Sediments of Lake Rotorua

Report to Hartley Contracting

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February 8th, 2005

Executive Summary

This report is an interim summary of 38 cores (Appendix 1) taken from the sediments of Lake Rotorua in November/December 2004. Samples from 15 of these cores have been analysed by Hill Laboratories (Appendix 2). The results show that phosphorus is concentrated in the upper portions of sediment from the bottom of the lake at water depths greater than about 10 metres. It is recommended that this sediment should be removed from the lake to reduce the recycling of phosphorus from the lake sediments to the overlying water. Trace elements (cadmium, arsenic, mercury and lead) do not pose an environmental problem for on land disposal of these sediments. Coring should continue to complete a 1km grid pattern, and further coring should be focused on sediments from deeper parts of the lake. Recommendations for further work are given.

Introduction

An initial sampling program has been established with core samples being taken on a grid pattern at approximately 1km intervals. It is estimated that this will involve about 100 coring sites. At this time 38 cores have been taken using a variety of techniques depending on the nature of the sediments encountered.

Stratigraphy of Lake Rotorua sediments

In the centre and deeper part of the lake a 3m piston corer was utilized to recover very loose diatomaceous ooze. Loose sediments in shallower waters have also been cored using a 100x100mm box corer, and stiff sediments using a 1200mm piston corer. All of the cores have been split and described, with the box cores being cut into intervals and retained in plastic bags. A reference half of each of the piston cores has been archived, and the remainder cut into intervals and stored in plastic bags.

Location of cores in Lake Rotorua

It quickly became evident that two tephra were commonly encountered. The Tarawera tephra (Rotomahana mud) was typically encountered as a 10 – 20mm lens about 300mm below the surface,

Tarawera tephra (grey band) in core Ru8

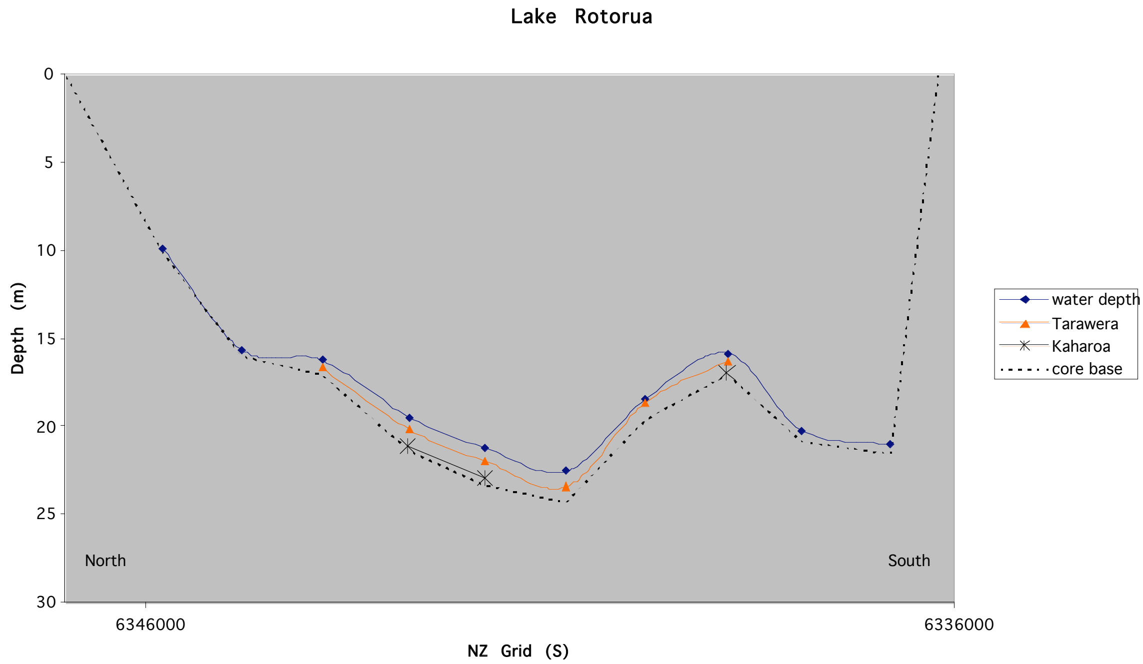
while the Kaharoa tephra was much coarser with sand and pea gravel sized hard grey pumice was encountered 2 – 3m below the surface in the deeper parts of the lake.

Kaharoa tephra (pale pumice band) in Lake Rotorua sediments

In shallower sediments Kaharoa or reworked Kaharoa often made up the surface sediments. These sites also contained abundant shells of fresh water mussels (dead) and macrophyte remains.

Kaharoa pumice gravel forming a lag surface on the top of core Ru19 (8.92m depth)

A depression towards the northern end of the lake contained thin diatomaceous ooze over thick laminated volcanoclastic sediments. This appears to have been an explosion crater, possibly from a hydrothermal eruption which has exposed a window into older, but as yet unidentified, tephras.



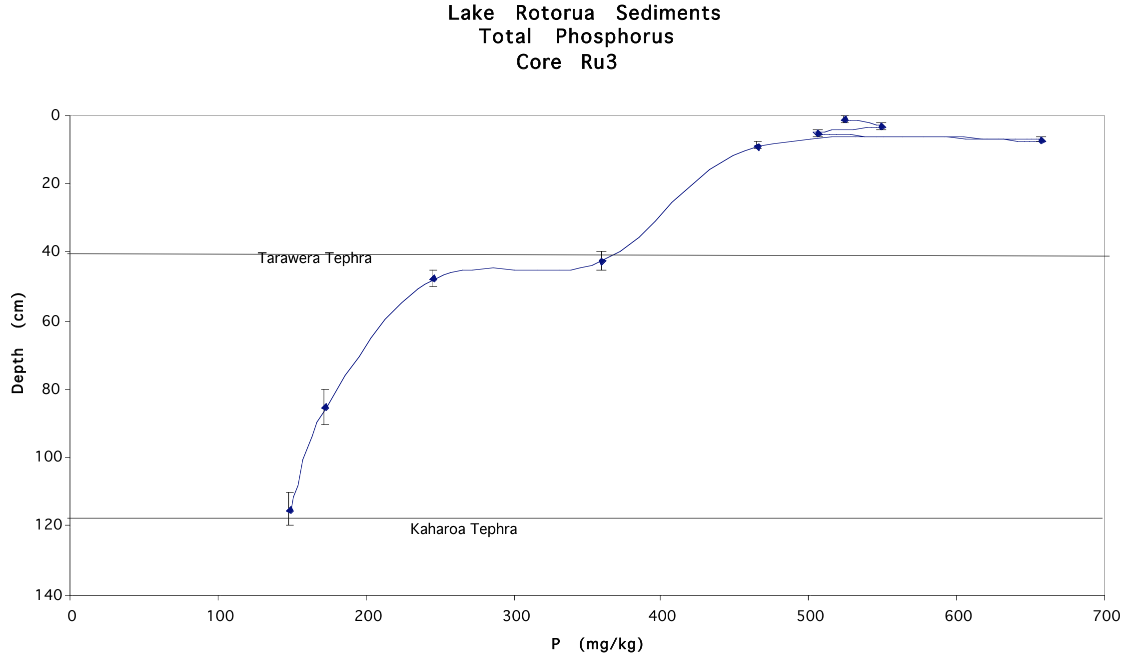
North/south cross section of Lake Rotorua showing coring depths and tephra stratigraphy

Chemical composition of Lake Rotorua sediments

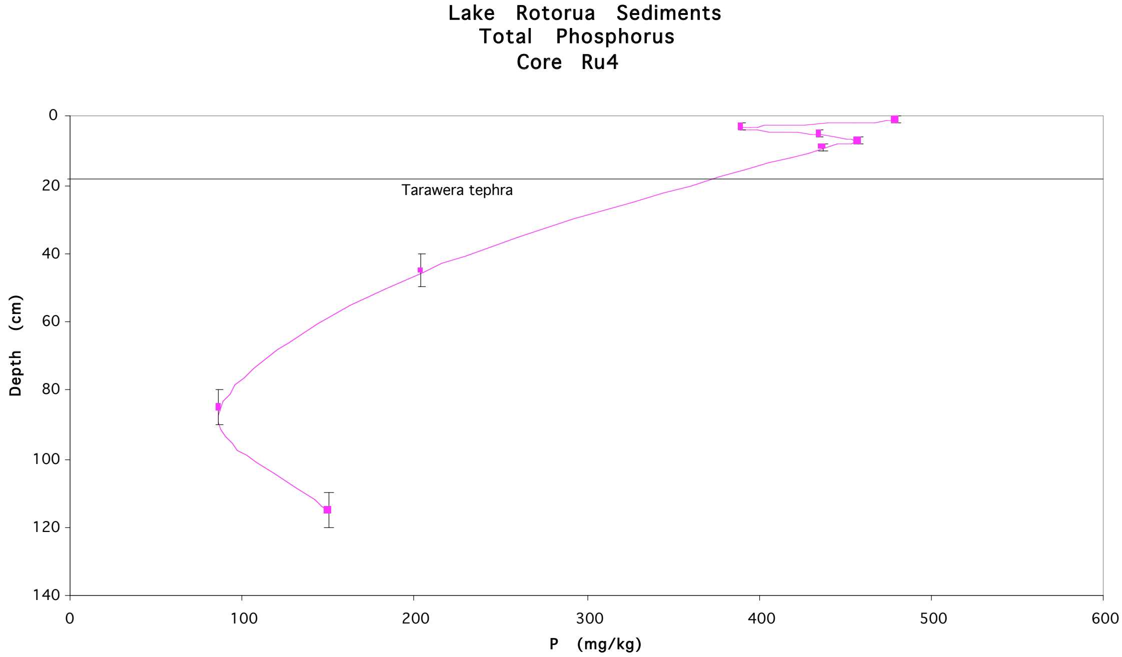
86 samples from 15 cores from the first round of coring were sent to Hill Laboratories for analysis (total carbon, total nitrogen, total phosphorus, total arsenic, total iron, total manganese, total zinc, total cadmium, total mercury and total lead).

Of critical concern are the total phosphorus analyses. Cores Ru3, Ru4, Ru7, Ru10, Ru13 and Ru25 were taken in deeper water (14 to 23m) and have accumulated sediments very rapidly. It is likely that frequent wave action remobilises the low density diatomaceous ooze in shallow waters concentrating these sediments in more sheltered deeper waters. The cores from deeper sites show a pattern of high phosphorus in the uppermost few tens of centimetres of sediment with concentrations dropping to low levels below the Tarawera tephra but above the Kaharoa tephra. I interpret this as the consequence of two processes. Firstly I believe that there is recycling within the sediments as the burial of organic matter results in reduction of iron and manganese and consequential release of phosphorus and other adsorbed species to the pore waters. As these approach the lake/sediment interface the iron and manganese are reoxidised resulting in readsorption of the trace species. Secondly I believe that the replacement of diatom dominated phytoplankton with cyanobacteria has resulted in a major change in sedimentation rates. While diatoms were dominant, sediment accumulation rates would have been high resulting in significant dilution of phosphorus and other trace elements. With the switch to cyanobacterial blooms, little of the phytoplankton biomass is surviving to be incorporated into the sediment resulting in an apparent concentration of phosphorus and other trace elements in the surviving sediment.

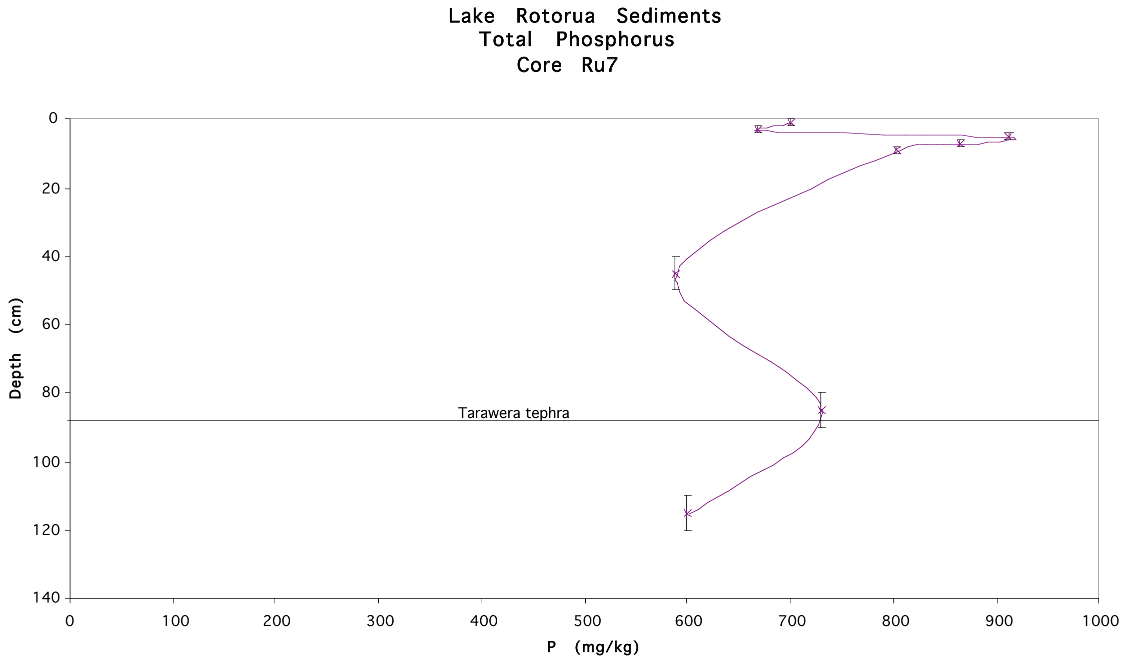
Plots of the total extractable phosphorus content of cores so far analysed follow.



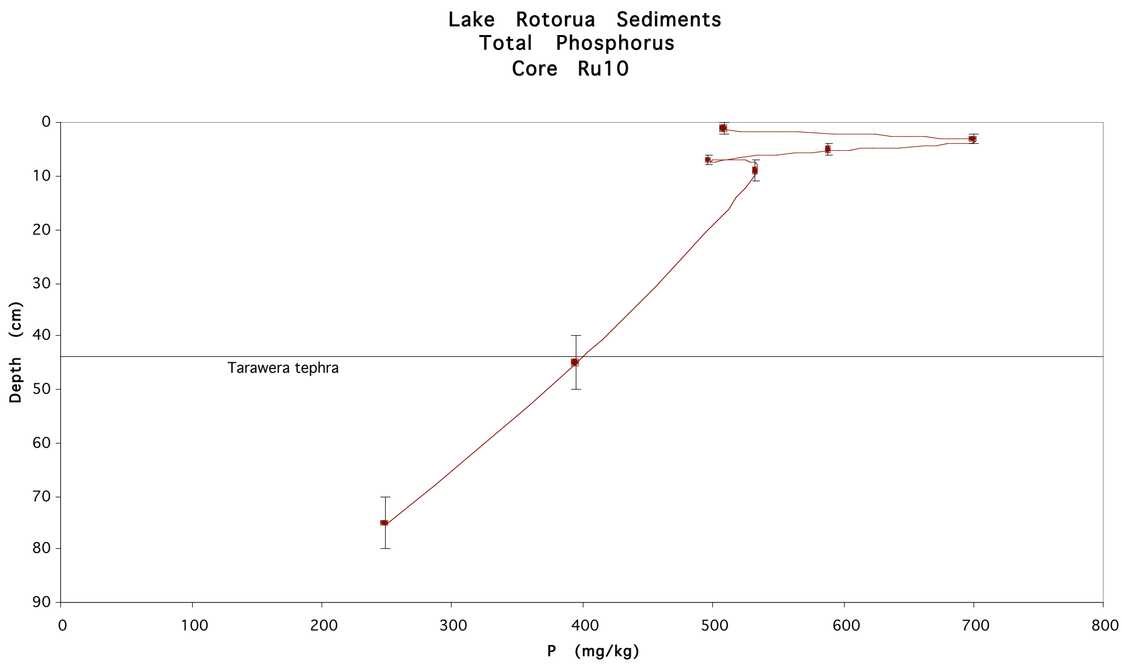
Concentration of total extractable phosphorus in core Ru3 (15.8 m. depth)



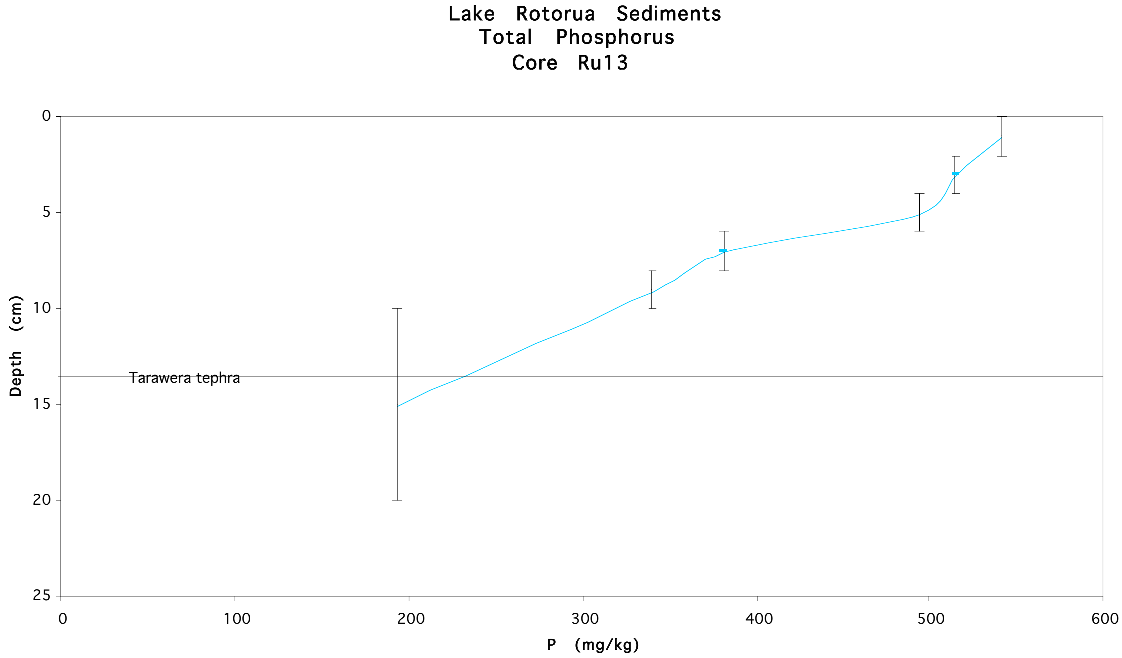
Concentration of total extractable phosphorus in core Ru4 (18.4 m. depth)



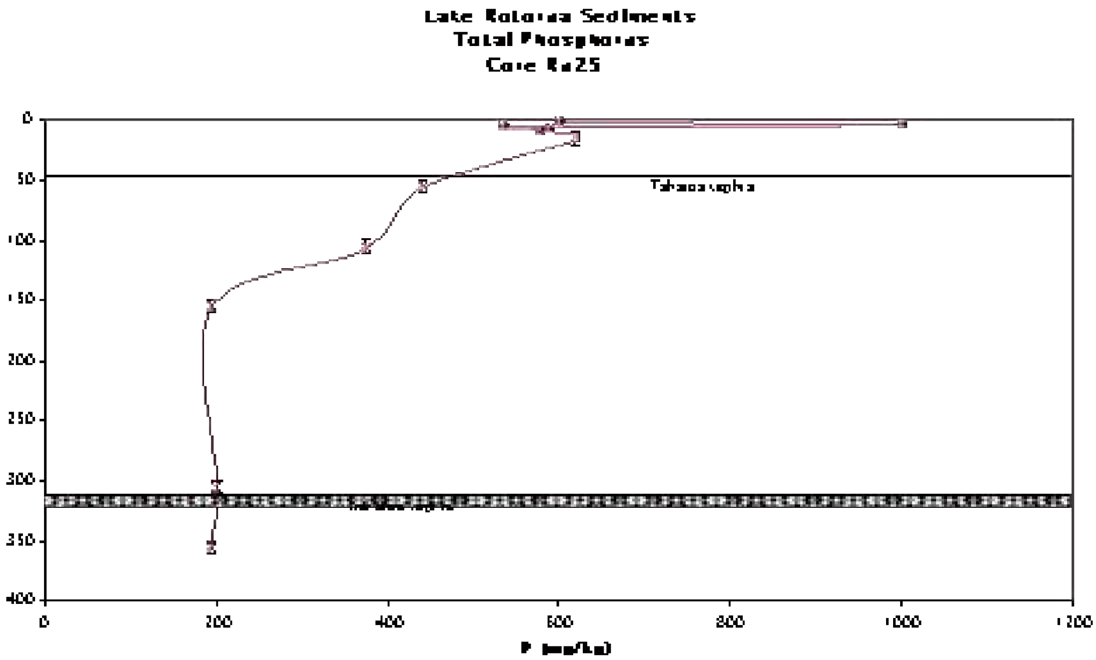
Concentration of total extractable phosphorus in core Ru7 (22.5 m. depth)



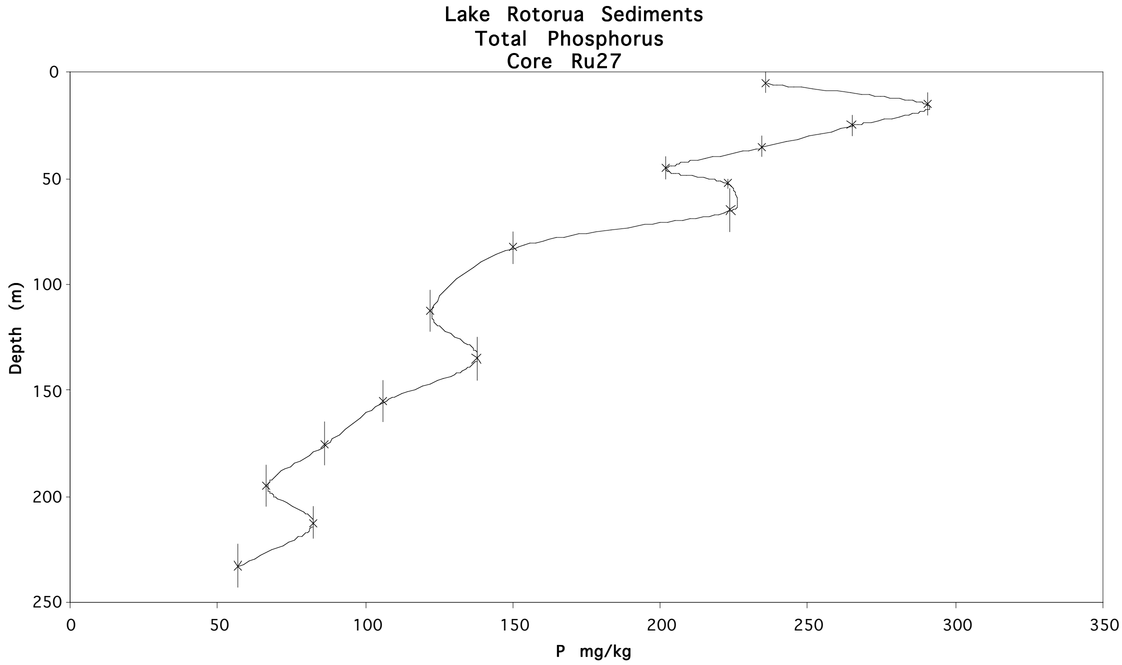
Concentration of total extractable phosphorus in core Ru10 (16.2 m. depth)



Concentration of total extractable phosphorus in core Ru13 (14.1 m. depth)

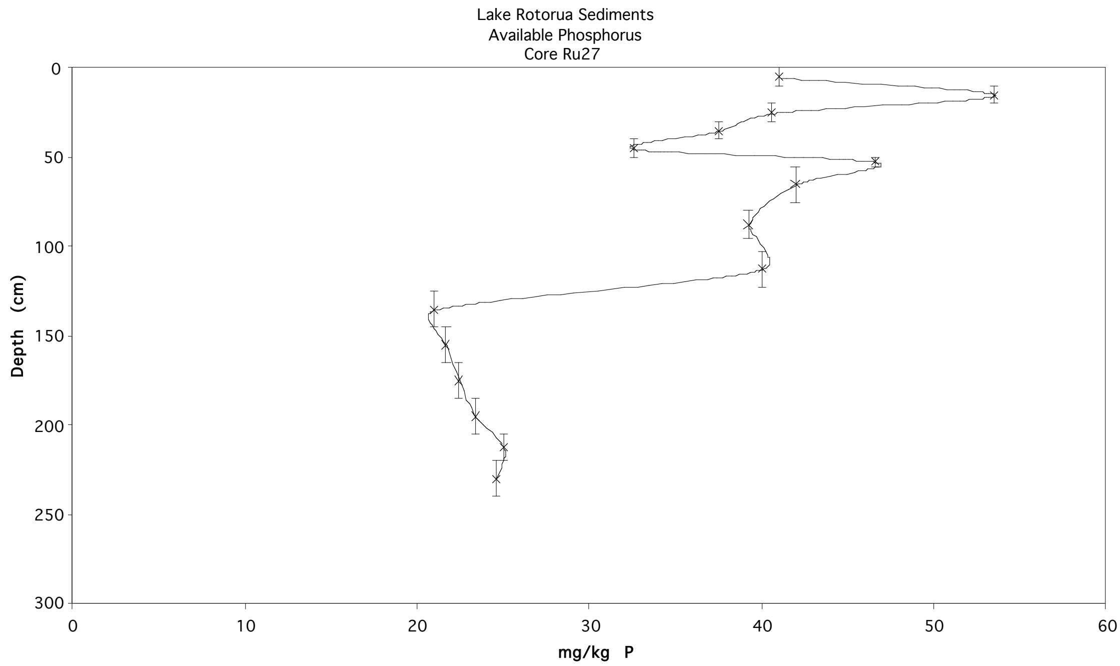


Concentration of total extractable phosphorus in core Ru25 (14 m. depth)



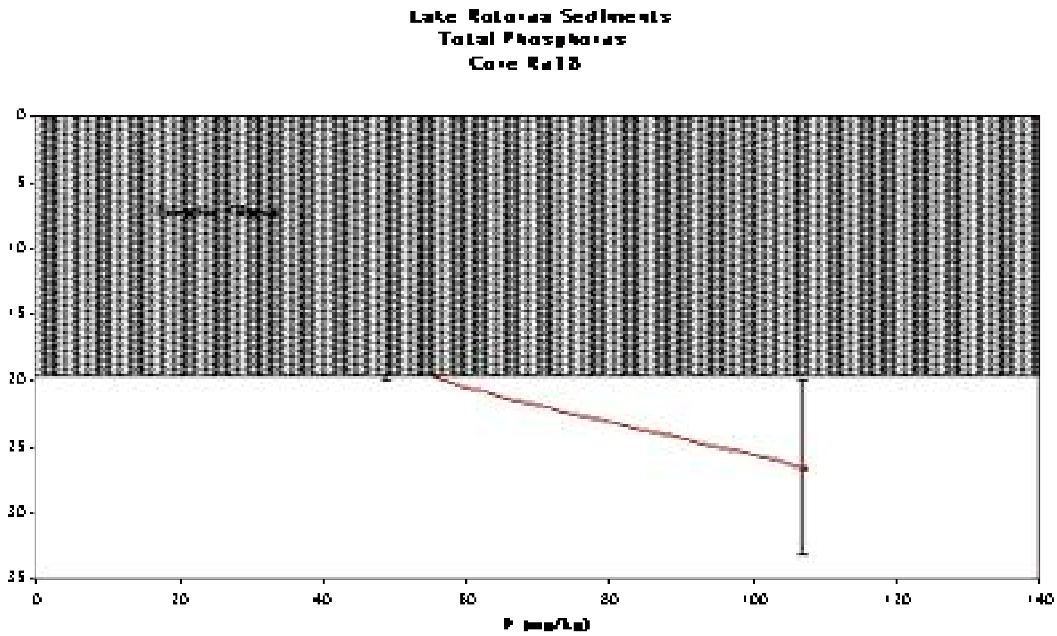
Concentration of total extractable phosphorus in core Ru27 (18.6 m. depth)

Core Ru27 has been analysed by staff within the Chemistry Department at the University of Waikato. Two contrasting techniques have been used. Total extractable phosphorus has been obtained by digestion with concentrated hydrochloric and concentrated nitric acids (*aqua regia*) with the resulting extracts analysed by ICPOES. Hill Laboratories used the same extraction technique but analysed their extracts with ICPMS. This technique gives a good estimate of the total phosphorus present in the sample but overestimates the quantity potentially available for recycling back into the lake. A second digestion has also been performed using a 1% solution of ascorbic acid. By providing a reducing environment with slightly acidic conditions, this technique is likely to give a more realistic estimate of the phosphorus available to be recycled back into the lake as a result of reduction of iron and manganese in the sediments. These digests were also analyzed by ICPOES.

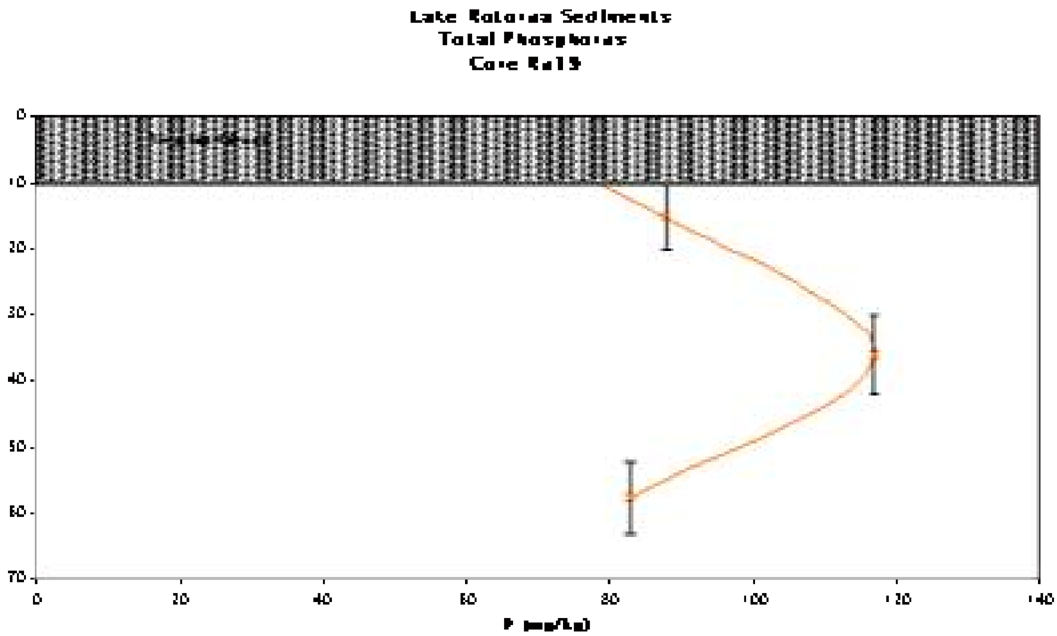


Concentration of ascorbic acid extractable phosphorus in core Ru27 (15.8 m. depth)

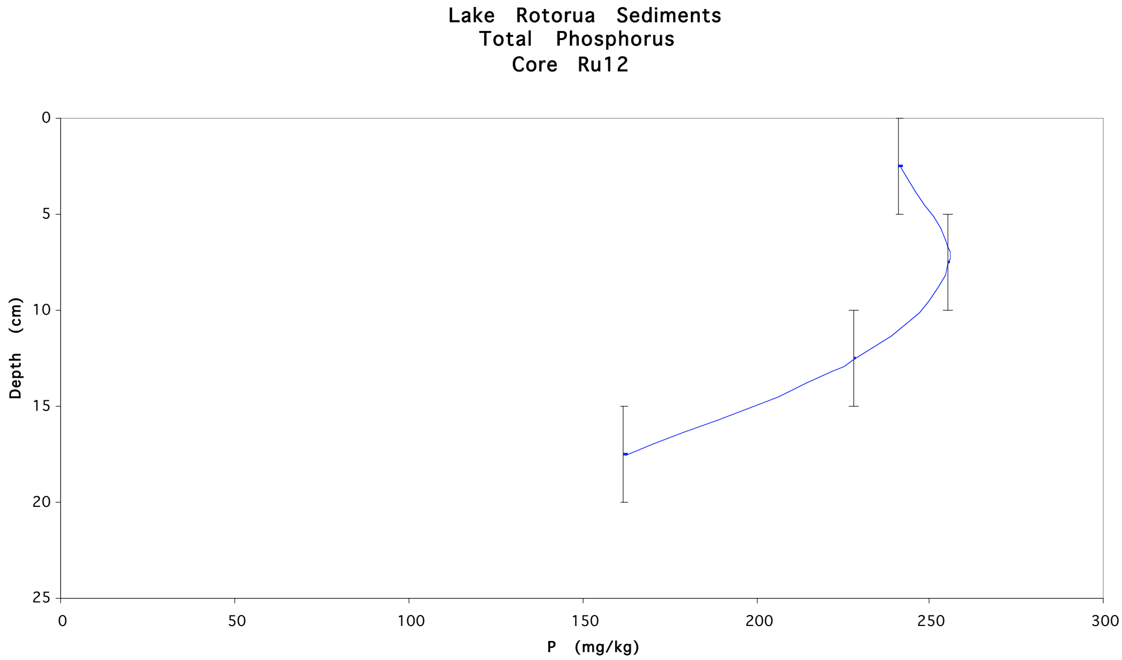
Cores taken from shallow water sites (less than 10m water depth) either have a lag surface of gravel sized pumice or sand, often have sub fossil fresh water mussel or appear to have been reworked. These sediments generally have much lower extractable phosphorus concentrations than deeper water sediments.



Concentration of total extractable phosphorus in core Ru18 (2.46 m. depth

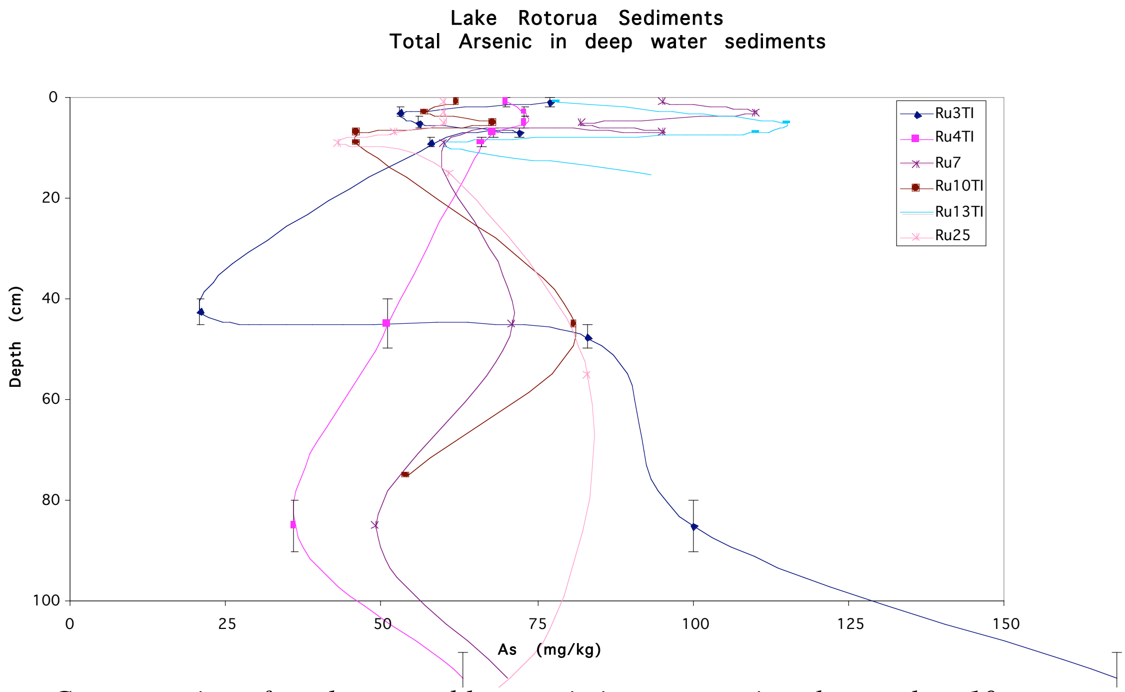


Concentration of total extractable phosphorus in core Ru19 (8.9 m. depth)



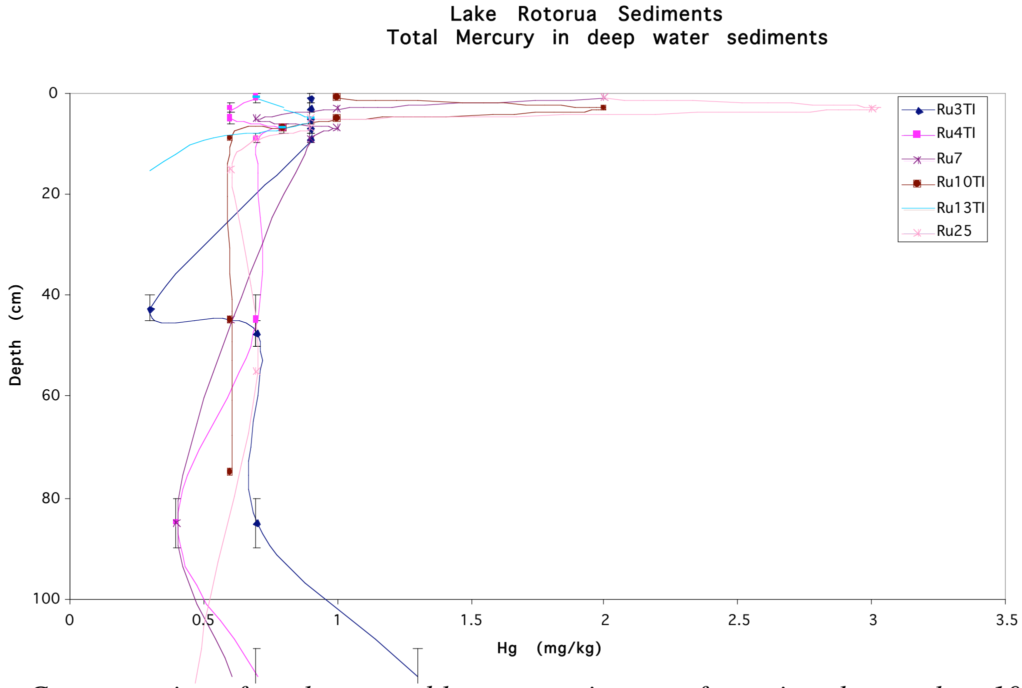
Concentration of total extractable phosphorus in core Ru12 (9.9 m. depth)

As the deep water sediments appear to show considerable benefit for dredging, it is necessary to examine them for their potential environmental hazards. With Lake Rotorua receiving geothermal discharge, arsenic and mercury present two likely such hazards. Analysis of arsenic from the set of deep water cores shows slight enrichment in the surface with the mean concentration around 70mg/kg.



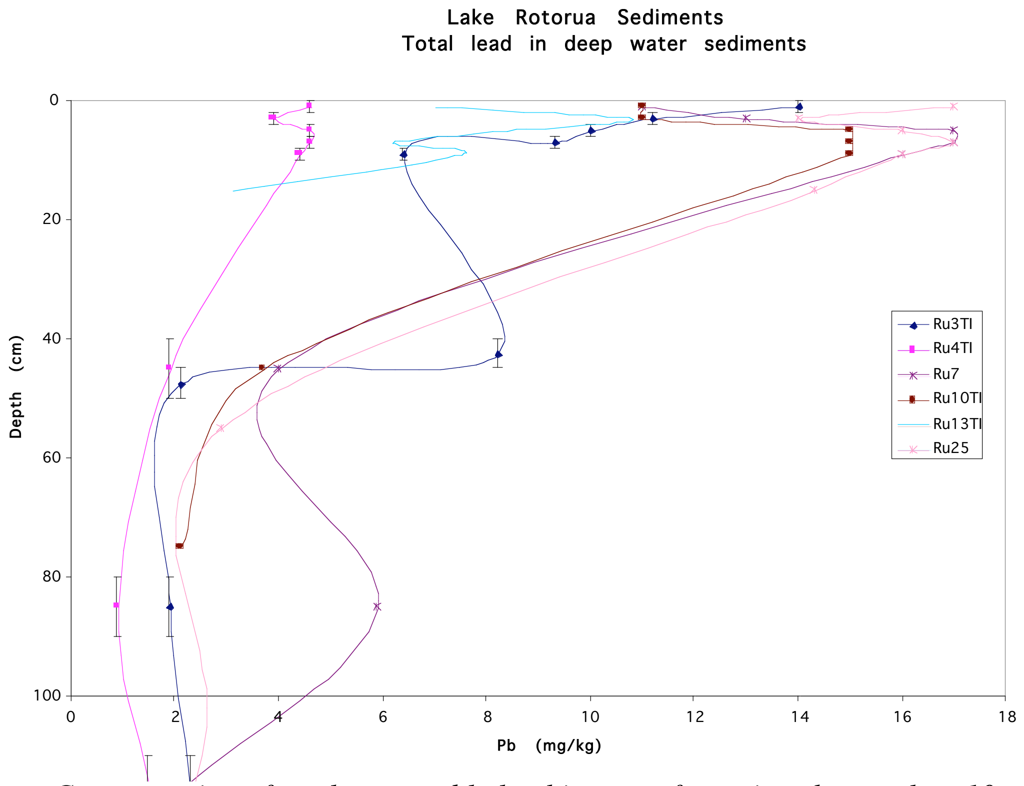
Concentration of total extractable arsenic in cores at sites deeper than 10m.

Mercury also shows very low concentrations having an average concentration of less than 1mg/kg and a peaking in the upper few centimetres. These concentrations should not pose an environmental hazard.



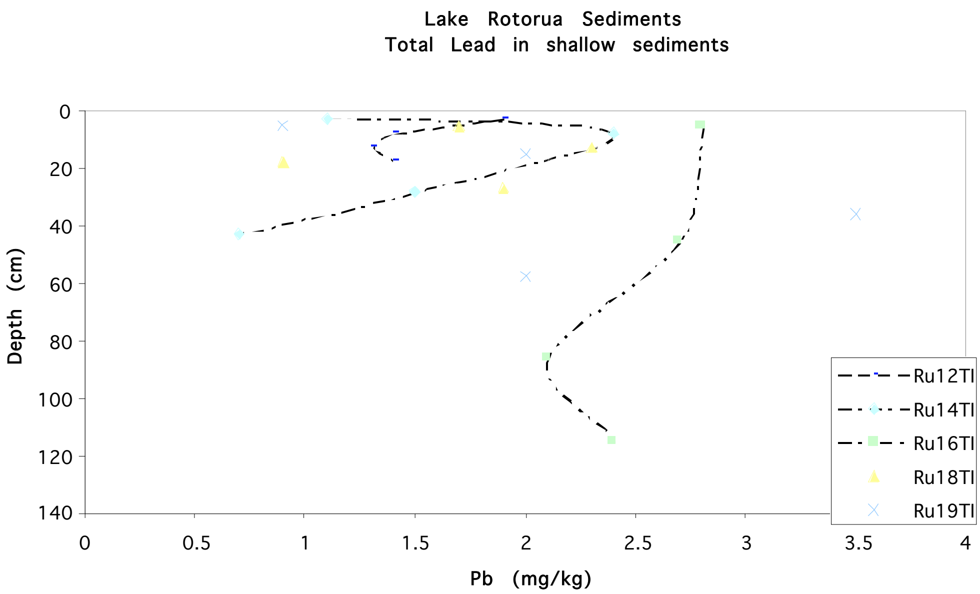
Concentration of total extractable mercury in cores from sites deeper than 10m.

Lead has been used as an indicator of anthropogenic pollution as it was used in increasing quantities as an antiknock agent in petrol based fuels until it was banned in the 1990s. Use of these fuels resulted in the discharge of lead halides and oxides as aerosols from motor vehicle exhaust systems. Most of these fell on or close to highways and tended to be washed into roadside drainage systems. Although reduction of iron and manganese within the sediments and their subsequent re oxidation near the lake water/sediment interface could lead to enrichment in the upper portion of the sediments, the enrichment of lead is much greater than that of other trace elements. I am therefore of the opinion that the lead profiles reflect the history of lead discharge into Lake Rotorua.

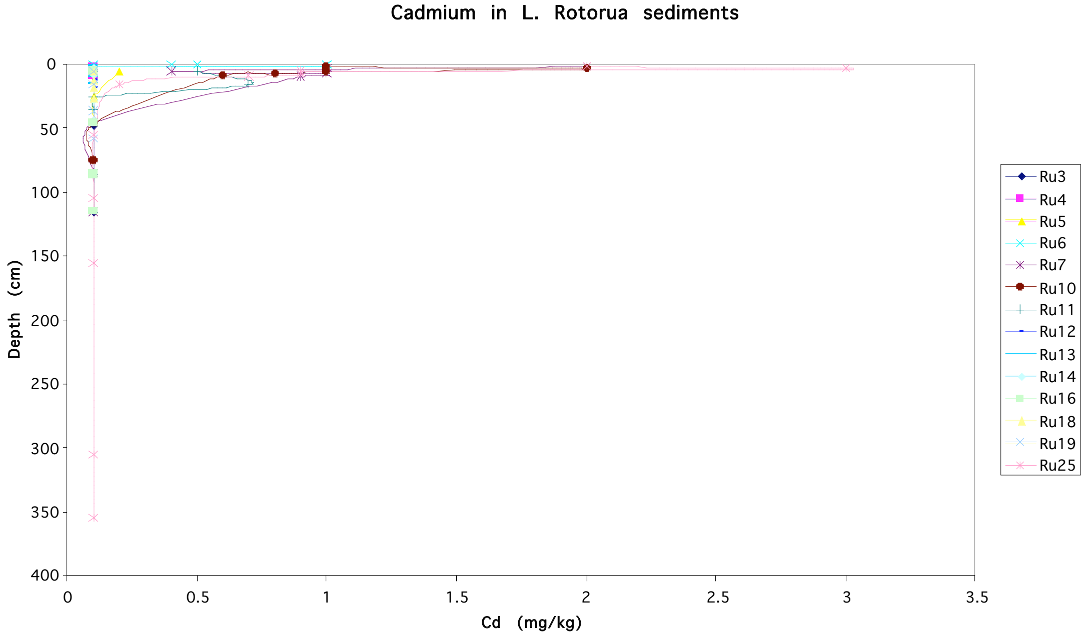


Concentration of total extractable lead in cores from sites deeper than 10m.

In contrast to the undisturbed deep water sediments the reworked shallow water sediments show very low lead concentrations with no tendency to peak near the lake/sediment interface.



Concentration of total extractable lead in cores shallower than 10m

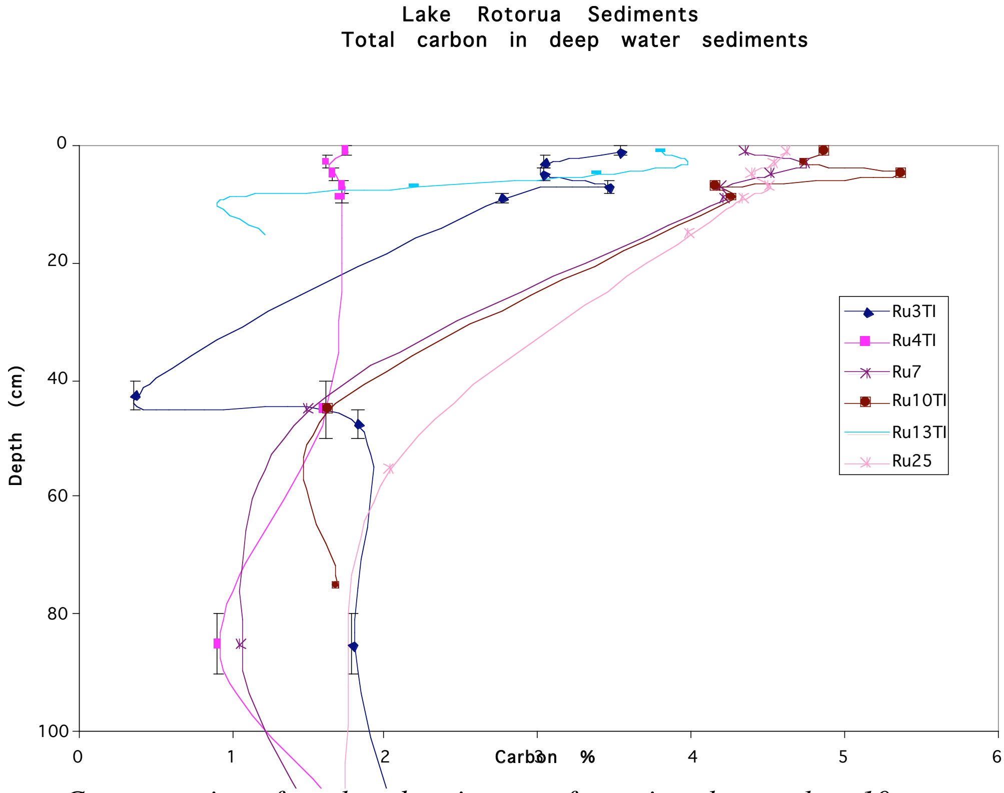


Concentration of total extractable cadmium in Lake Rotorua sediments

The cadmium concentrations show a very similar pattern to that of lead and mercury, being very low (average 0.3mg/kg) with a tendency to concentration near the surface in the deeper water cores. As with lead this could be the result of diagenetic recycling, but could also be influenced by accelerating inputs of cadmium. In New Zealand the major source of cadmium to the environment is as a trace contaminant in superphosphate. The concentrations in the sediment are not yet sufficiently high to be of concern for the use of these sediments as a soil conditioner.

The use of Lake Rotorua sediments as a soil conditioner

The carbon analyses show that carbon is concentrated towards the top of the sediment column reflecting the loss of carbon due to diagenetic process following burial.



Concentration of total carbon in cores from sites deeper than 10m.

A mean carbon content of ~2% would not be ideal for use as a soil conditioner, but could be improved by adding additional carbonaceous material. The very fine particle size of the diatomaceous ooze results in a material which will be prone to slumpage when wet and wind erosion when dry. Mixing with coarse grained material such as wood waste and pumice are likely to alleviate both of these problems.

Recommendations

1. Coring be continued until the preliminary 1km grid is completed.
2. The sediment structure of Lake Rotorua be surveyed using a suitable sub-bottom profiler to reveal the stratigraphy of the Kaharoa and Tarawera tephras, and identify those parts of the lake bottomed by coarse lag sediments. These will need to be mapped as there is no advantage for these sediments to be removed.
3. The results at this stage should be reviewed, but my recommendation would be to core sample the diatomaceous ooze bottomed portion of the lake at 0.5km intervals (approximately a further 100 cores) \.
4. Pore water chemistry and gas chemistry should be included in future sediment analyses in order to assess the environmental impact of sediment dredging from the lake. It will be noted that significant quantities of gas were encountered in some cores. This is likely to be either methane or carbon dioxide.