Water flow between Ohau Channel and Lake Rotoiti following implementation of a diversion wall

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Prepared for Environment Bay of Plenty

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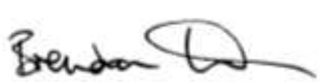

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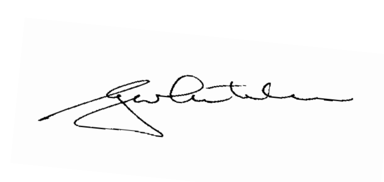

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1. Executive Summary

The water quality in Lake Rotoiti has degraded since the 1950s. Water from Lake Rotorua, with elevated phytoplankton and nutrient concentrations, has entered Lake Rotoiti via the Ohau Channel. To help improve water quality in Lake Rotoiti, a constructed wall was completed in July 2008, to divert water from the Ohau Channel towards Okere Arm in Lake Rotoiti, with the objective to transport this water into the Kaituna River instead of entering the main basin of Lake Rotoiti. This report has been produced in response to a request from the Rotorua Lakes Technical Advisory Group to determine water velocities in the region of the constructed wall, in order to consider the effectiveness of the diversion.

Three current meters were positioned on the lake bed to measure water speed and direction immediately above the lake bed. One was within the new diversion channel, one near the end of the wall but within Lake Rotoiti, and the other within Lake Rotoiti and further into the main body of the lake. Water temperature and current speed and direction data were recorded at each station at 15-minute intervals from 20 August to 9 September 2008. These data were supplemented with temperature, chlorophyll fluorescence, dissolved oxygen and conductivity data collected with a 'BioFish' along a depth-varying transect from the western end of Lake Rotorua, through the Ohau Channel and as far as the eastern end of Lake Rotoiti, on 11 August 2006, 29 August 2007 and 26 August 2008, for comparisons amongst years before (2006, 2007) and following (2008) construction of the diversion wall. Wind speed and direction data from Rotorua Airport were also used for comparison with flow direction data from the current meters. Additional information included a photo of the downstream end of the completed diversion wall and a satellite image of the region, also following completion of the wall.

Direction of water flow at current meters in Lake Rotoiti was partitioned at frequencies from 11 to 38% amongst NE, SE, SW and NW quadrants. At the site in Lake Rotoiti closest to the diversion wall there was an indication that NE and SW currents were more frequent (38 and 33%, respectively) and for some periods were aligned with the predominant wind directions at Rotorua Airport. It may be surmised that there is little consistency to currents at the two Rotoiti sites though this information pertains only to

measurements immediately above the lake bed. By contrast, currents at the site within the diversion wall were relatively consistent around 14 cm s^{-1} and aligned in the direction of the diversion wall towards the Kaituna outflow. These speeds were around seven to nine fold larger than at the two Rotoiti stations.

Water temperature, chlorophyll fluorescence and conductivity data from a BioFish transect on 11 August 2006, before implementation of the diversion wall, indicate the presence of an underflow of Ohau Channel water into Lake Rotoiti, traceable from lower temperature and conductivity, and elevated chlorophyll fluorescence in Lake Rotorua and into the western end of Lake Rotoiti adjacent to the lake bed, compared with water of similar depths in the main basin of Lake Rotoiti. No such underflow could be discerned on 29 August 2007 when properties of water in Lake Rotoiti were similar to those of Lake Rotorua. On 26 August 2008, following construction of the diversion wall, there were lower temperatures at depths of 10 to 20 m near the lake bed in the western end of Lake Rotoiti compared with water of similar depths elsewhere in this lake. We cannot discern whether this was an underflow as it was discontinuous with water temperature near the end of the diversion wall and there were not corresponding changes in any of the other variables (notably fluorescence and conductivity) at the western end of Lake Rotoiti.

A satellite image of the western end of Lake Rotoiti on 17 November 2008 shows a marked difference in water clarity between the relatively turbid diversion channel water and the clear waters of Lake Rotoiti. On this occasion the water from Lake Rotoiti can be discerned well past the end of the diversion wall and into the Okere Arm region of the lake.

A suite of water quality data, current speeds and directions and satellite images and aerial photos presented in this report indicate that the diversion wall is performing according to its design specifications. Monitoring data are consistent with predictions based on earlier three-dimensional model simulations in the early design phase of the diversion wall. The monitoring data collected to date does not, however, include vertically resolved measurements of water currents and directions in Lake Rotoiti, which may be useful to examine the complex transport processes around the diversion wall. A deployment of current profilers to resolve the vertical (depth) distribution of water velocity at the sampling sites in Lake Rotoiti could provide further verification that the diversion wall is performing according to specifications.

2. Introduction

This report has been prepared by the Centre for Biodiversity and Ecology Research at the University of Waikato in response to a request from the Rotorua Lakes Technical Advisory Group for to provide information on water flow in the vicinity of the Ohau Channel diversion wall completed in mid-July 2008. The specific focus of the investigation was to examine the fate of the water diverted from Lake Rotorua once it reached the end of the Ohau Channel Diversion Wall.

2.1 Background

Water quality in Lake Rotoiti has declined since the 1950s (Vincent *et al*. 1984; Hamilton, 2004) coinciding with increasing prevalence of cyanobacterial blooms in the western basin and its embayments (Vincent *et al*. 1984; Gibbs *et al*. 2003; Stephens, 2004; Hamilton *et al.,* 2005). Water entering Lake Rotoiti from Lake Rotorua via the Ohau Channel introduced an algal inoculum to the lake, had high levels of suspended sediment and was also enriched in nutrients (Vincent *et al*., 1984; Gibbs, 1992). As a means of restoration and protection of Lake Rotoiti's water quality, the Ohau Channel Diversion Wall was constructed, to divert nutrient-rich water from Lake Rotorua towards the Kaituna River, and prevent this water from entering the main body of Lake Rotoiti. The wall is 1,275 m long, was completed, after a year's construction, in July 2008, (Darren Bentham, pers. comm.) and officially opened on 20 October 2008 (Moran, 2008).

Models of lake hydrodynamics, specifically including water transport and mixing processes, were applied by Stephens (2004) to examine the most effective wall location and its length, and by Hamilton *et al*. (2005) to predict likely effects of the diversion on water quality in Lake Rotoiti. Stephens (2004) found two designs likely to divert c. 98% of the Ohau Channel water directly down Kaituna River, and predicted minor increases in flow velocity and a 2.5 cm increase in water level at the downstream end of the Ohau Channel after diversion. Hamilton *et al*. (2005) modelled a 100% diversion scenario in which it was predicted that there would be a 40% reduction of cyanobacterial biomass by the fourth summer after completion of the diversion. On average, 13.3 tonnes TP yr^{-1} and

164 tonnes TN yr^{-1} entered Lake Rotoiti via the Ohau Channel before the diversion wall was constructed (Hamilton *et al*. 2004).

The Ohau Channel is the outlet for Lake Rotorua (Gibbs *et al*. 2003) and exits into the north-western end of Lake Rotoiti, 2.6 km from the head of the Kaituna River, the outlet for Lake Rotoiti (Gibbs *et al*. 2003). Before the diversion, an estimated 40 to 100% of the Lake Rotorua water flowed from the Ohau Channel into Lake Rotoiti, varying mostly with season and specifically with density differences from variations in temperature between the incoming Ohau Channel water and Lake Rotoiti, while the remainder of the water flowed relatively directly down the Kaituna River (Spigel 1989; Gibbs *et al*. 2003; Stephens 2004; Hamilton *et al*. 2005). The Ohau Channel entered Lake Rotoiti as an underflow, overflow or interflow depending on the density difference between the two waterbodies. The underflow plume dominated during winter, interflow occurred mostly in summer and overflow mostly in spring (Gibbs *et al*. 2003; Hamilton *et al*. 2005). Stephens (2004) found that wind had an effect on direction of surface and return flows associated with the Ohau Channel inflow.

3. Methods

3.1 Study Site

The focal point for this study was the end of the Ohau Diversion Wall and the Okere Arm of Lake Rotoiti (Figures 1 and 2). This study site is incorporated into a larger lake setting through use of BioFish data collected along a transect from Ngongotaha in Lake Rotorua, through the Ohau Channel and into the eastern end of Lake Rotoiti (Figure 2). The diversion wall begins on the western side of the Ohau Channel entrance and runs parallel to the lake edge for 1,275 m, forming a diversion channel of width approximately 75 m. North-east of the diversion channel exit is Kaituna River, the outlet for Lake Rotoiti (Figure 1).

The speed of flow, direction of flow and temperature measurements used in this report were collected with current meters (Sontek ADV Triton) installed at three sites from 20 August to 9 September 2008 (Figure 2). Each meter was positioned just above the lake or channel bed. Site 1 (ROT1) was located at a water depth of 6 m on the Lake Rotoiti side of the diversion wall; site 2 (ROT2) at a water depth of 5 m within the diversion channel and site 3 (ROT3) at a water depth of 9.5 m on the Lake Rotoiti side of the diversion wall but further from the wall than ROT1 (Figure 2). Data were recorded at intervals of 15 minutes.

Meteorological data (hourly wind speed and direction, and air temperature) were obtained from Rotorua Aerodrome Automated Weather Station (38° 7' 0" S and 176° 19' 0" E) at elevation 285 m AMS.

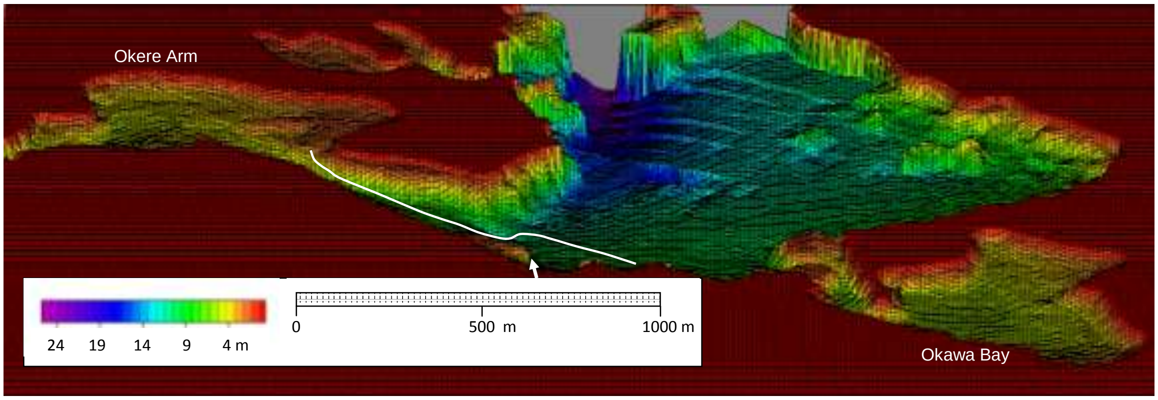

Figure 1. Bathymetry of the western end of Lake Rotoiti showing the entrance of the Ohau Channel (white arrow) and the diversion wall (white line). The main basin of Lake Rotoiti is in the mid-upper. The left-hand coloured bar shows water depth and the right-hand bar shows an approximate width scale. The Kaituna outlet of Lake Rotoiti is further to the left of the figure, beyond the Okere Arm.

A photograph of the diversion wall July 28, 2008 and anecdotal observations of water flow at the end of the diversion wall were supplied by local resident and chemical consultant, Nick Miller.

Water temperature, conductivity, dissolved oxygen, chlorophyll fluorescence and conductivity data used in this report were obtained from monthly surveys using a BioFish (ASD Sensortechnik GmbH, Germany). These data were collected at 4 Hz whilst the instrument was towed behind a boat, undulating in a vertical path. A transect was made within Lake Rotorua, through surface waters in the shallow Ohau Channel and then into Lake Rotoiti. Precise location of the BioFish was obtained through the combination of GPS on the boat and a pressure transducer on the instrument. The pathway followed on 11 August 2006 and 29 August 2007 was a transect from Ngongotaha in Lake Rotorua, through the Ohau Channel, into the western basin of Lake Rotoiti, then proceeding to the eastern end of the lake (Figures 3A and 3B). The path taken on 26 Aug 2008 included through the channel within the diversion wall but otherwise remained largely the same as in 2006-7 (Figure 3C). Each survey started at 10:00 hr and was concluded by 14:00 hr. Data from the BioFish surveys were graphed with Ocean Data View (Version 3.3.2, 2007).

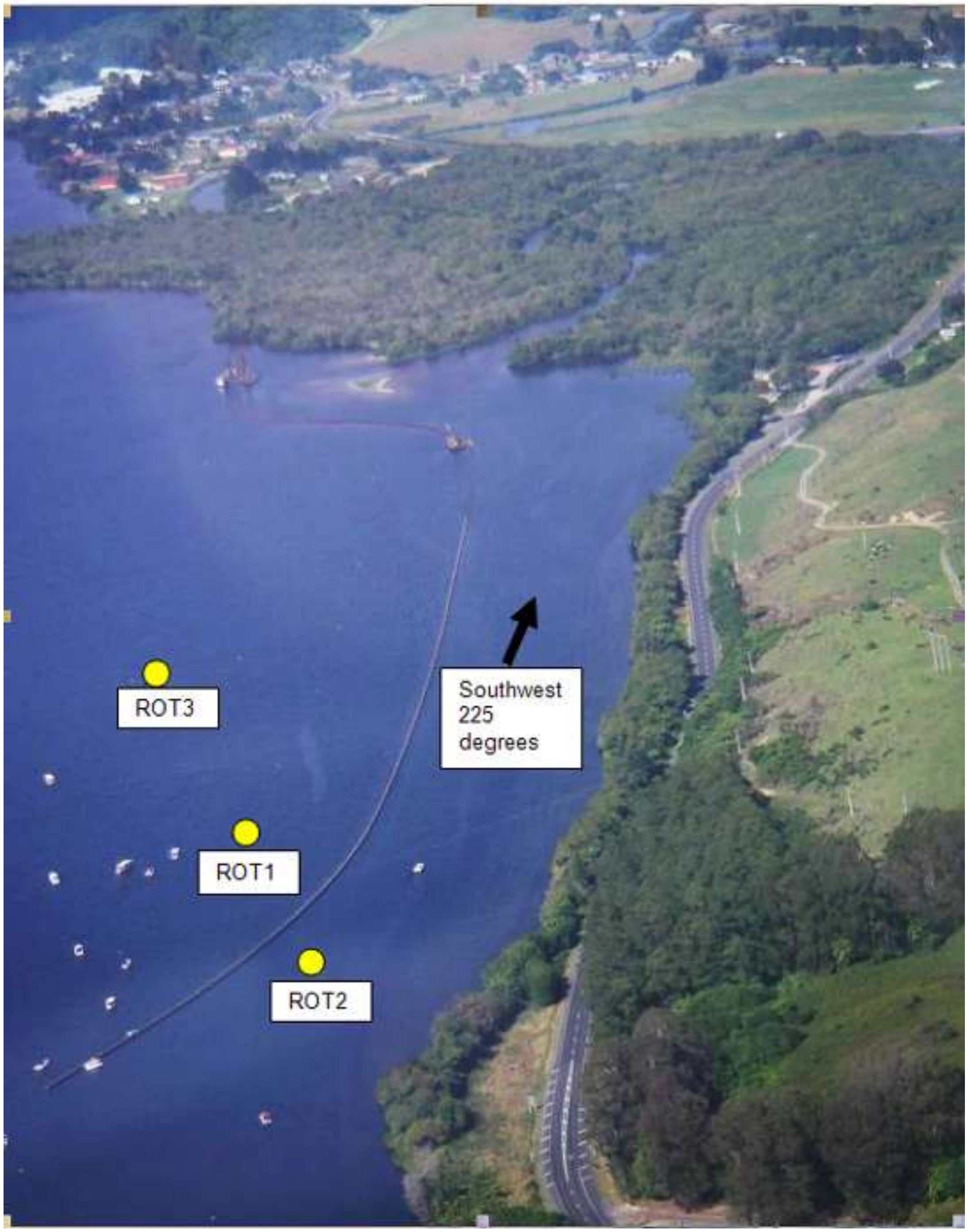

Figure 2. Location of current meters installed from 20 Aug to 9 Sept 2008 at sites ROT1, ROT2 and ROT3. The black arrow denotes a directional marker (not the current direction which was aligned almost 180^{o} opposite).

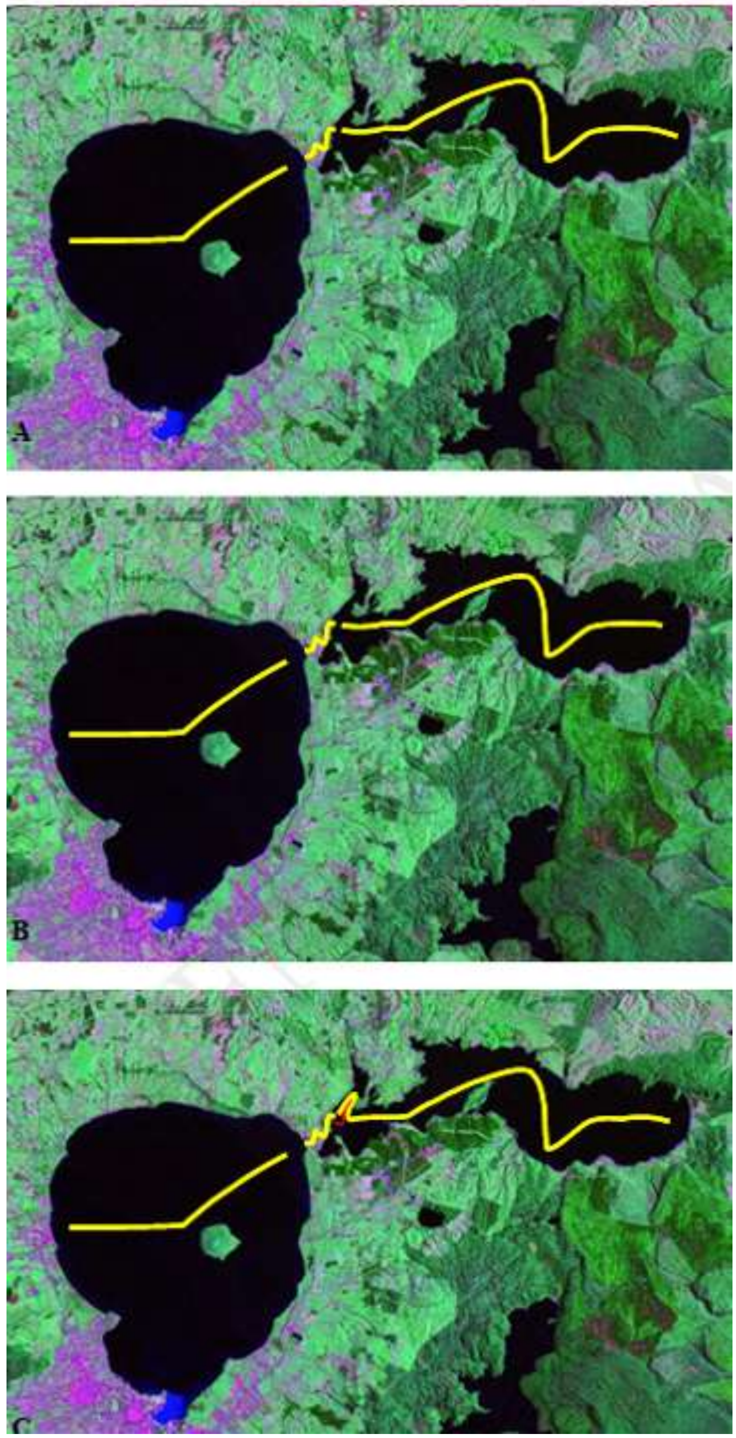

Figure 3. Transect of the BioFish from Ngongotaha at the western end of Lake Rotorua, through Ohau Channel to the eastern end of Lake Rotoiti (A) 11 August 2006 (B) 29 August 2007 (C) 26 August 2008. denotes the diversion wall.

4. Results

4.1 Water temperature

The mean water temperature for ROT1, ROT2 and ROT3 was very similar at 10.8, 10.7 and 10.6 ^{o}C, respectively (Figure 4). However, short term variations in temperature between sites were much greater. ROT2, the site within the diverted Ohau Channel, varied most from ROT1 and ROT3 (sites within Lake Rotoiti). The range of temperatures recorded at ROT2 was 8.0-13.7 ^{o}C, whereas ROT1 was 9.5-12.4 ^{o}C and ROT3 was 9.0 – 12.0 ^{o}C. There were periods when ROT2 varied strongly with both ROT1 and ROT3, with the greatest temperature difference of nearly 3 ^{o}C recorded on 6 September 2008 between the Ohau Channel site (ROT2) and the Lake Rotoiti sites (ROT1 and ROT3). Water temperatures were $\geq$0.5 ^{o}C between ROT2 (Ohau Channel) and ROT1 and ROT3 for 35% and 36%, respectively, of all measurements.

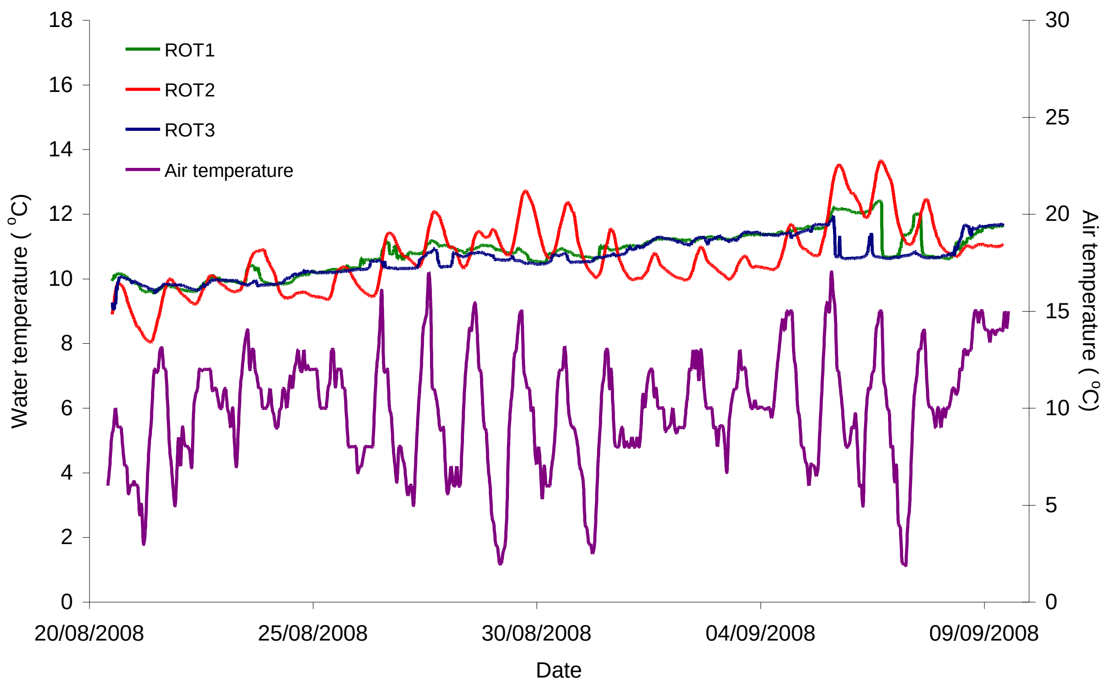

Figure 4. Temperature measured by current meters at sites ROT1, ROT2 and ROT3 and air temperature measured at Rotorua Airport, 20 August to 9 September 2008.

4.2 Current speeds and directions

The direction of flow at ROT2 was always north-east (NE), aligned with the diversion wall and towards the Kaituna River (Table 1 and Figure 5). At ROT1 in Lake Rotoiti water flow was NE towards the Kaituna River for 38% of the time and SW towards Lake Rotoiti for 33% of the time, while at the deeper site (ROT3) flow was in the direction of Lake Rotoiti for 29% of the time (Table 1).

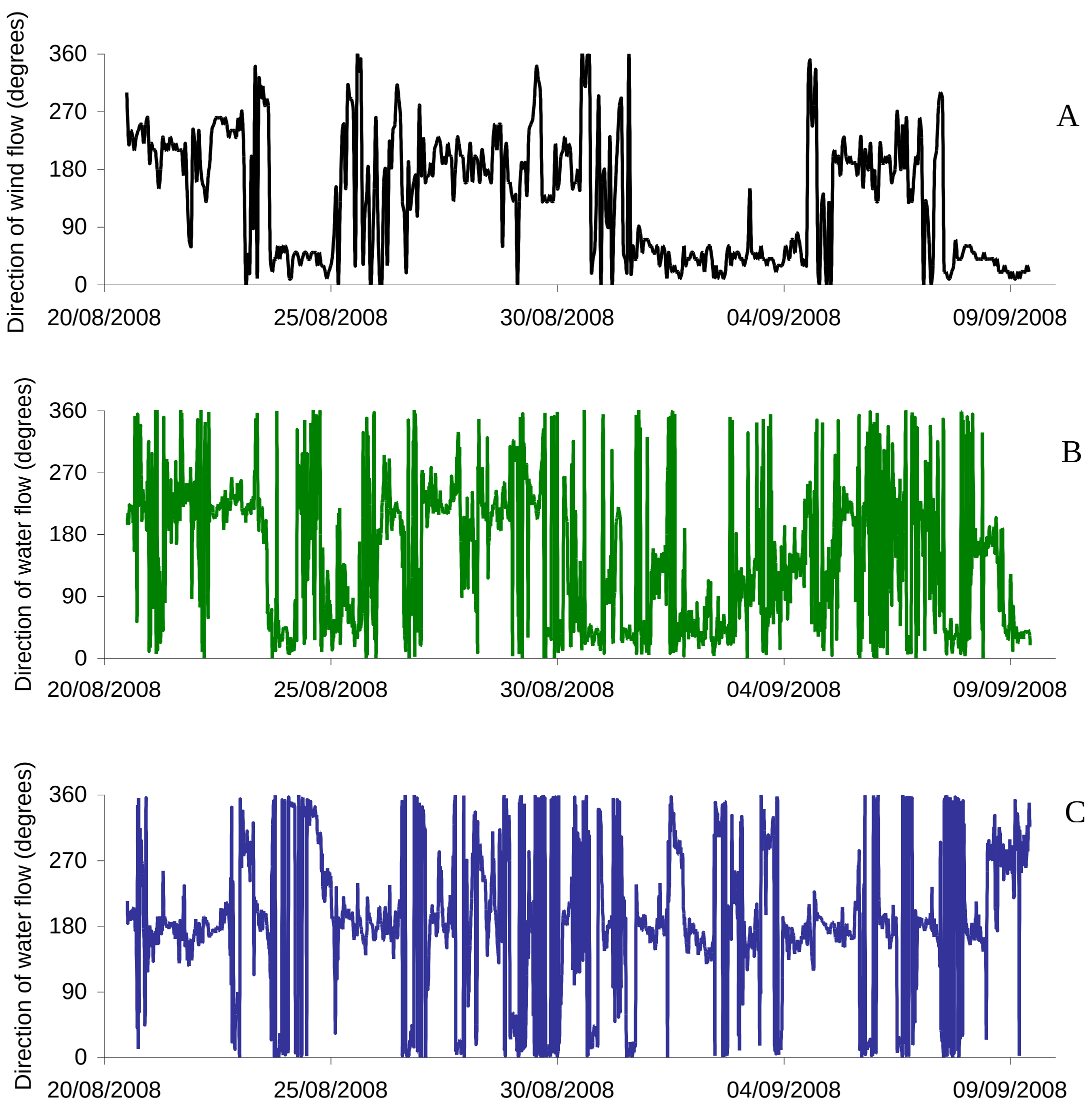

Figure 5. Wind and water current directions for 20 August to 9 September 2008. (A) Hourly wind direction measured at Rotorua Airport, and current flow direction (15 minute intervals) at (B) ROT1 (C) ROT3.

Table 1. Summary of percentage of flow measurements for each compass quadrant at sites ROT1, ROT2 and ROT3, 20 August to 9 September 2008.

Degrees (direction)	ROT1 (%)	ROT2 (%)	ROT3 (%)
0 to 90 (N-E)	38	100	17
91 to 180 (E-S)	18	0	33
181 to 270 (S-W)	33	0	29
271 to 360 (W-N)	11	0	21

There was some correspondence of water flow direction at ROT1 and ROT3 during periods of sustained, relatively constant wind direction, but with periodic interruptions and reversals of flow at the two lake monitoring stations.

Higher values of current speed at the Lake Rotoiti stations (ROT1 and ROT3) tended to be associated with water flow in south-west (SW) or north-west (NW) directions. A summary of current speeds at the three sites is shown in Figure 6. Current speeds at ROT2 (within the diversion wall) were higher than those in Lake Rotoiti (ROT1, ROT3) in all but one instance. Mean current speed during sampling was 14.1 cm s^{-1} at ROT2 and 1.6 and 2.1 cm s^{-1} at ROT1 and ROT3, respectively. Current speed range was 0.01-14.03 cm s^{-1} at ROT2, 8.4-21.4 cm s^{-1} at ROT1 and 0.02-9.4 cm s^{-1} at ROT3. The maxima of the range corresponded to dates of 7 September at ROT1, 6 September at ROT2, and 3 September at ROT3.

The highest wind speed of recorded at Rotorua Airport during the period of current meter deployment was 13.9 m s^{-1} on 24 August 2008. Wind came mainly from the north-east and south directions (Figure 6). The wind direction at Rotorua Airport and the current direction at both ROT1 and ROT3 showed rough correspondence, especially at ROT 1 (Figures 5, 6 and 7).

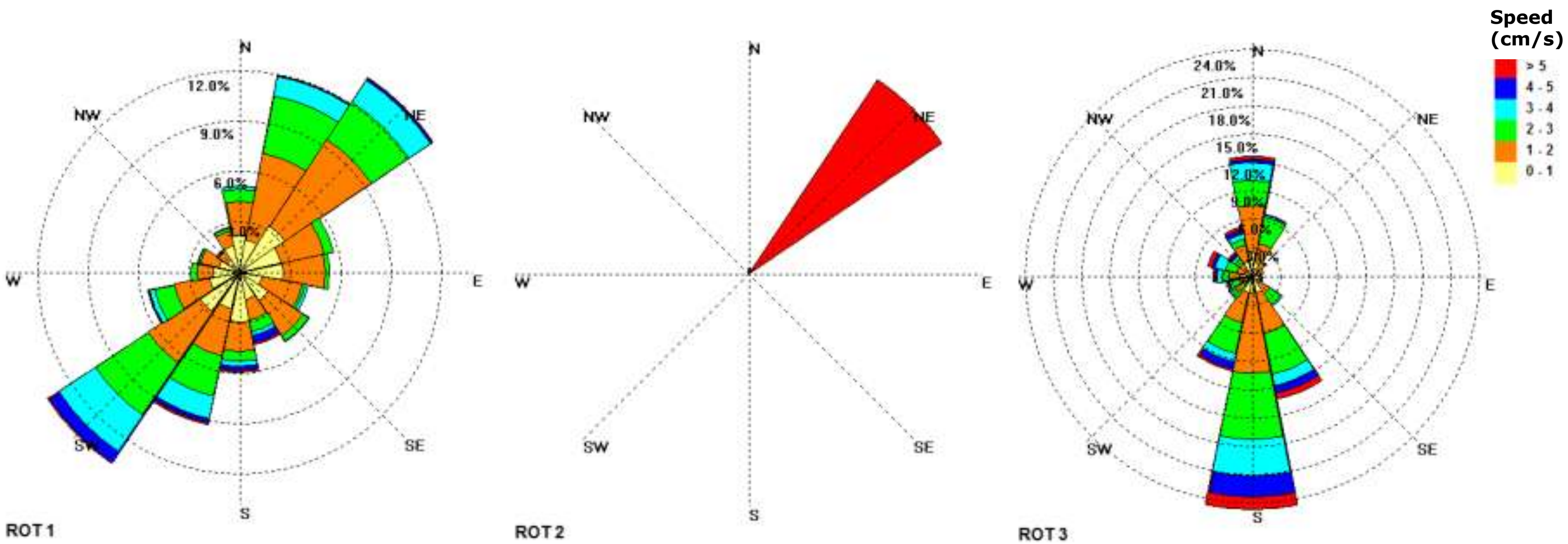

Figure 6. Summary of water current speeds and directions from data taken at 15 minute intervals 1 m above the lake bed at sites ROT1, ROT2 and ROT3. Percentages based on 15-minute readings from 20 August to 9 September 2008.

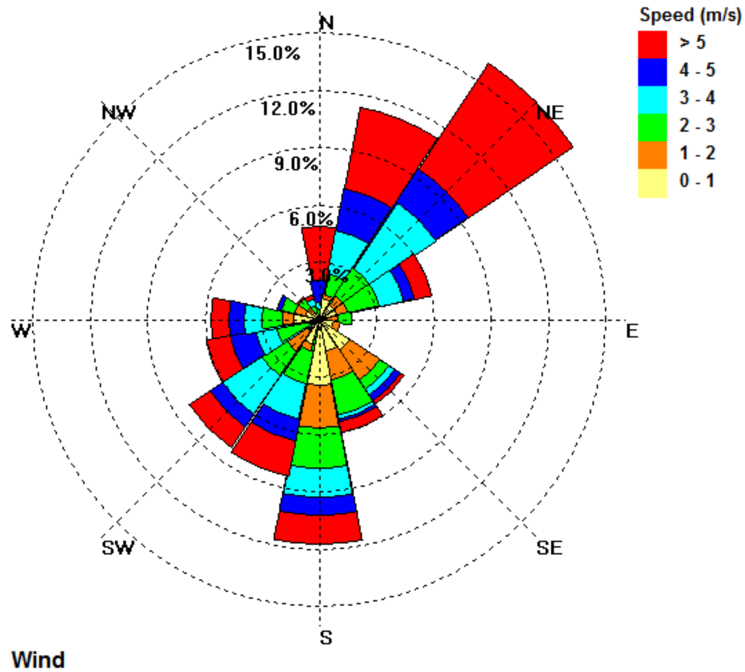

Figure 7. Hourly wind direction and wind speed at Rotorua Airport for 20 August to 9 September 2008.

4.3 Observations and photographic evidence

Our measurements have been supplemented with five cases of visual evidence of the plume. The first is a photo of the south-east end of the Ohau Channel at 13:40 hr on 24 July (Figure 8). The second is a satellite image taken on 17 November 2008 (Figure 9). The photo on 24 July shows relatively turbid water from the Ohau Channel tending to spread laterally once it flows past the end of the diversion wall. At 14:00 hr on this day the wind speed was 7.7 m s^{-1} and wind direction was south-west at Rotorua Airport. The remote sensing image was from 17 November 2008. It shows a marked difference in water clarity between the turbid diversion channel water and the clear waters of Lake Rotoiti (Figure 9). The water from Lake Rotoiti can be discerned well past the end of the diversion wall and into the Okere Arm end of the lake. Three other aerial photos from 16 December 2008 are shown to provide additional perspective on the diversion wall (Figures 10, 11 and 12).

Figure 8. Photo of the end of Ohau Channel Diversion wall taken 13:40 hr on 24 July 2008. Note relatively turbid water from the diversion channel (left-hand side of photo) flowing into relatively clear water of Lake Rotoiti. Photo courtesy of N. Miller.

Figure 9. Remote sensing image of Ohau Channel, Okawa Bay, Kaituna exit and western basin on Lake Rotoiti. Photo taken 17 November 2008. Image made available through agreement entered into for the license from National Space Program Office of the National Applied Research Laboratories for the limited use of ROCST-2 satellite image and data by the University of Waikato, and supported through the Global Lake Ecological Observatory Network (GLEON). The horizontal resolution is 2 m and the image has been pan-sharpened from a true colour image through assistance from Mat Allan (University of Waikato).

Figure 10. Photo of the Ohau Channel diversion wall showing the Okere Arm towards the outlet of Lake Rotoiti (upper left). Photo: Environment Bay of Plenty.

Figure 11. Photo of the Ohau Channel diversion wall, also showing Lake Rotorua (top waterbody) and including Mokoia Island (upper left). Note the variation in water appearance between in the photo foreground arising from mixing between water from the Ohau Channel from Rotoiti. Photo: Environment Bay of Plenty.

Figure 12. Photo of the Ohau Channel diversion wall, also showing Lake Rotorua (top waterbody). Photo: Environment Bay of Plenty.

4.4 BioFish profiles

A series of figures has been used to compare 2006, 2007 and 2008 winter data arising from BioFish transects through Lake Rotorua, Ohau Channel and Lake Rotoiti. Lake Rotorua shows little vertical variation of temperature in each of the three years but a moderate horizontal gradient in 2007 (Figure 13), which may be indicative of diurnal solar heating acting in combination with south-westerly winds advecting warmer surface waters towards the north-east end of the lake in the vicinity of the Ohau Channel. The cooler water temperature near Ngongotaha in 2008 appears to be a localized phenomenon which may also be an artifact of the data interpolation scheme. There are small vertical gradients in water temperature close to the surface in Lake Rotoiti, particularly in 2006 and 2008, which are most likely due to diurnal solar heating. Water temperature was lower in Lake Rotorua than in Lake Rotoiti in all three years but the range in water temperature (10-12 ^{o}C) is small. The temperature difference in surface waters between the Ohau Channel and the western end of Lake Rotoiti was approximately 1 ^{o}C in 2006, 0.2 ^{o}C in 2007 and 0.4 ^{o}C in 2008. There was a small horizontal gradient of water temperature (c. 10.5-11 ^{o}C) from 10 to 20 m in Lake Rotoiti in 2008.

For all years, concentrations of dissolved oxygen (DO) were slightly higher in Lake Rotorua than in Lake Rotoiti (Figure 14). There was a slight tendency for DO to be higher at the water surface than in bottom waters of Lake Rotoiti but otherwise few distinctive spatial patterns.

Chlorophyll fluorescence for each of the three years was higher in Lake Rotorua than in Lake Rotoiti (Figure 15). Fluorescence was especially elevated in 2006 compared with 2007 and 2008. We attribute decreases in fluorescence in surface waters (0-3 m) in Lake Rotorua in 2007 and 2008, and in Lake Rotoiti over all three years, to the effects of solar quenching; an artifact of bright light near the middle of the day quenching the emission of fluorescence by phytoplankton. An awareness of this influence is required in any analysis of fluorescence data from within these. Excluding locations where solar quenching may have been present, there was little variation in fluorescence in Lake Rotoiti except for 2006, when it was intermediate between levels in Lake Rotorua and Lake Rotoiti but elevated adjacent to the lake bed near where the Ohau Channel entered

Lake Rotoiti (Figure 16). Conductivity is generally slightly higher in Lake Rotoiti than in Lake Rotorua. For 2006 it is possible to track the underflow of water from the Ohau Channel into the western end of Lake Rotoiti as a signature of water with lower conductivity. No such indication is given by the conductivity transects of the subsequent two years.

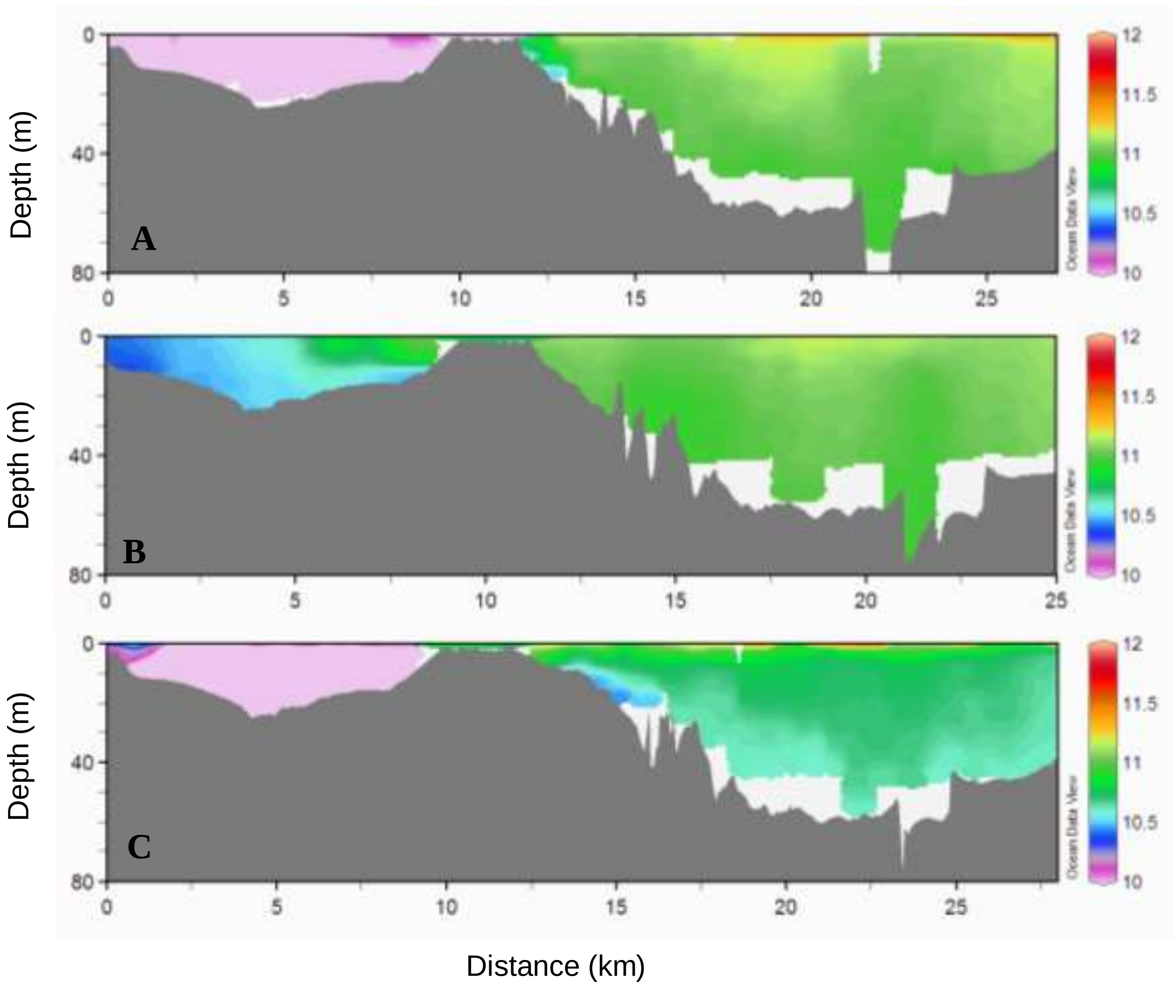

Figure 13. Water temperature (^{o}C) for (A) 11 August 2006, (B) 29 August 2007 and (C) 26 August 2008 from a BioFish transect across Lake Rotorua from Ngongotaha to the Ohau Channel (0-10 km), through the Ohau Channel (10-12 km) to the eastern end of Lake Rotoiti (12-30 km). In (C) the diversion wall is represented by the distance from 12-13.3 km.

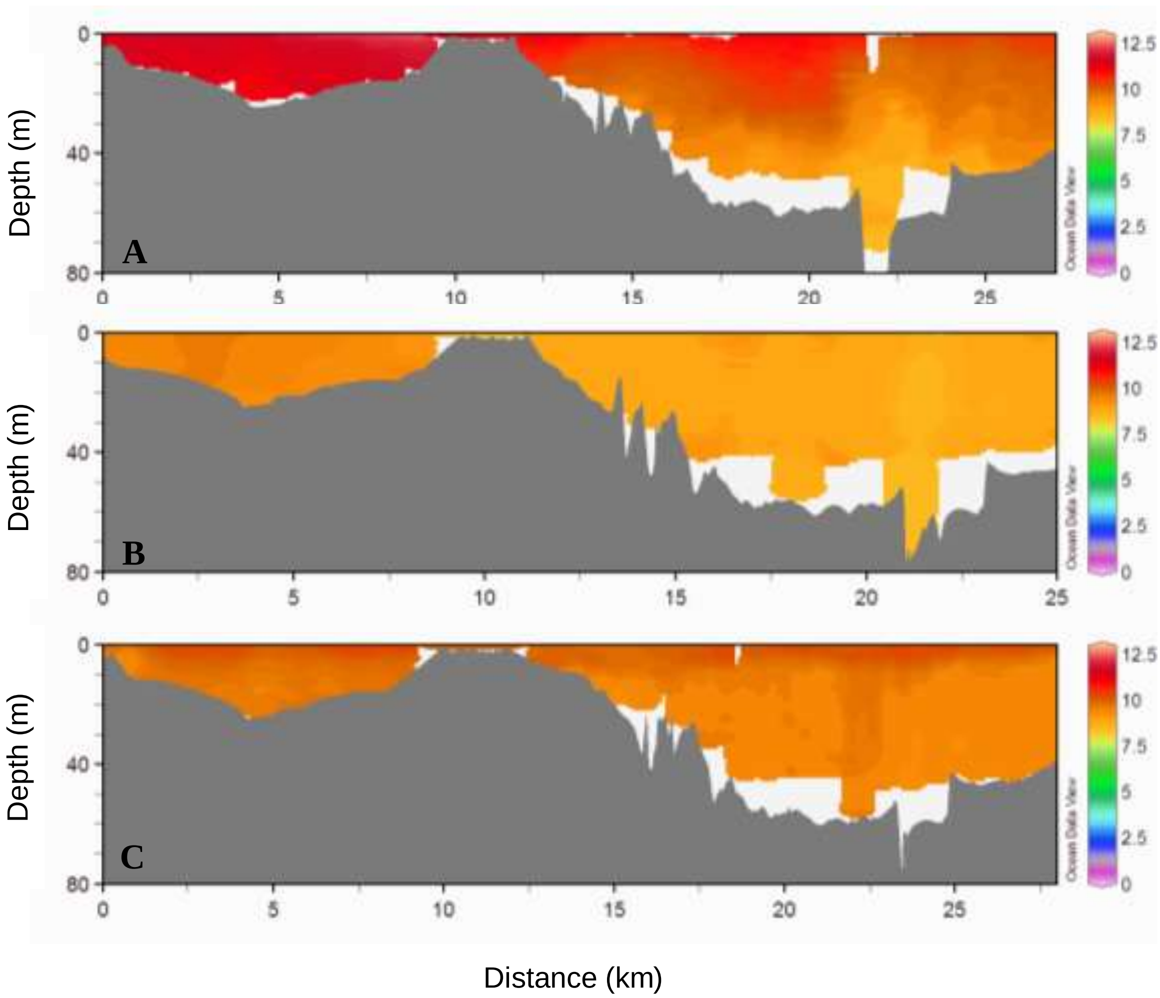

Figure 14. Dissolved oxygen (mg L^{-1}) for (A) 11 August 2006, (B) 29 August 2007 and (C) 26 August 2008 from a BioFish transect across Lake Rotorua from Ngongotaha to the Ohau Channel (0-10 km), through the Ohau Channel (10-12 km) to the eastern end of Lake Rotoiti (12-30 km). In (C) the diversion wall is represented by the distance from 12-13.3 km.

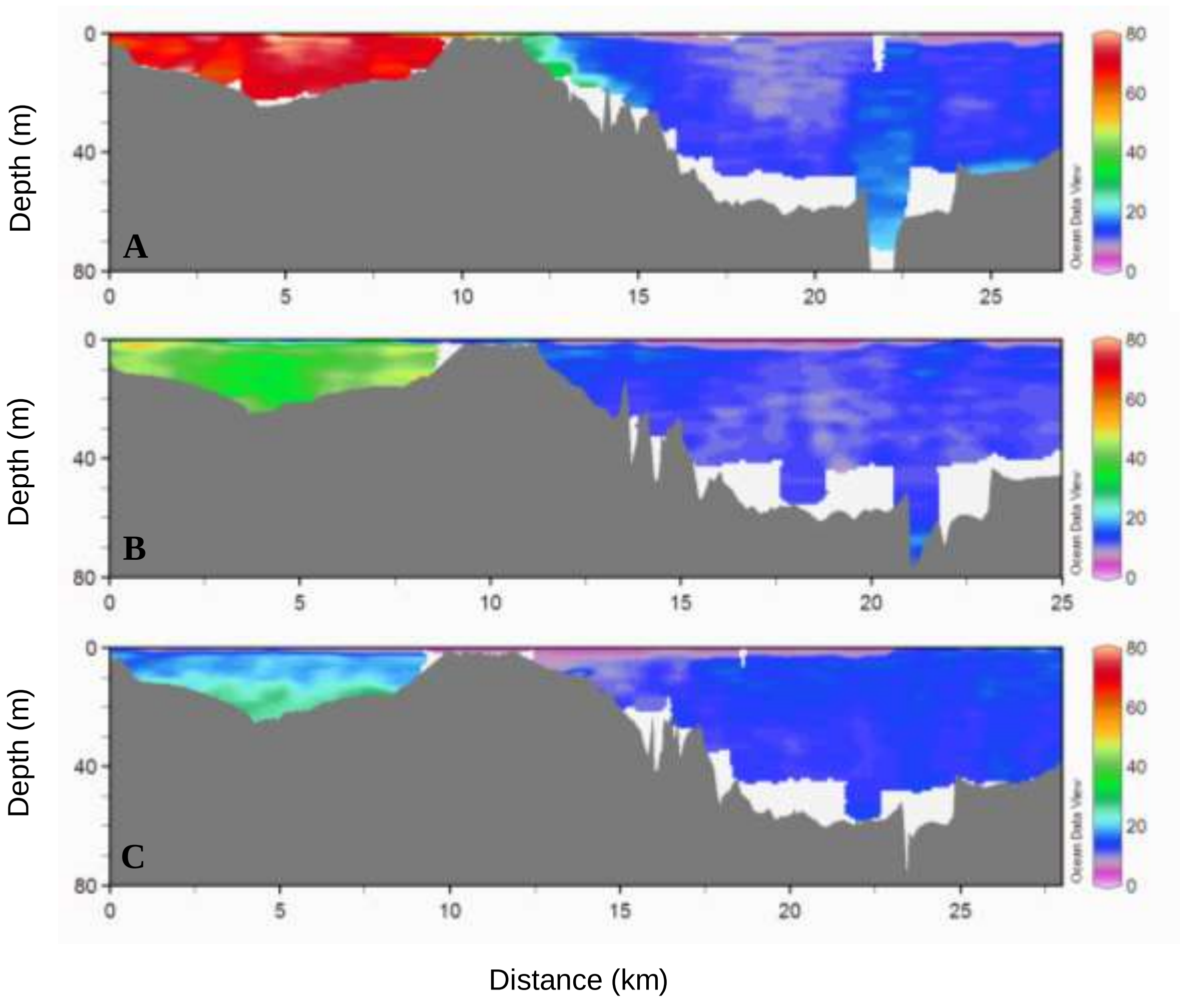

Figure 15. Fluorescence for (A) 11 August 2006, (B) 29 August 2007 and (C) 26 August 2008 from a BioFish transect across Lake Rotorua from Ngongotaha to the Ohau Channel (0-10 km), through the Ohau Channel (10-12 km) to the eastern end of Lake Rotoiti (12-30 km). In (C) the diversion wall is represented by the distance from 12-13.3 km.

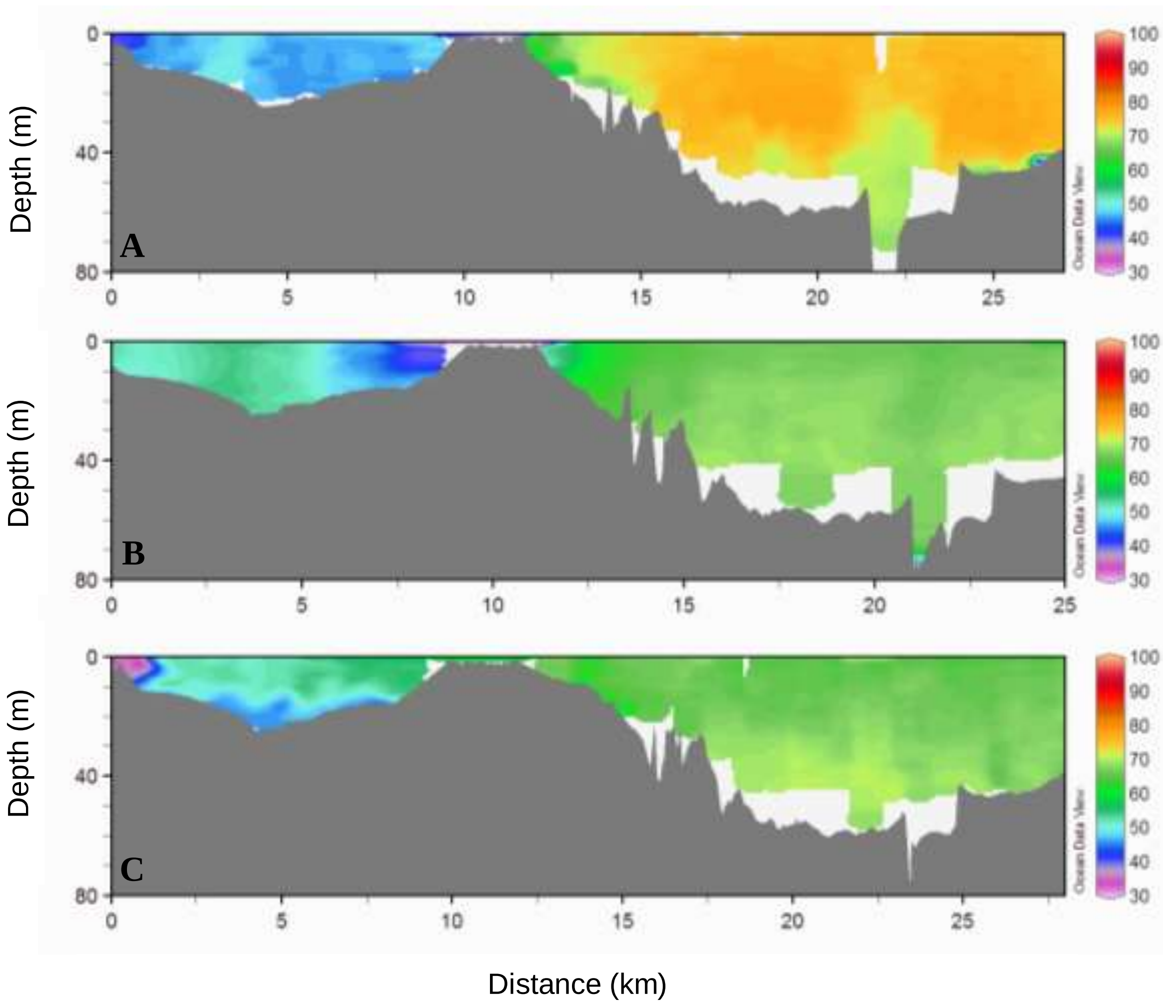

Figure 16. Conductivity (µS cm^{-1}) for (A) 11 August 2006, (B) 29 August 2007 and (C) 26 August 2008 from a BioFish transect across Lake Rotorua from Ngongotaha to the Ohau Channel (0-10 km), through the Ohau Channel (10-12 km) to the eastern end of Lake Rotoiti (12-30 km). In (C) the diversion wall is represented by the distance from 12-13.3 km.

5. Discussion

This study cannot rule out that there is some ‘leakage’ of water around the end of the Ohau Channel diversion wall and into the main basin of the lake, but this appears to be small and intermittent, on the basis of this study. Water speeds in the region where an intrusion might occur are small compared with those within the channel. Although current directions are towards Lake Rotoiti between 51 and 62% of the time (Table 1), the observed water velocities at the two stations in Lake Rotoiti appear to be influenced primarily by wind (Figures 5 and 6), especially in the case of ROT1. Water flow ‘into the wind’ is commonly found in many lakes and may have been generated by normal return-flows or as a response to temporary relaxation of sustained wind-stress (Webster and Hutchinson, 1994; Stevens and Imberger, 1996).

When cooler, denser water flows into receiving water that is warmer and more buoyant, then the denser water sinks and moves downslope along the bottom as an underflow. Conversely, warmer and more buoyant water flowing into cooler, denser receiving water spreads and flows over the surface as an overflow (Pickrill and Irwin, 1982). A number of studies (e.g., Vincent *et al.* 1986; Stephens, 2004; Hamilton *et al*. 2005) have used different temperature differentials between the Ohau Channel inflow and surface waters of Lake Rotoiti to define the occurrence of underflow or overflow conditions. When modelling the efficacy of the diversion wall designs, Stephens (2004) used a temperature differential of ±2.5 ^{o}C, while Hamilton *et al.* (2005) used ±1 ^{o}C to define overflow and underflow conditions. Vincent *et al.* (1986) found underflows occurred when water in the Ohau Channel was 0.2 to 0.7^{o}C cooler than surface waters of Lake Rotoiti. The temperature difference in surface waters between the Ohau Channel and the western end of Lake Rotoiti based on BioFish transects was approximately 1 ^{o}C on 11 August, 2006, 0.2 ^{o}C on 29 August, 2007, and 0.4 ^{o}C on 26 August, 2008. There was clear evidence of an underflow in 2006, which was supported by observations of reduced conductivity and increased chlorophyll fluorescence in water adjacent to the lake bed at the western end of Lake Rotoiti. There was a hint of an underflow in the temperature transect of 2008 (Figure 13c) but this could not be corroborated by additional data (i.e., dissolved oxygen, conductivity and fluorescence) from the BioFish transect, as it was for 2006 (Figures 14, 15 and 16).

The satellite image (Figure 9), shows turbid water within the diversion channel moving past the end of the diversion wall and into the Okere Arm. This is in contrast to the clear waters of Lake Rotoiti and is visual evidence that the diverted water was flowing towards Kaituna River at this time. Overflow conditions were most likely to have been prevalent in November (Gibbs *et al*. 2003; Hamilton *et al*. 2005a), at the time of the satellite photo.

The region at the end of the diversion channel is where there is convergence of fast-flowing water from the Ohau Channel with relatively quiescent water in the Okere Arm, creating a zone of mixing on the edge of the inflow jet (Spigel *et al*. 2005). Temperature differentials between the two water masses, based on records from the current meters, were > $\pm 0.5^{o}$C for 53% of the time during the study period, which could extend the duration on which the Ohau Channel water remained relatively distinct as an intrusion. Even if this were to be an underflow, as it enters the shallow, relatively broad Okere Arm region, wind mixing will likely play an important role in its rapid assimilation with water from Lake Rotoiti as it initially moves downslope towards the Kaituna River. In the case of an overflow, which would spread in a radial fashion into the Okere Arm, even if there was very strong wind-driven surface flow towards Lake Rotoiti, there would be likely to be minimal re-intrusion into the lake. This could be tested with current meter measurements in mid-summer, when during the day surface waters of Lake Rotorua can increase above those of Lake Rotoiti. This period is also the one of most interest as there may be a greater inoculum of phytoplankton biomass, particularly cyanobacteria, from Lake Rotorua.

Measurements in this study were confined to two stations within Lake Rotoiti and close to the lake bed. Consideration could be given in a future study to measurements through the entire water column, possibly with an Acoustic Doppler Current Profiler, and at a different time of year to the present study; either specifically when strong underflows had occurred at times before the diversion wall (e.g., April-May) or when there were strong overflows (e.g., January-February).

There is considerable visual evidence, including a satellite image, aerial observations (from plane) and on-ground observations, that indicate that the diversion wall is acting in a manner consistent with its design and what was targeted for in the restoration actions for Lake Rotoiti, and that there does not appear to be substantial 'leakage' of water from the diversion canal back into Lake Rotoiti.

6. Acknowledgments

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