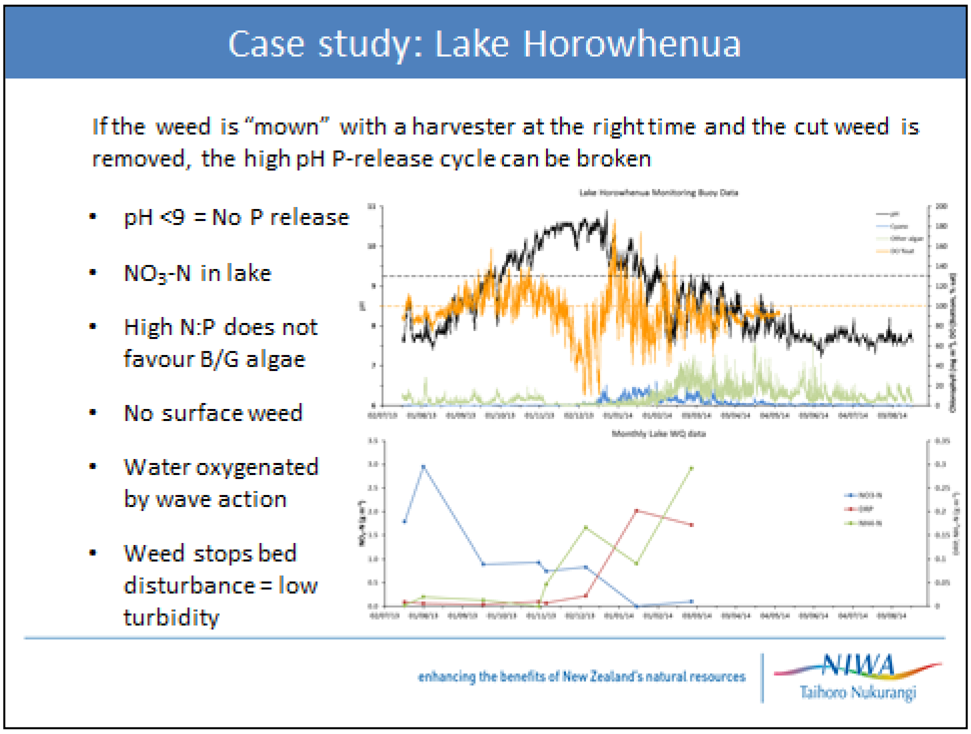
What are the management options?

Reducing the source of phosphorus by reducing sediment erosion from cropping is a priority. If the source is known, the impact on the lake can eventually be reduced. Spraying the weed was thought not to be an option, but in light of earlier presentations, that statement may need to be reconsidered.

Harvesting the weed to stop high pH has the potential to reduce the incidence of cyanobacteria. In this case the top of the plants have been mowed at the right time of the year to slow down the photosynthesis and therefore keep the pH below 9.

Slide 11



Case study: Lake Horowhenua

If the weed is "mown" with a harvester at the right time and the cut weed is removed, the high pH P-release cycle can be broken

- pH <9 = No P release
- NO_3-N in lake
- High N:P does not favour B/G algae
- No surface weed
- Water oxygenated by wave action
- Weed stops bed disturbance = low turbidity

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Weed is both the problem and part of the solution. If the weed is mown with a harvester at the right time and the cut weed removed, the pH release cycle can be broken. **(Slide 11)** At a pH less than 9 there is no phosphorus release, nitrate remains in the lake because there is not enough weed to remove it all, so therefore there is a higher N to P ratio which does not favour blue green algae. The lake does not have surface weeds and wind action can mix oxygen down to the bottom so there is no anoxic event. The weed that remains in the lake after cutting stops the bed disturbance, resulting in low turbidity.

Bay of Plenty Regional Council has an overall objective of improving the maintenance of the water quality in the Rotorua Te Arawa lakes. To achieve this, BOPRC uses a number of rules set out in a Regional Plan to manage the nutrient loads entering each lake. There is an Action Plan for each lake that sets out the remedial acts required to achieve a specific water quality based on its Trophic Level Index. Each Action Plan is based on good science and the water quality goal was agreed by a Technical Advisory Group or TAG Group of water quality specialists and scientists. Management strategies to achieve the water quality goal for a lake may use a combination of land based in-lake processes and interventions.

For example nutrient N and P loads in Lake Rotoehu support the growth of cyanobacteria and the invasive exotic weed hornwort. Cyanobacteria production is favoured by the high P relative to N concentrations in the lake. The P sources are the spring waters, sediment release under anoxic conditions and suspended sediments from land erosion. Nitrogen sources are from land run off, ground water and the lake sediments. Management strategies for P include P-locking the spring water inflows with alum and the investigation of aeration to stop the occurrence of anoxia. Management strategy for nitrogen is to remove the hornwort using a weed harvester and introduce land management changes. The weed harvester removes on average about 4.1 tonne of nitrogen and 0.55 tonnes of phosphorus each year.

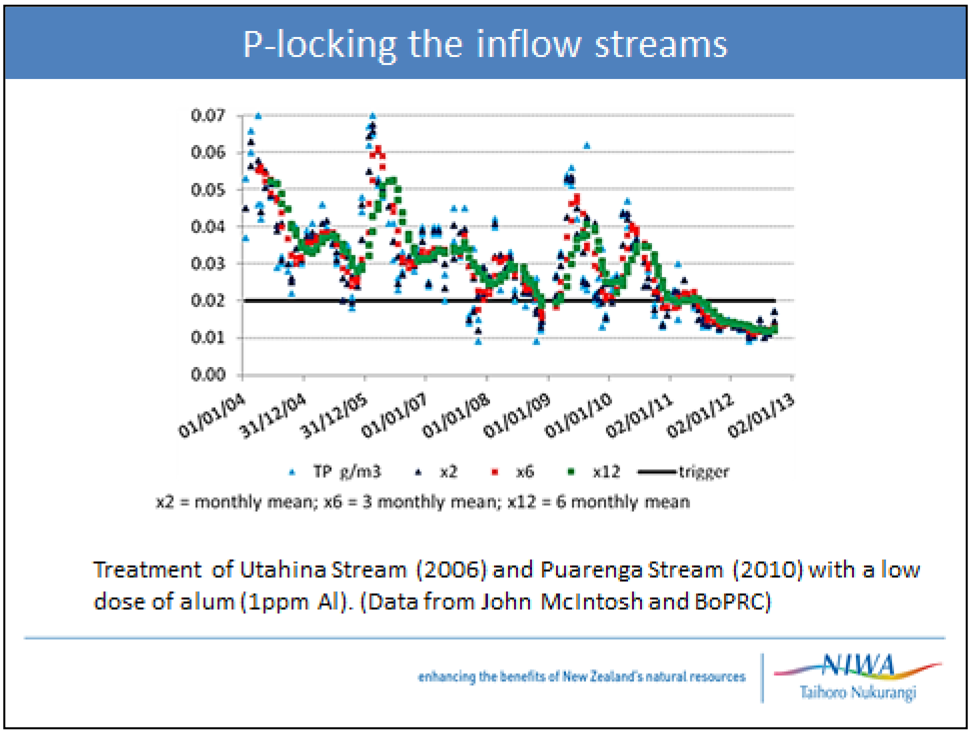
Nutrient N and P loads in Lake Rotorua come from the natural cold and hot springs, from farming, forestry, urban development and treated wastewater. Strategies for the lake must encompass all of these factors.

The Rotorua Action Plan states that nitrogen inputs into the lake need to be reduced by a total of 320 tonnes per year. The phosphorus inputs need to be reduced by a total of 10 tonnes per year and the impact of nitrogen and phosphorus loads in the lake also need to be reduced. Management strategies include P-locking of the inflow streams, removal of nitrogen from Tikitere, sewerage reticulation of septic tanks around the lake, land use changes and more recently, weed harvesting in the lake.

P-locking the inflow streams has shown that phosphorus in the lake can be reduced, and reduced substantially, by just locking up the phosphorus going into the lake from the Utahina and Puarenga Streams. 40% of the phosphorus that goes into the lake has DRP's from spring water. **(Slide 12)**

Slide 13 graphs the TLI status of Lake Rotorua (its indication of health), which over time gradually meandered. The blue 3 year average is now reaching a level of 4.2 TLI units, almost meeting the objective target of the Regional Water and Land Plan. The Action Plan target for P reduction of 10 tonnes per year has been met; in fact about 11 tonnes is being removed. To meet the Action Plan target for nitrogen a further reduction of about 50 tonnes of nitrogen is required; one option being considered is the weed harvester. This option would remove weed from the lake together with nutrients in the plant material. But it has to be remembered that nutrients in a lake cannot be effectively controlled by weed harvesting.[2]

Slide 12



P-locking the inflow streams

x2 = monthly mean; x6 = 3 monthly mean; x12 = 6 monthly mean

Treatment of Utahina Stream (2006) and Puarenga Stream (2010) with a low dose of alum (1ppm Al). (Data from John McIntosh and BoPRC)

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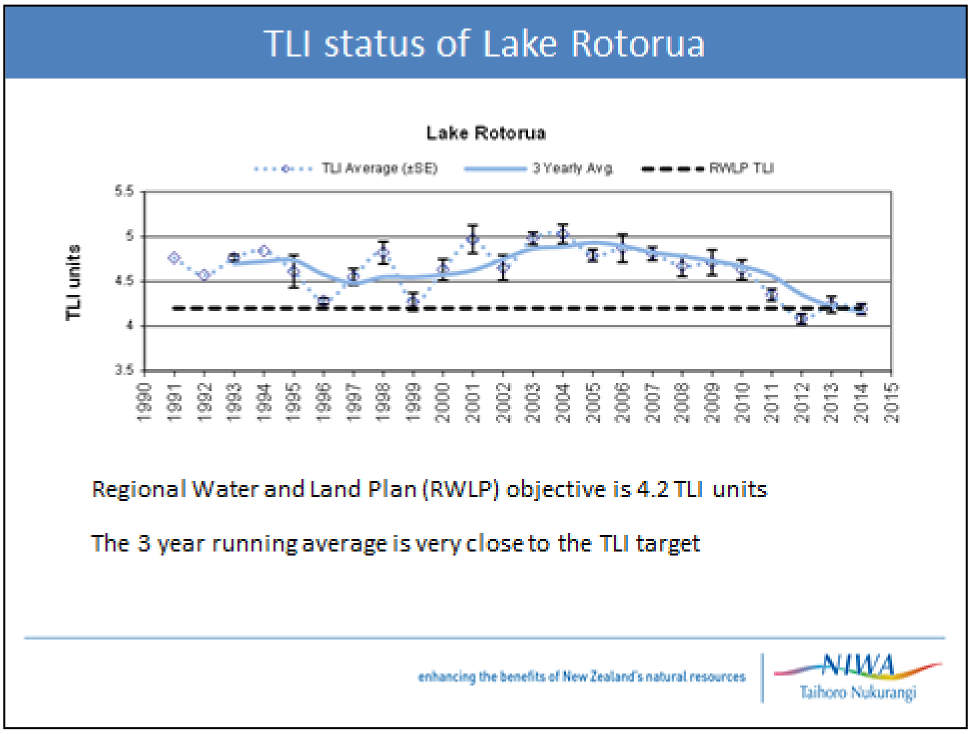
Slide 13



TLI status of Lake Rotorua

Regional Water and Land Plan (RWLP) objective is 4.2 TLI units

The 3 year running average is very close to the TLI target

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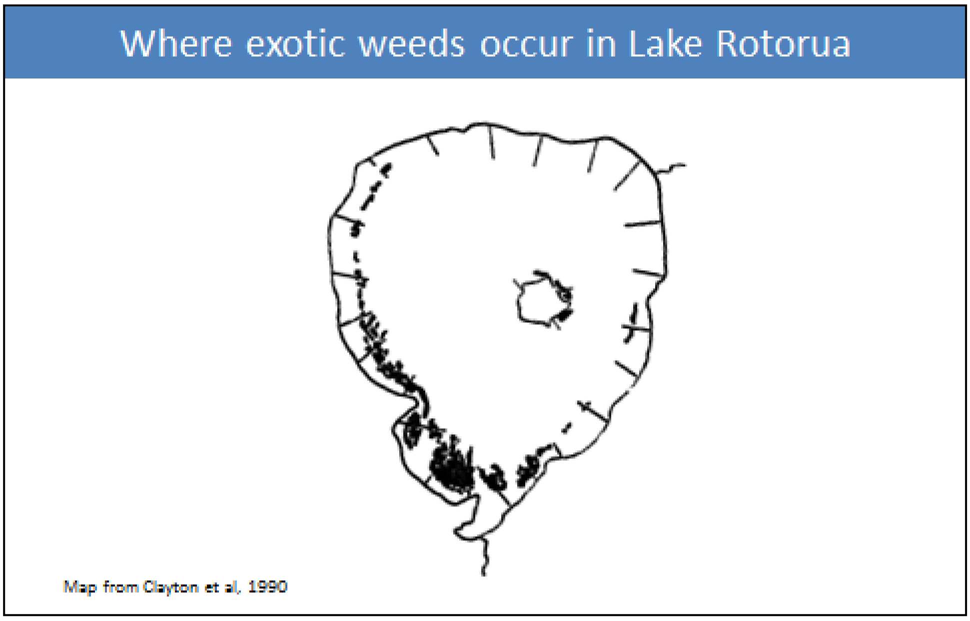
[2] Advantages and disadvantages of Aquatic Plant Management Techniques, *Lakeline* 20 (1):22-34

Rotoehu removed 4.1 tonnes a year of nitrogen and 0.55 of phosphorus; is it feasible to reduce nutrients in Lake Rotorua by weed harvesting? The aquatic weeds occur mainly on the southern western shores of the lake particularly in front of the city; they are there because the water depth allows them to grow. **(Slides 14 and 15)** Thus there is a depth restriction on where the weeds can grow and they happen to grow in those positions.

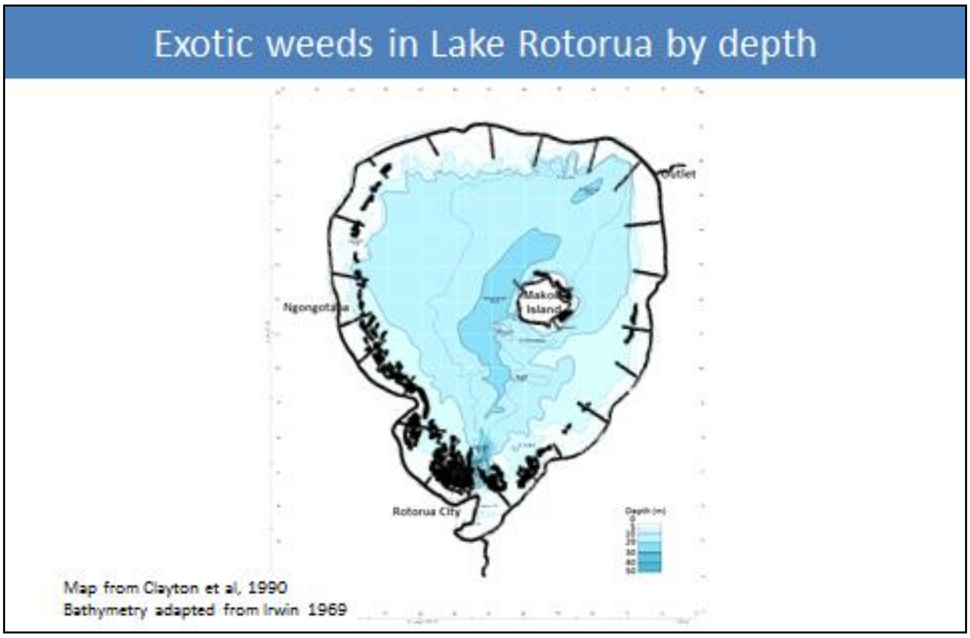
Slide 14



Where exotic weeds occur in Lake Rotorua

Map from Clayton et al, 1990

Slide 15

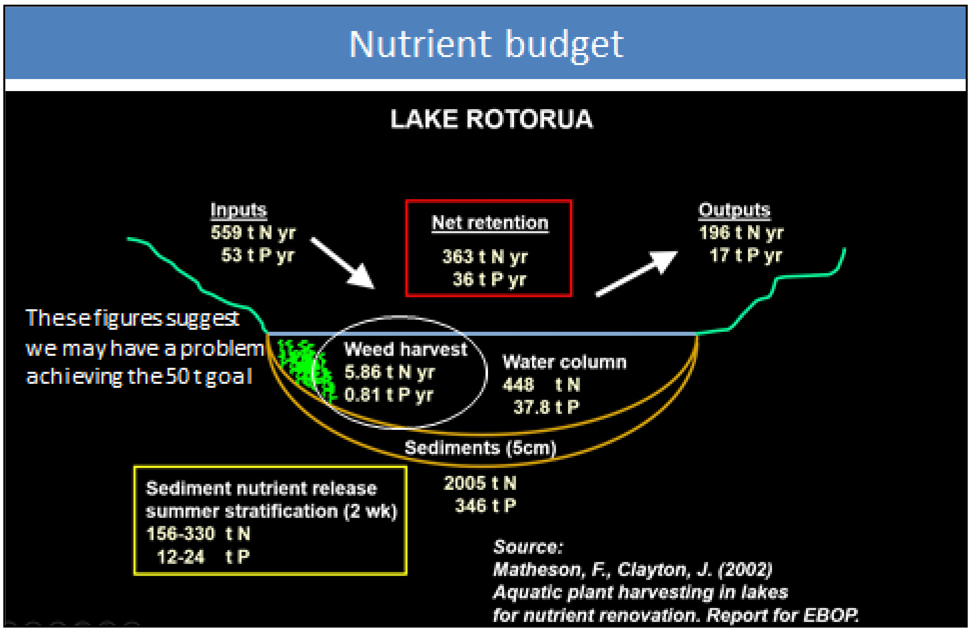


Exotic weeds in Lake Rotorua by depth

Map from Clayton et al, 1990
Bathymetry adapted from Irwin 1969

Slide 16 gives a rough idea of the nutrient budget in the lake, the inflows, the outflows and an interesting estimate of weed harvesting. Unfortunately these figures suggest that there may be a problem in achieving the goal of 50 tonnes. **Slide 17** show some calculations using a depth cut of 1.5 metres, a 6 minute turnaround from cutting to offloading from the harvester (based on the possibility of using a transfer barge) showed that to remove 50 tonnes, 130 eight hour days of harvesting would be needed. This is probably not feasible; 5 to 10 tonnes of nitrogen might be removed assuming there is enough weed to harvest. And that would be worth removing.

Slide 16



Nutrient budget

LAKE ROTORUA

Inputs
559 t N yr
53 t P yr

Net retention
363 t N yr
36 t P yr

Outputs
196 t N yr
17 t P yr

These figures suggest we may have a problem achieving the 50 t goal

Weed harvest
5.86 t N yr
0.81 t P yr

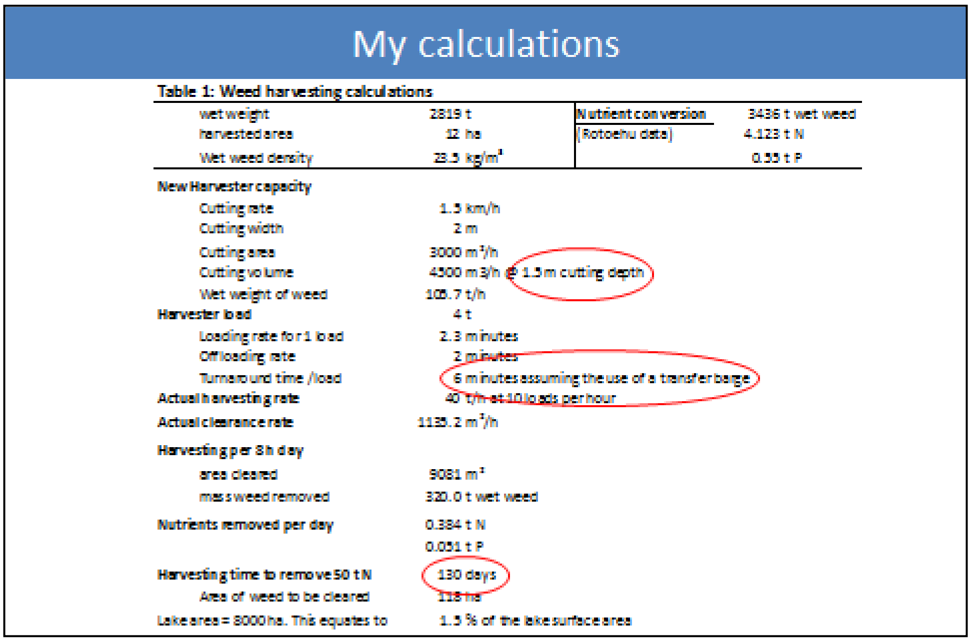
Water column
448 t N
37.8 t P

Sediments (5cm)
2005 t N
346 t P

Sediment nutrient release summer stratification (2 wk)
156-330 t N
12-24 t P

Source:
Matheson, F., Clayton, J. (2002)
Aquatic plant harvesting in lakes for nutrient renovation. Report for EBOP.

Slide 17



My calculations

Table 1: Weed harvesting calculations

wet weight	2819 t	Nutrient conversion	3436 t wet weed
harvested area	12 ha	(Rotoehu data)	4.123 t N
Wet weed density	23.5 kg/m²		0.55 t P

New Harvester capacity		
Cutting rate	1.5 km/h	
Cutting width	2 m	
Cutting area	3000 m²/h	
Cutting volume	4500 m 3/h	@ 1.5 m cutting depth
Wet weight of weed	105.7 t/h	
Harvester load	4 t	
Loading rate for 1 load	2.3 minutes	
Offloading rate	2 minutes	
Turnaround time /load	6 minutes assuming the use of a transfer barge	
Actual harvesting rate	40 t/h at 10 loads per hour	
Actual clearance rate	1135.2 m²/h	
Harvesting per 8 h day		
area cleared	9081 m²	
mass weed removed	320.0 t wet weed	
Nutrients removed per day	0.384 t N	
	0.051 t P	
Harvesting time to remove 50 t N	130 days	
Area of weed to be cleared	118 ha	
Lake area = 8000 ha. This equates to	1.5 % of the lake surface area	

The success of the P-locking programme has improved water clarity. This reduces light limitation to weed growth and the weed beds are likely to expand. As the weed beds expand they will also take up nitrogen. By my calculations, it would require an additional weed bed area of about 35 hectares, 5 metres deep to lock up 50 tonnes of nitrogen. Therefore the weed harvester might not be used to remove the nutrients but it could be used to manage the inshore spread of the weed and reduce the weed breakoff and drift to shore after storms. Perhaps it may not be necessary to remove those 50 tonnes of nitrogen if they can be held so they are not available to the algae in the water.