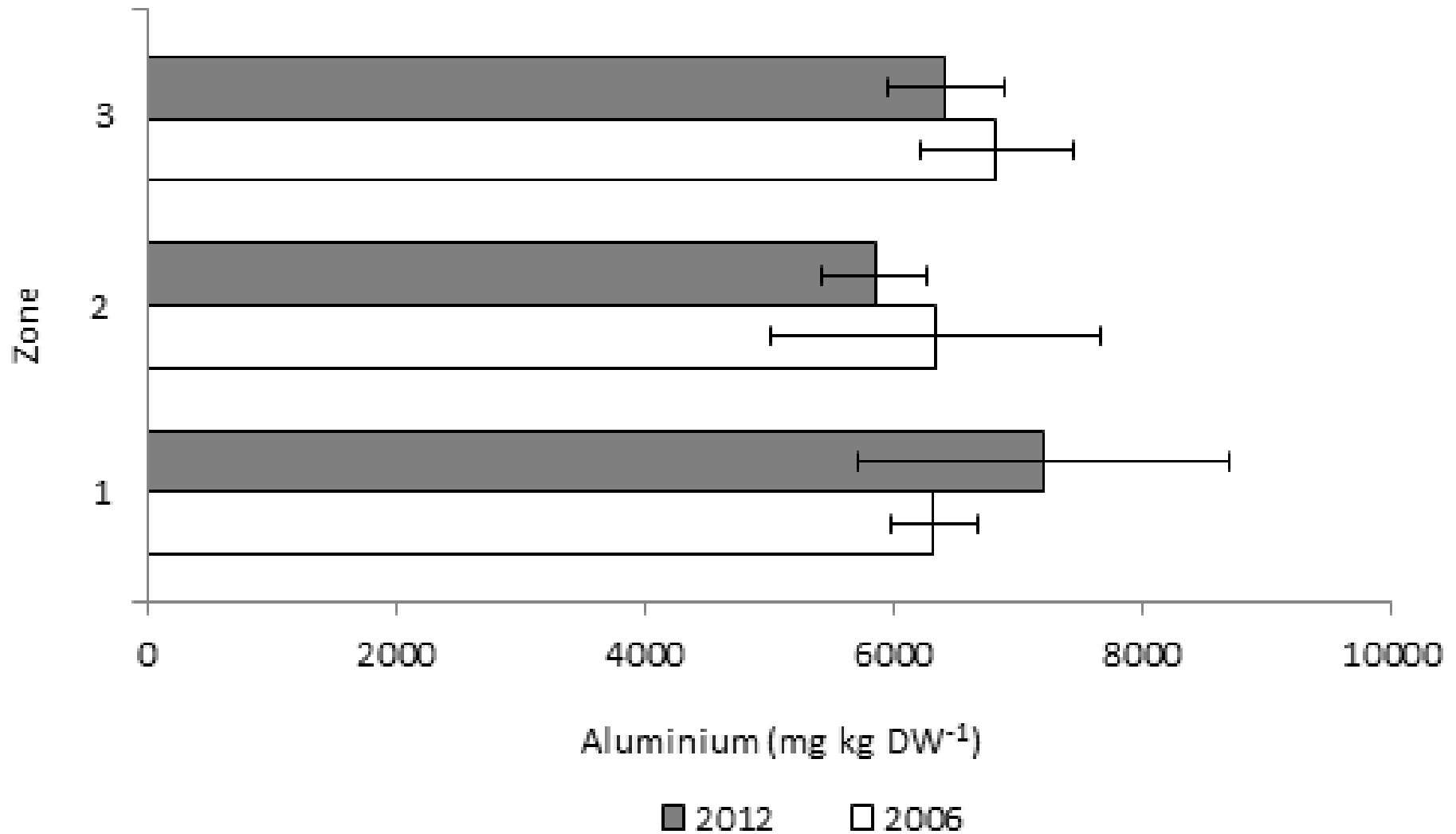# Sediment survey in Lake Rotorua

Objective

- To provide empirical data on the potential aluminium and phosphorus accumulation in the Lake Rotorua basin.

- Data presented by McIntosh (2012) and Abell et al. (2012) showed that bottom water phosphorus concentrations in Lake Rotorua have declined in 2011 and 2012 compared with previous long term records.

- However, there is currently no direct evidence which could explain why this reduction occurred.

- Thus, accumulation of aluminium onto the bottom sediments, forming a capping layer should be regarded speculative at this point and warrants further investigation.
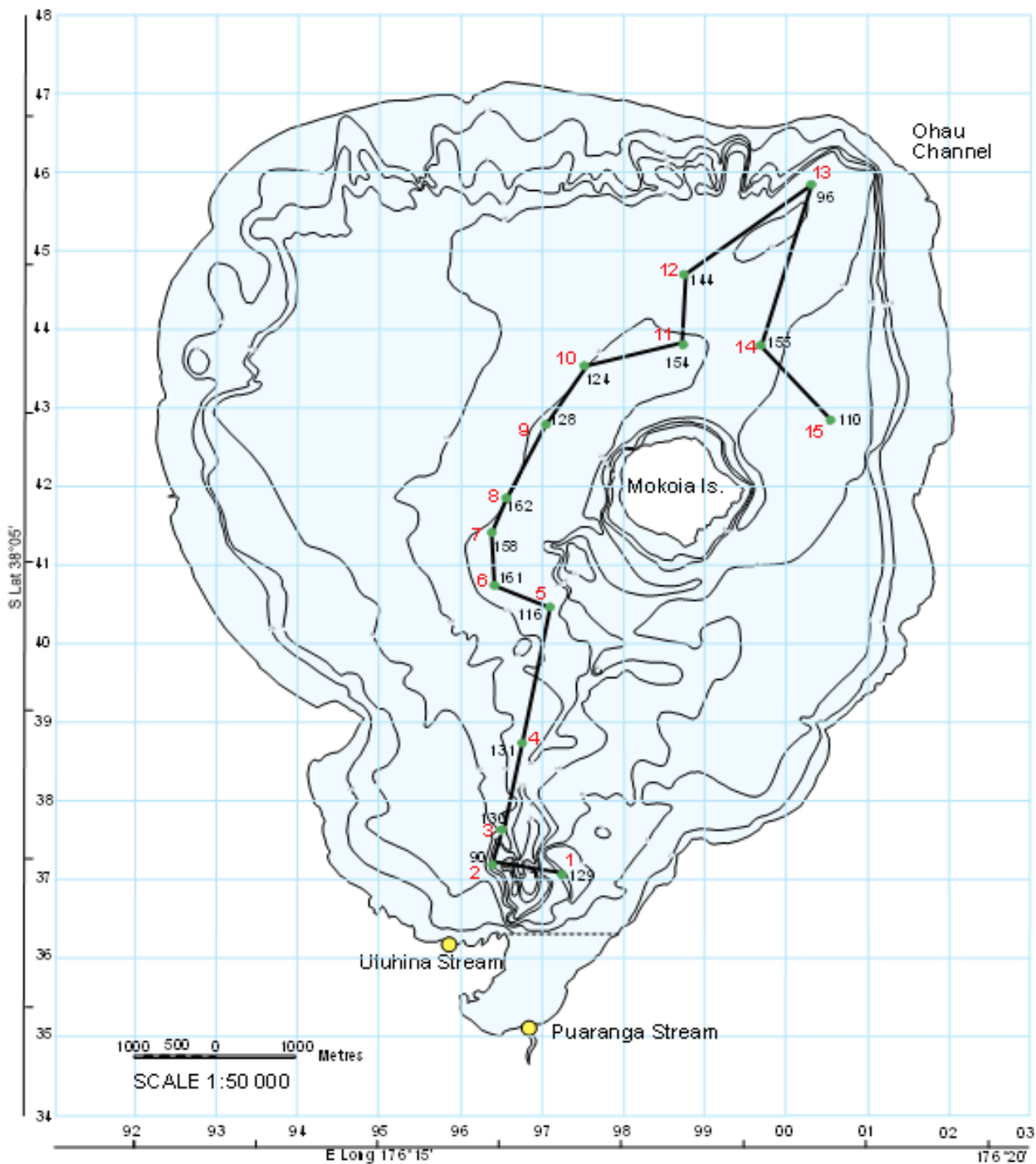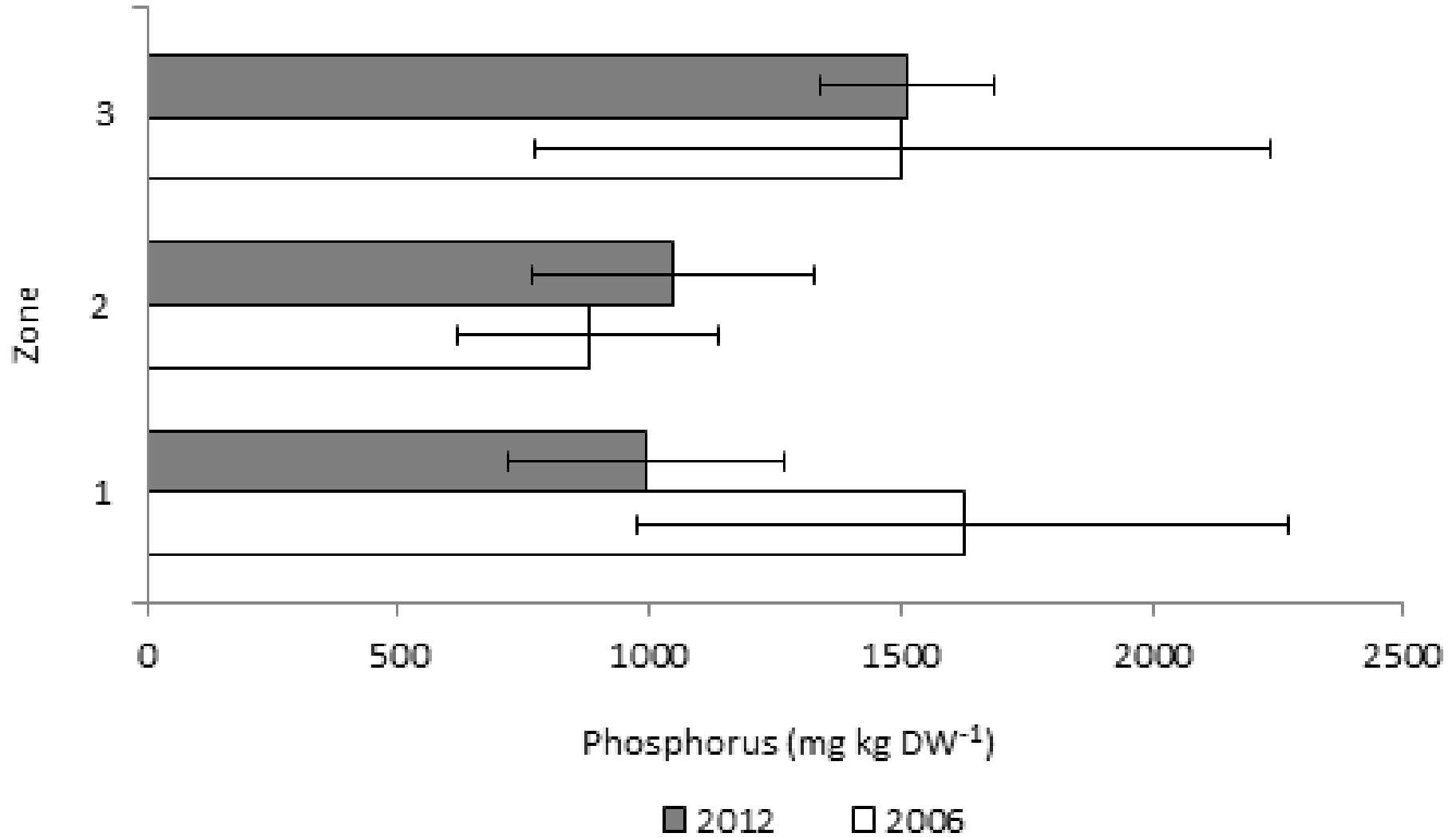
Core locations sampled by Pearson (2007) with sampling transect for this study shown by a black line and location numbers shown in red. The Utuhina and Puaranga Streams are shown with yellow dots where they enter Lake Rotorua.

Results

Results

Alum mass balance

Reference	Range molar of Al:P$_{Al}$ ratios	Comments
Pilgrim et al. (2007)	25-100	Sediment cores taken from four lakes in Minneapolis, USA, and treated with alum at different dose rates. Sediment P fractionation using a NaOH extraction was carried out to determine Al bound P.
Rydin et al. (2000)	34.8-40.4	Sediment cores were taken from six alum treated lakes in Washington, USA. Sediment P fractionation P fractionation using a NaOH extraction was carried out to determine Al bound P.
Rydin and Welch (1999)	10-100	Estimated from Al-bound P relative to the added Al added in short-term laboratory experiments with lake sediments.
Huser (2012)	5.6-15	Sediment cores from six alum treated lakes in Minneapolis, USA. Sediment P fractionation using a NaOH extraction was carried out to determine Al bound P.
Egemose et al. (2013)	5-31	Sediment cores were taken at 6-8 sites in six Danish lakes. Phosphorus bound to aluminium was determined using NaOH extractions.
DeVincente et al. (2008)	7.7-9	Sediment cores were taken from 2 Danish lakes. Phosphorus bound to aluminium was determined using NaOH extractions. Laboratory adsorption experiments were also carried out using synthesised alum flocs with the aim to determine the effect of alum floc aging on P adsorption properties. The results of these experiments are not listed here, because the calculated ratios partially reflect hypothetical maximum adsorption capacities based on adsorption isotherms.
Lewandowski et al. (2003)	2.1	Ratio was calculated based on NaOH extractable phosphorus in laboratory sediment core experiments relative to the added aluminium.
Gibbs et al. (2010)	1.11	Ratio was calculated based on the dose rate required to block 100% of the P release from Lake Rotorua sediments in a short-term laboratory sediment incubation experiment. The dose rate was 77 g m^{-2} of alum to block the P release from 3.168 g P m^{-2}, assuming that ~4% of alum is the form of aluminium.

Alum mass balance

Phosphorus uptake by alum was modelled using simple zero-order reaction kinetics for which the uptake was proportional to the TP mass in the reactor (i.e. a fraction of TP) taking into account a potential effective Al:TP uptake ratio. Thus, as alum takes up phosphorus in each reactor, the alum load to the next reactor is reduced by the following amount:

$$W_{Al,j} = W_{Al,i} - a_i\, b_i\, TP_i$$
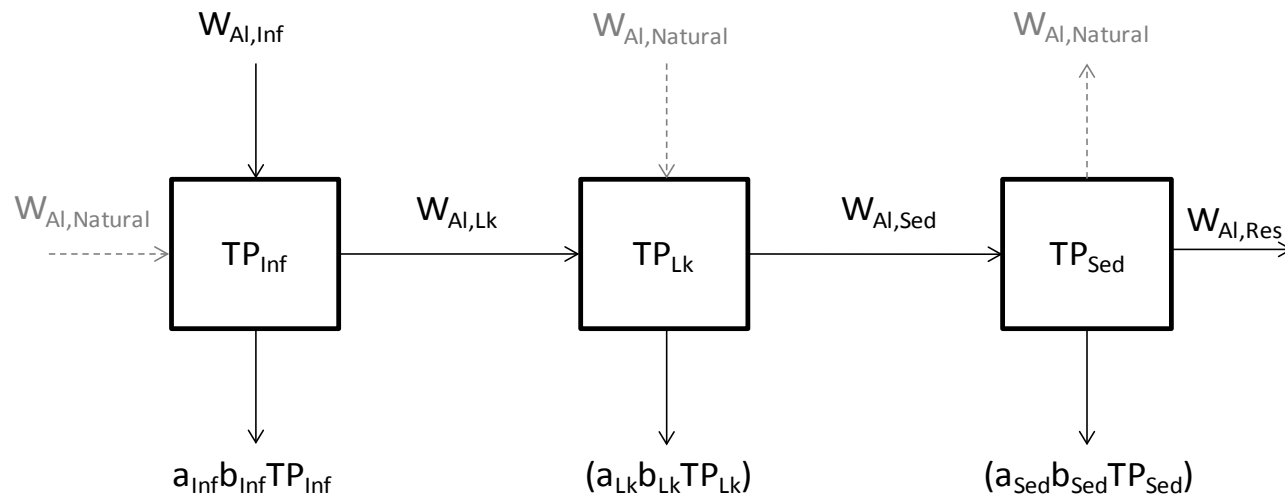
Conceptual diagram of alum mass balance model for Lake Rotorua. Note: The grey arrows represent the natural aluminium inputs and outputs of aluminium and were not explicitly accounted for here.

Alum mass balance

- Because of the uncertainty in the values for the reaction coefficients a and b, a Monte Carlo simulation was implemented, comprising of 10,000 model runs, for which a and b were varied randomly within their respective bounds.

- The coefficient a was varied between 0.27 to 1 for the inflow and between 0 to 1 for the water column and sediment. The bounds for a in the inflow were constrained because field data showed that dissolved reactive phosphorus was at the detection limit in the Puarenga stream downstream of the alum dosing plant, but on average constituted 27% of TP upstream of the dosing plant between 2010 and 2011.

- The bounds for the coefficient b (Al:P ratio by weight) were 3.5 and 35 (or 4 – 40 molar ratio). This range was chosen based on a series of published values.

Summary of results
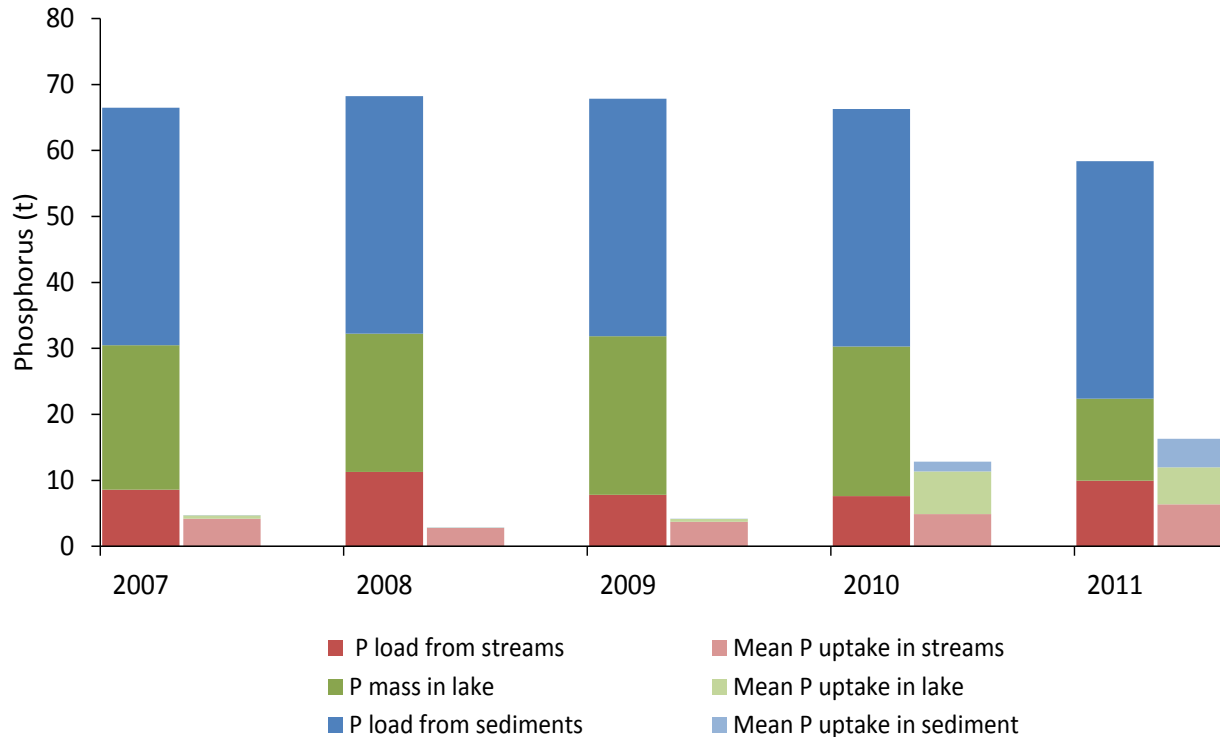
Clustered stacked histogram comparing the annual contribution of the total phosphorus mass of each of the three reactors of the alum mass balance between 2007 and 2011 and the mean P uptake in each reactor simulated using a Monte Carlo approach which encompasses 10000 simulations.

P load from streams calculated from Hamilton et al., (2012); Lake TP mass calculated from data collected by BoPRC; Internal loading assumed constant (values from BoPRC 2009)

Conclusions

- Sediment survey data do not support the hypothesis that Al accumulated in the main basin of Lake Rotorua.

- It is suggested here, that long- to medium-term catchment and in-lake dynamics had more influence on the net change in sediment P concentrations than alum.

- The alum mass balance corroborate these findings: There is a compelling probability that very little alum was deposited into the main basin.

- The mass balance approach indicates, however, that alum may have reduced water column P and internal loading to some extent, but this reduction alone cannot explain the recent substantial improvement in water quality.