Potential application of aeration/artificial destratification to Rotorua lakes

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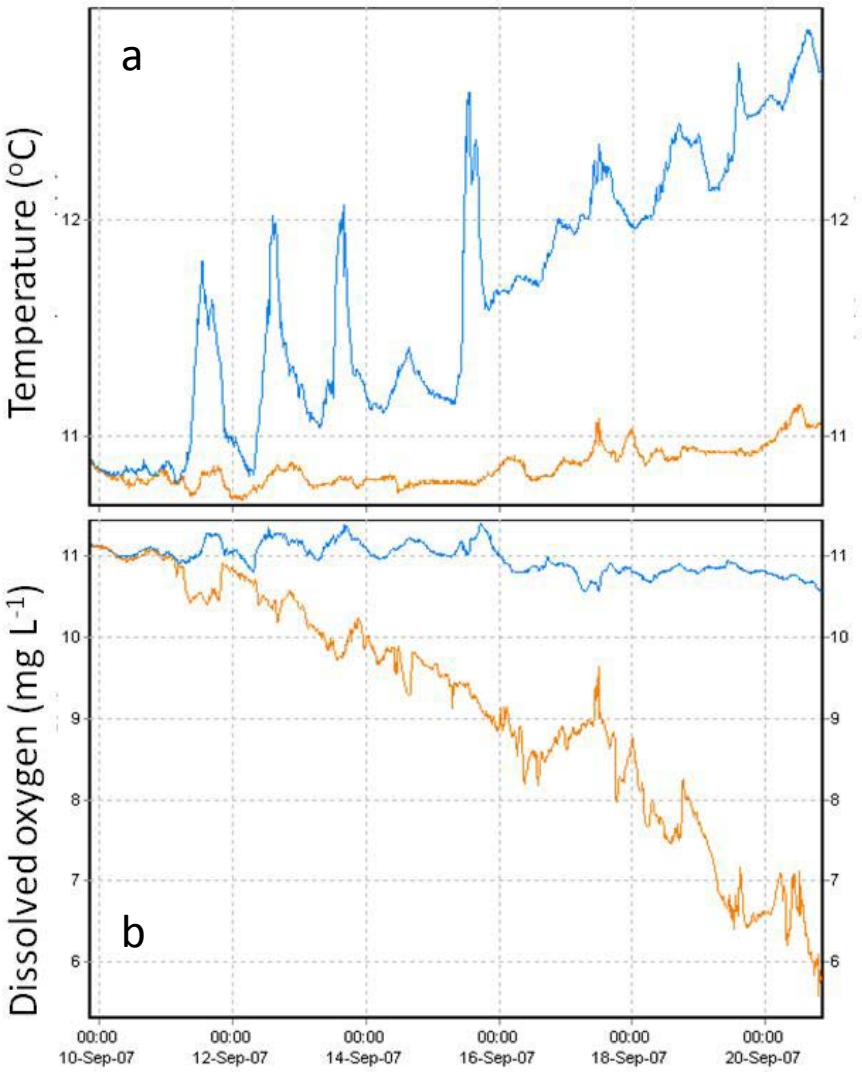
Stratification – Lake Rotorua



Lakes in the Rotorua region stratify either:
a) Seasonally (e.g., Rotoiti, Tarawera, Rotoma) for 8-9 months of the year
b) In calm periods for periods of hours to 2-3 weeks (e.g., Rotoehu, Rotorua)

Left: a stratification event in Lake Rotorua:
a)Surface temperature (blue) and bottom temperature (orange) separate (no mixing of surface with bottom waters)
b)Surface oxygen (blue) and bottom oxygen (orange) also separate

- Lake Rotorua has about three periods of stratification of 10 days' duration each year, when oxygen concentrations become zero in bottom waters.
- **Each stratification event releases the equivalent of about one-third to one-half of the annual incoming nutrient load from the bottom sediments.**

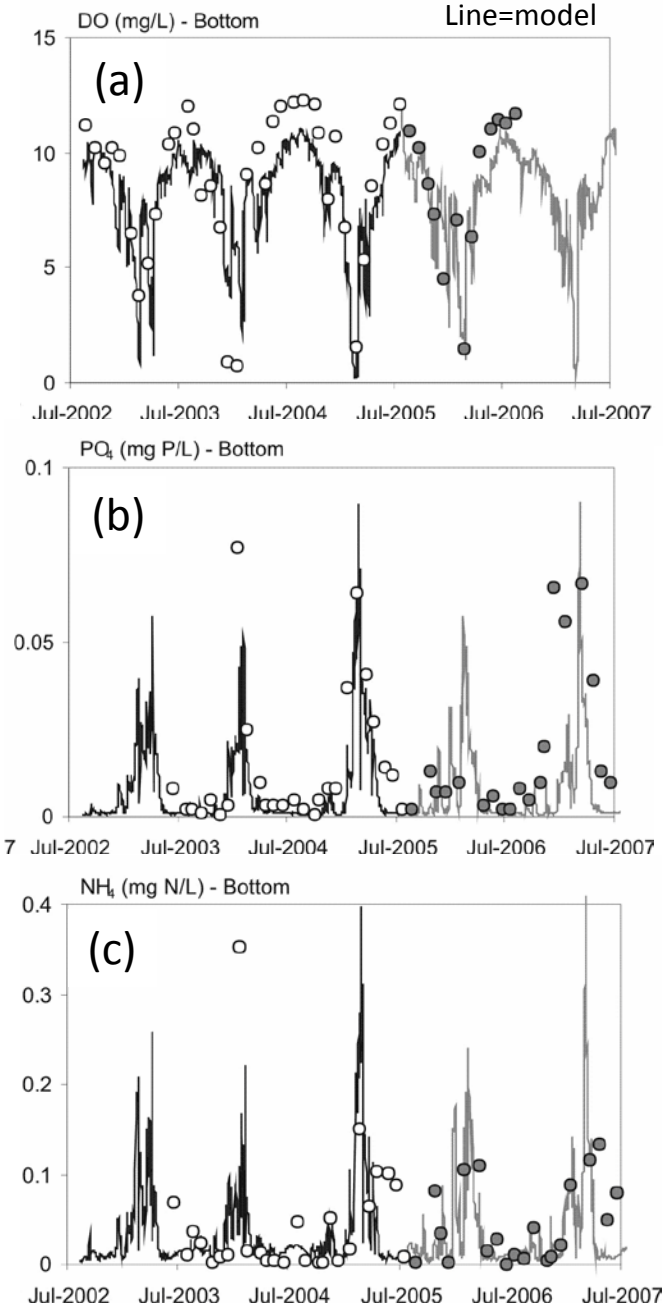
Effects of stratification in Lake Rotoehu

(a) The bottom waters of Lake Rotoehu are rarely well oxygenated in summer

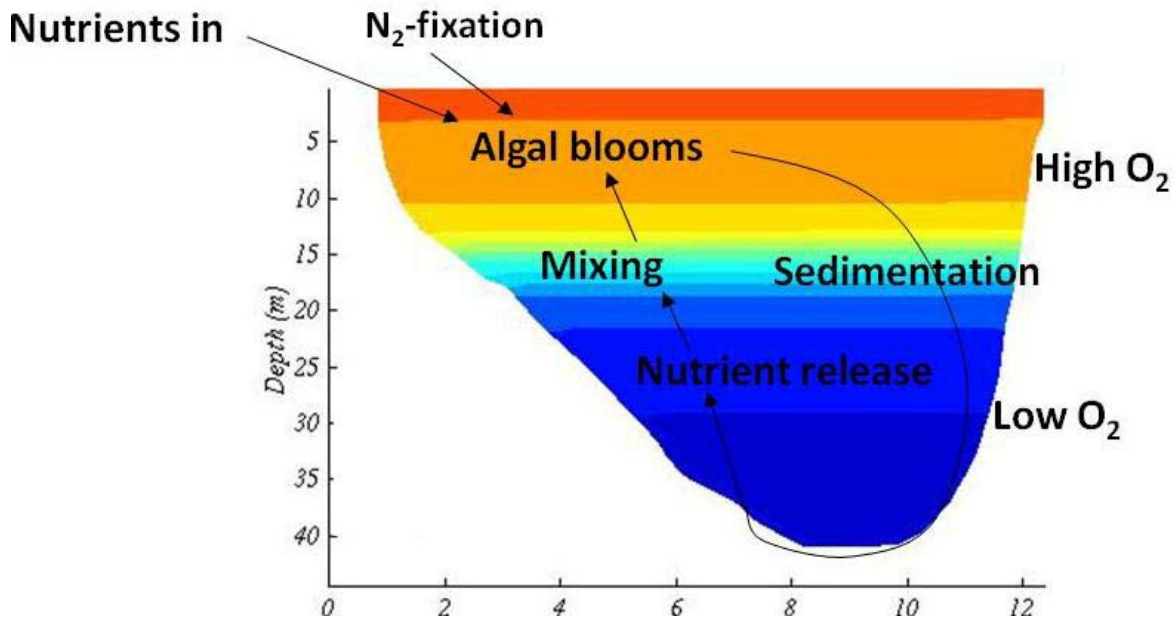
The greatest deoxygenation in bottom waters results in:
a)Levels of phosphate approaching 0.1 mg/L
b)Levels of ammonium approaching 0.4 mg/L
These concentrations are more than 10-fold higher than what is required to stimulate algal blooms.

Algal bloom, Lake Rotoehu

Dots=measurements
Line=model



The consequences of deoxygenation



Lakes whose bottom waters deoxygenate in response to excess nutrient loading from their catchments will become tied into a nutrient 'treadmill':

- Nutrients are released in increasing quantities due to deoxygenation
- This stimulates more algal growth which, as it settles and decays, stimulates more deoxygenation
- Nutrients released from bottom sediments tend to have low N:P ratios – this is likely to also stimulation more algae.

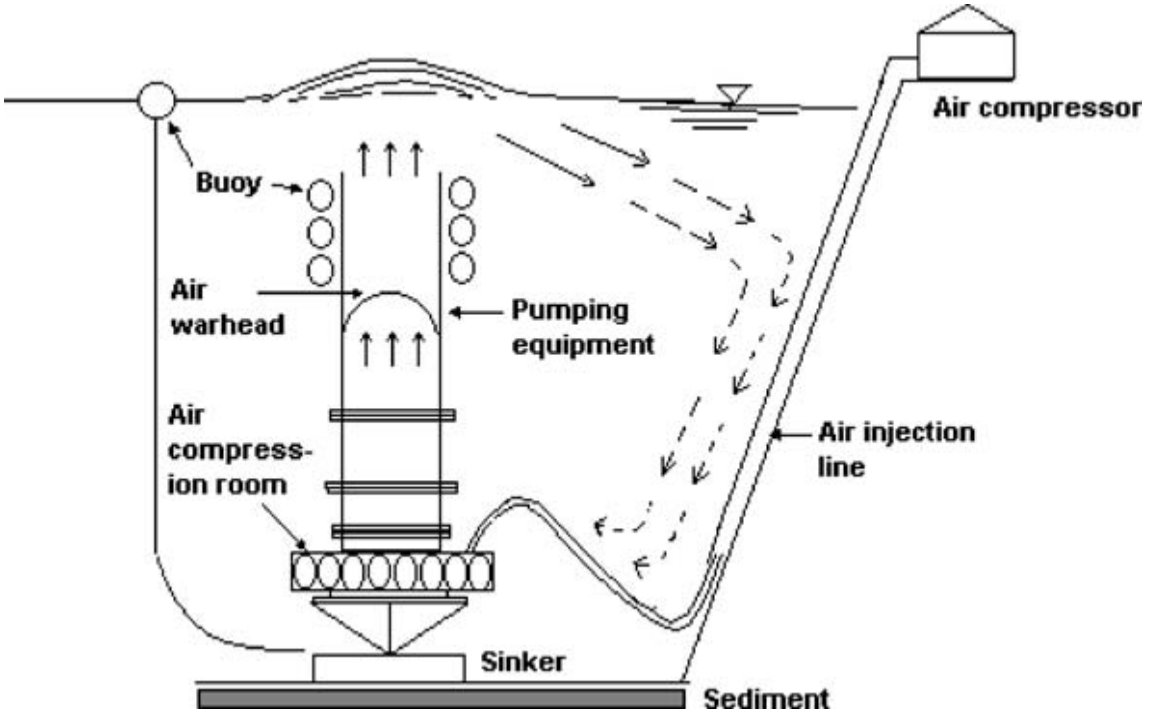
Intervention will be likely to be needed to break this cycle.

Breaking the nutrient treadmill – artificial destratification

David Hamilton's colleague, Bomchul Kim, has been using artificial destratification for water quality control in a reservoir for a number of years. It is used in lakes and reservoirs across the world.

Note: the effect of the bubbles in oxygenating the water is negligible. It is their ability to entrain denser water from deep and lift it to the surface where it creates circulation to break down stratification.

Mixing the water creates a greater flux of oxygen into the water because the oxygen concentration in surface waters is reduced slightly as a result of mixing with bottom waters.



Hydrobiologia **524:** 229–239, 2004.

The effect of artificial destratification on phytoplankton in a reservoir

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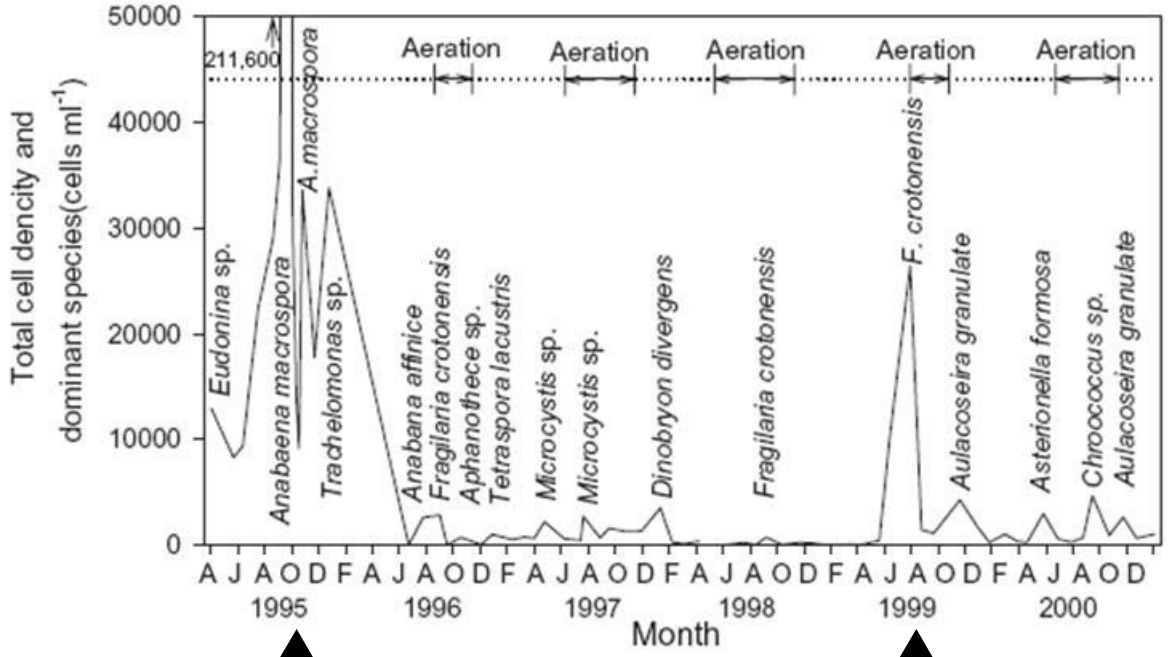
How well does artificial destratification work?



Massive blooms of blue-green algae prior to aeration (note that correct term should really be artificial destratification (203,000 cells/ml of blue-green algae corresponding to total value of 211,600 cells/ml)

Moderate concentration of a benign diatom prior to seasonal aeration

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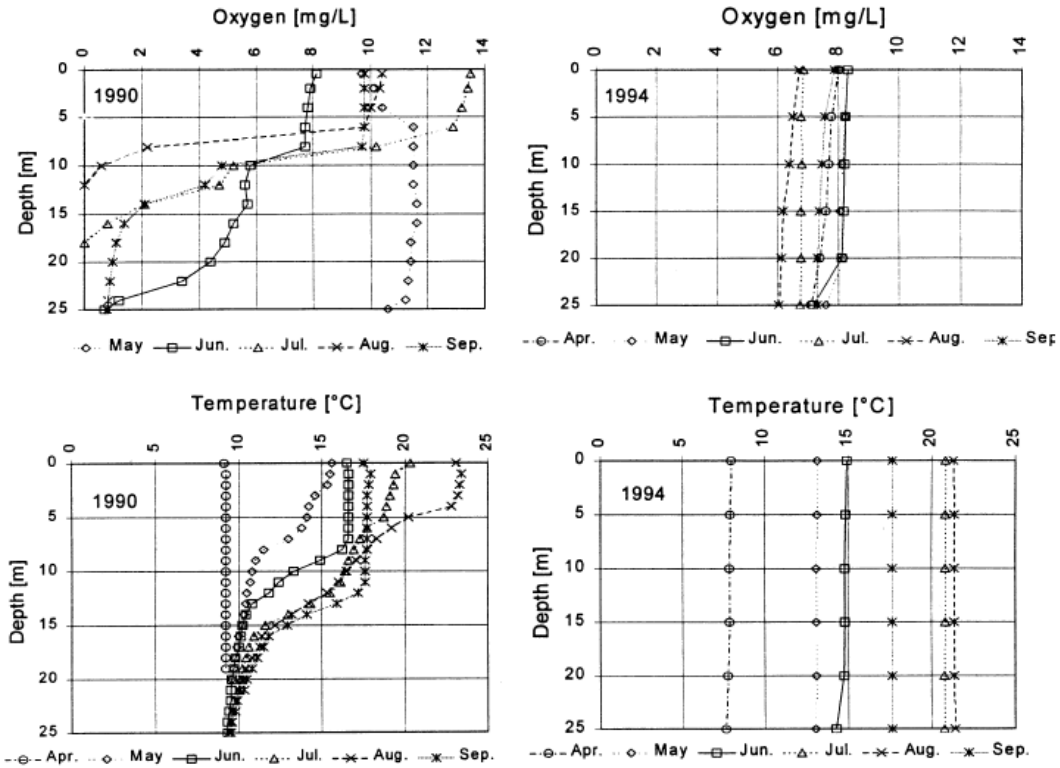

A highly efficient destratification system in Lake Nieuwe Meer, Netherlands: before destratification (left-hand side) and after destratification (right-hand side)

David Hamilton's colleague Petra Visser has built up nearly 20 years' experience with destratification systems.

Figure 3 Oxygen and temperature situation before and with mixing.

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Artificial mixing to reduce growth of the blue-green alga *Microcystis* in Lake Nieuwe Meer, Amsterdam: an evaluation of 7 years of experience

Edgar Jungo[1]*, Petra M. Visser[1], Jasper Stroom[3] and Luuc R. Mur[2]

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How well does artificial destratification work?

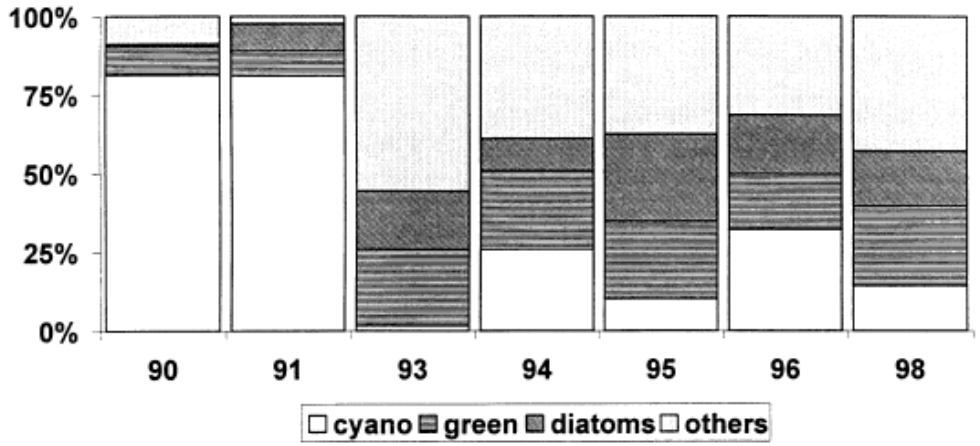

Figure 2 The percentage of the different algal groups (cyanobacteria, green-algae, diatoms and others) in Lake Nieuwe Meer in the years without (90 and 91) and with (93-99) artificial mixing.

Visser has shown how destratification systems prevent buoyant blue-green algae from coming to the surface to form blooms – other benign species (e.g. diatoms, which tend to sink) begin to out-compete them due to mixing.

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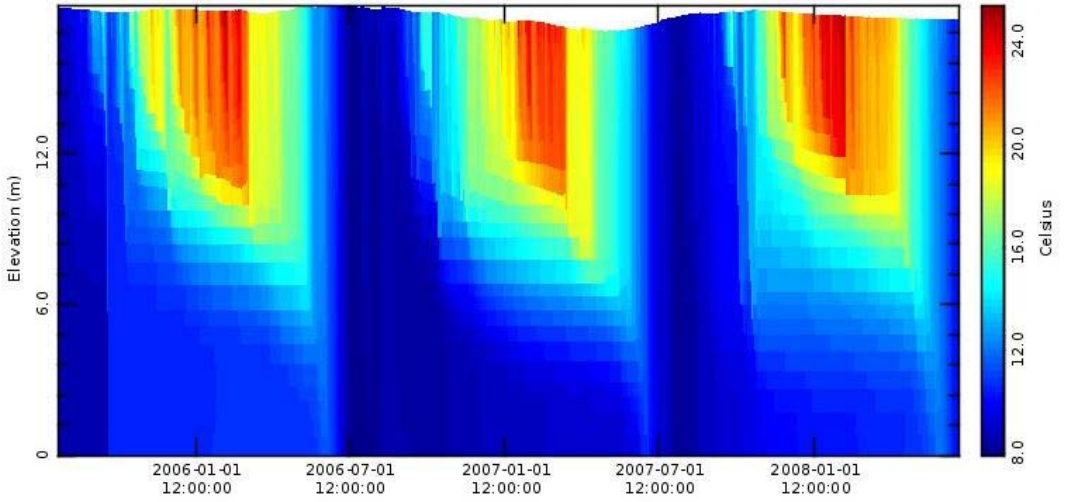
Temperature comparison in Lake Okaro – wave pump destratification

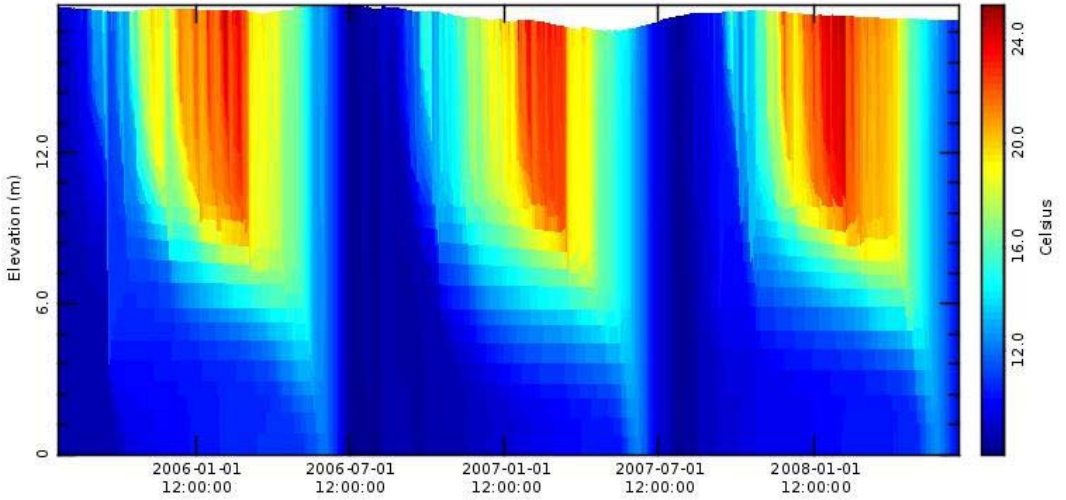
Q) Could destratification fail to mix the water?

Yes, if underdesigned – see wave pump case.

Base case simulation



Scenario: 40 x wave pumps

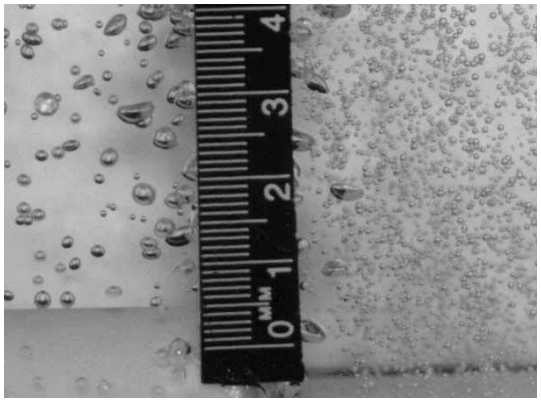


- **Outcome: slight deepening of surface mixed layer**

Q) How will we know if we have an under-design problem?

We have considerable experience in

a) aeration technology (Hans Burgraaf and collaboration with Ken Ashley, Canada): bubble size optimisation for mechanical lift of the water.
b) measurements and modelling of destratification systems (David Hamilton); sizing will be appropriate.



HYDROLOGICAL PROCESSES
Hydrol. Process. **15**, 2465–2480 (2001)
DOI: 10.1002/hyp.298

The hydrology of the upper Swan River Estuary with focus on an artificial destratification trial

David P. Hamilton,[1]* Terence Chan,[1] Malcolm S. Robb,[2] Chari B. Pattiaratchi[1] and Michael Herzfeld[1]
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[2] *Water and Rivers Commission, Hyatt Centre, 2 Plain Street, Perth, WA 6004, Australia*

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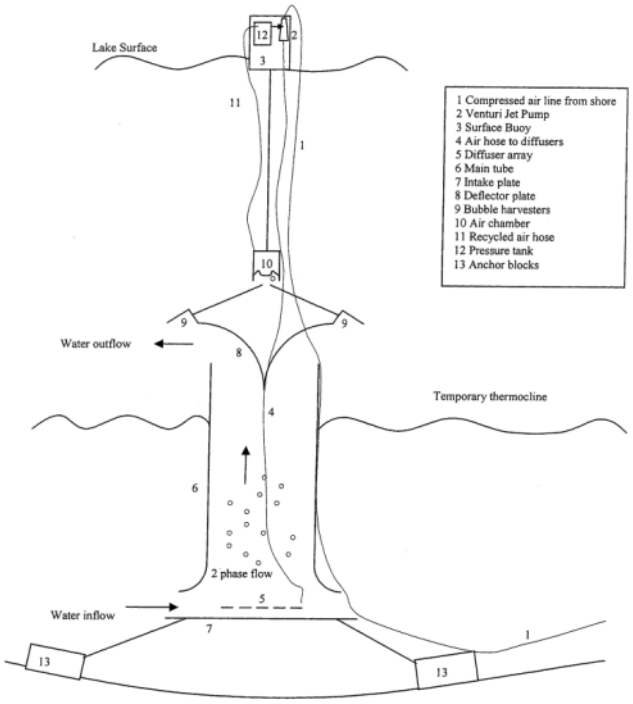
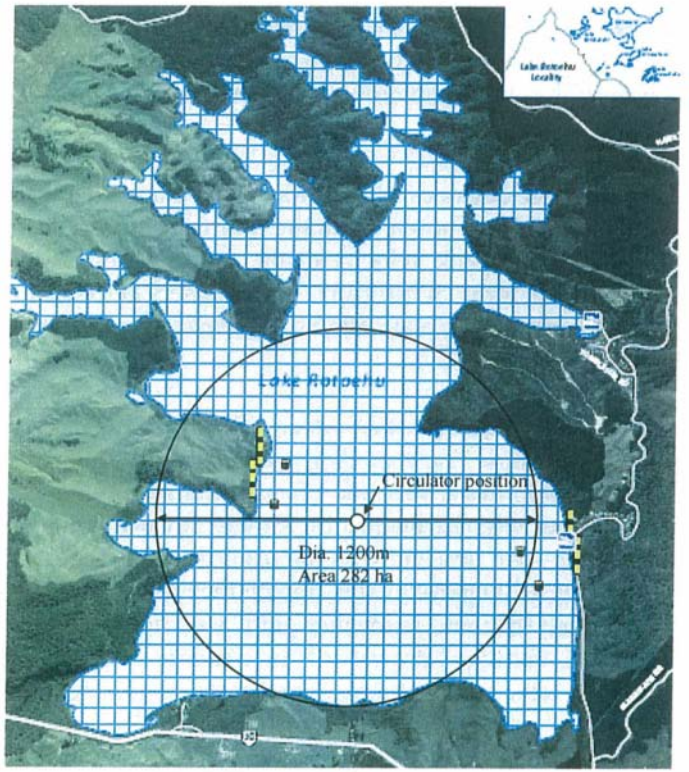
Effect of orifice diameter, depth of air injection, and air flow rate on oxygen transfer in a pilot-scale, full lift, hypolimnetic aerator[1]

K.I. Ashley, D.S. Mavinic, and K.J. Hall

Design of an artificial destratification system for Lake Rotoehu





1. Location: the unusual shape of Rotoehu will challenge the ‘reach’ of the system.
2. Usually used in monomictic (seasonally stratified) rather than polymictic systems (intermittently stratified): opportunities to use a buoy (oxygen measurements) to optimise power usage.

Risks

1. There has been a tendency in the past to try to minimise power requirements resulting in system under-design – model simulations will ascertain appropriate sizing and therefore power requirements.

2. There could be a tendency to aerate when the lake was going to be fully mixed anyway – we will optimise the operation by a control operator through our monitoring buoys.

3. A successful outcome could reduce the focus away from catchment nutrient control – L&W Plan has goals.

4. Capital and maintenance costs.