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Review of the benefits of the Okere Gates Control Structure for Environment Bay of Plenty

Date:
13 March 2009

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Revision 0

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Contents

1. Executive Summary

Background

Lake levels in Lake Rotoiti are currently controlled via operation of the Okere radial gates which regulate the rate of discharge to the Kaituna River. The Okere radial gates are currently owned and operated by the Rivers & Drainage group of Environment Bay of Plenty in accordance with their resource consent. Te Arawa Lakes Trust are the new lakebed owners upon which the control structures are located. This is a significant change from the situation in 1996 when the consent was first issued. A copy of the consent is included in Appendix A.

Resource consents for Okere gates and Ohau weir control structures are due to expire on 30 June 2010. Before applying to renew this consent EBOP wish to know what the positive and negative impacts of the current structure and its operating regime are, and what impacts there would be in removing the gates or replacing them with an alternative control structure. Rivers & Drainage will then use this information to engage with Te Arawa Lakes Trust to define an acceptable solution or solutions.

The level of Lake Rotorua may also be affected as it discharges to Lake Rotoiti via the Ohau Channel and flows in the Ohau Channel depend on the relative levels of both lakes.

Study Objectives

- i) Option 1 - Model replacement of the Okere gates with a stoplog structure that approximately replicates the natural rock ledge weir that existed prior to the construction of the gates
- ii) Option 2 - Model replacement of the Okere gates with an alternative non-gated structure that broadly aims to maintain current target lake levels.
- iii) Option 3 - Model retention of the existing Okere gates structure but keeping the radial gates permanently fully open (to be closed only in an emergency).
- iv) Assess what impacts these options have on the range and variability of;
  - a) Lake levels in Lake Rotoiti
  - b) Lake levels in Lake Rotorua
  - c) Outflows into the Kaituna
- v) Discuss qualitatively the positive and negative impacts the three different scenarios above would have on the community and stakeholders on both of the lakes and the Kaituna River.

Methodology

The general approach was to use historical gauge data of lake levels and outflows to derive inflow hydrographs to Lakes Rotorua and Lake Rotoiti for the 10 year period 1998 to 2007. (This period included significant floods and droughts.)

A Mike-11 hydraulic model was set up of the two lake system linked by the Ohau Channel and discharging to the Kaituna River via the Okere Channel. Alternative outlet structures were tested on the Okere outlet Channel for this 10 year period and lake levels modelled and compared with the 10 year historical record.

Results

(Please - refer graphs and tables in Appendix D)

- i) The range and variability of lake levels in Lake Rotoiti **increase** significantly if the current gate operating regime is replaced with any type of weir control structure
- ii) The average level of Lake Rotoiti with a weir outlet is directly dependent on the level the weir is set at. Option 1 therefore gives a significantly higher average Lake Rotoiti level than option 2, or the historic gauged levels. (Note a review of levels since 1905 in a report by NIWA - 2003 shows that average Lake Rotoiti lake levels were generally higher than the current target level.) Option 3 by contrast with a lower effective weir/sill level gives significantly lower Lake Rotoiti levels.

iii) The range and variability of outflows from Lake Rotoiti to the Kaituna River **decrease** significantly if the existing control gate is replaced with a weir type control structure or kept permanently fully open.

iv) If average levels in Lake Rotoiti are increased significantly (such as by 200 mm in option 1) then this causes a small but measureable (about 25 mm) increase in the level of Lake Rotorua. Similarly lowered average Lake Rotoiti levels (such as by 700mm in option 3) cause a decrease in the average Lake Rotorua level (by around 65mm).

Benefits/Impacts

A full review of benefits/impacts are given in section 5 of the full report. However benefits of the current narrow range of Lake Rotoiti levels include allowing private and public boat ramps to be always operational, and to avoid any/flooding/inundation of properties/roads and septic tanks.

Disadvantages include impacts on lake edge ecology and the loss of lakeside beaches. It also increases the variability and peakiness of flows released to the Kaituna River which may cause downstream erosion.

On the plus side the gates allow control of flows to the Kaituna River in flood or drowning emergencies. Impacts on Lake Rotorua levels are generally very minor.

Recommendations

Full consultation is just commencing and it is therefore not feasible to recommend the status quo or any particular option.

It is recommended that the results of this study be used to help inform the consultation process between EBOP and other stakeholders.

It is suggested that if an alternative to the current gate operation is the preferred outcome from the consultation process that the gate structure should not be removed but instead retained, with the gates left fully open. In this way there is still the ability to close the gates in a flooding or drowning type emergency.

Other alternatives that could be considered, such as maintaining the manual operating regime of the gates but with a larger target lake level range, are listed in the full report.

2. Background and objective

Lake levels in Lake Rotoiti are currently controlled via operation of the Okere radial gates which regulate the rate of discharge to the Kaituna River. The Okere radial gates are currently owned and operated by the Rivers & Drainage group of Environment Bay of Plenty in accordance with their resource consent. Te Arawa Lakes Trust are the new lakebed owners on which the control structures are located. This is a significant change from the situation in 1996 when the consent was first issued, a copy of which is included in Appendix A.

Resource consents for Okere gates and Ohau weir control structures are due to expire on 30 June 2010. Before applying to renew this consent EBOP wish to know what the positive and negative impacts of the current structure and its operating regime are and what impacts there would be in removing the gates or replacing them with an alternative control structure. Rivers & Drainage will then use this information to engage with Te Arawa Lakes Trust to define an acceptable solution or solutions.

The level of Lake Rotorua may also be affected as it discharges to Lake Rotoiti via the Ohau Channel and flows in the Ohau Channel depend on relative lake levels of both lakes.

The objectives of this study are to;

i) Model replacement of the Okere gates with a stoplog structure that approximately replicates the natural rock ledge weir that existed prior to the construction of the gates and assessing what impacts this has on the range and variability of;
   a) Lake levels in Lake Rotoiti
   b) Lake levels in Lake Rotorua
   c) Outflows into the Kaituna River

ii) Model replacement of the Okere gates with an alternative structure that broadly aims to maintain current target lake levels. Assess what impacts this has on the range and variability of;
   a) Lake levels in Lake Rotoiti
   b) Lake levels in Lake Rotorua
   c) Outflows into the Kaituna River

iii) Model retention of the existing Okere gates structure but keeping the radial gates permanently fully open (to be closed only in an emergency). Assess what impacts this has on the range and variability of;
   a) Lake levels in Lake Rotoiti
   b) Lake levels in Lake Rotorua
   c) Outflows into the Kaituna River

iv) Discuss qualitatively the positive and negative impacts the three different scenarios above would have on the community and stakeholders on both of the Lakes and the Kaituna River.

3. Literature and data review

3.1 Literature

EBOP have provided a number of reports on both the Ohau Channel which discharges from Lake Rotorua into Lake Rotoiti, and the Okere gate structure which controls the discharge from Lake Rotoiti into the Kaituna River. These reports have been briefly reviewed for relevant information and are listed below. These reports (especially those by Titchmarsh (1995) and Surman (1998)) give a good background to the issues examined by this study. A repeat of that information is therefore not included in this report.

Table 1 – Background reports and documents

Title	Author and Organisation	Date and File No
Draft report Hydraulic Modelling of Ohau Channel	Philip Wallace	February 2003
Report on the technical issues and effects to be considered in the application for resource consents	B R Titchmarsh, Manager Technical Services, EBOP	December 1995 Operations report 95/5
Okere Radial Control Gates Lake Rotoiti to Kaituna River Operation Report	Matthew Surman, Design Engineer, EBOP	November 1998 Operations report 98/4
Upper Kaituna Catchment Control Scheme	Bay of Plenty Catchment Commission	April 1975
Upper Kaituna River Major Scheme Lakes Rotorua & Rotoiti	A.P Griffiths, Bay of Plenty Catchment Commission	
Flood warning manual (pages 93 – 96 only)	EBOP	July 1998

3.1.1 Existing Mike-11 Hydraulic Model

A Mike-11 hydraulic model of the Ohau Channel linking Lake Rotorua and Lake Rotoiti has already been developed, and is documented in the report "Draft Report– Hydraulic modelling of Ohau Channel- Phil Wallace February 2003". This model was supplied by EBOP for use in this study.

However examination of the model received from EBOP showed some inconsistencies with the aforementioned report. Phil Wallace was therefore contacted directly for the correct version of the model which was used in our analysis. This updated model had been calibrated (as discussed in Phil Wallace's report). Accordingly, after some brief verification checks, Phil Wallace's model was adopted unaltered.

3.1.2 Gauge Data

Automatic gauge data was provided by EBOP as detailed in Table 2 below;

Table 2- Gauge Data Details

Location	Data Type	Period
Lake Rotorua- Town Wharf	Lake Level	2003-2007
Lake Rotorua- Mission Bay	Lake Level	1998-2007
Lake Rotorua- Mission Bay	Flow into Ohau Channel	1998-2007
Lake Rotoiti- Okere Gates	Lake Level	1998-2007
Lake Rotoiti- Okawa Bay	Lake Level	June 2001-2007
Kaituna River- Taaheke	Flow	1998-2007

This gauge data has a nominal recording interval of 15 minutes. Although quite often there will be some missing data, there are usually at least two or three recordings per hour. The location of the gauges is shown on Drawing SK01 in Appendix B.

In addition, the Rivers and Drainage section of EBOP maintain a daily record of levels for Lake Rotorua and Lake Rotoiti, by a daily telephone interrogation (usually in the morning) of the lake level recorders. This record does not include weekend or holiday periods. This record does, however, include other useful information such as stoplog removal, gate settings and drawdown, and weather/rainfall.

3.1.3 Survey/Design Data

Design drawings from 1998 (not As-Builts) were provided for the stoplog structure in the Ohau Channel.

Survey of the Ohau Channel was undertaken by EBOP in 2002 and was provided in this study by way of the Mike-11 model from Phil Wallace. It should be noted that Phil Wallace had included levels of the stoplog structure from the 1998 design drawings in his Mike-11 model as As-Builts (post construction survey) of this structure are not available.

Design drawings (not As-Builts) for excavation of bed rock from the Okere Channel and construction of the Okere Gate structure were also provided (Murray North Partners Ltd-1978) and are included in Appendix C. A spot check by Graeme O'Rourke of EBOP in February 2009 confirmed the gate structure has been built to design levels.

Survey of the Okere Channel was included on the 1978 Murray North Ltd drawings. These drawings included only selected levels so other levels were scaled off by Aurecon's draughting team. It was assumed that the bed rock was excavated to the levels shown on the drawings. There are no as-builts to confirm this. This methodology was approved by EBOP for this phase of this study.

3.2 Data Processing

The raw 15 minute gauge data did not consistently have four records each hour. Hence the first available record was taken for each hour. The 24 hourly records hence obtained were averaged to arrive at a daily average level or flow. These were graphed and compared with the daily records. In this way spurious data could be identified and cleaned.

3.2.1 Drawdown Corrections

The lake level at the Okere Gates structure is subject to drawdown in the approach channel to the gate. The drawdown correction for each day is included in the comments of River and Drainage's daily record. This same factor was hence applied to the averaged automatic gauge data. From June 2001 automatic gauge data is available from the Okawa Bay site on Lake Rotoiti which is not subject to drawdown, due to its location and hence after June 2001 this data source was used in preference.

3.2.2 Datum Corrections

Due to geological factors, among others, there have been several datum adjustments in the area. (Graeme O'Rourke of EBOP should be contacted for details on this). This has caused a discontinuity in the lake level data as can be seen on Graph 1 in Appendix D. It can also be seen that there is a difference between around August 2001 and May 2005 between the processed and automatic gauge data and the Rivers and Drainage daily record. Glenn Ellery and Graeme O'Rourke of EBOP were contacted and reviewed the data. As a result the 15 minute Okawa Bay gauge data was slightly revised by Glenn Ellery and resent to Aurecon.

The revised data is shown in Graph 2 in Appendix D. Comparing it to Graph 1 it can be seen the revisions are minor. The resent data as reviewed by Glenn Ellery has been accepted as the 'best' record.

3.3 Lake Target levels

EBOP's flood warning manual (July 2008) –refer Appendix A - states Lake Rotorua's medium level is RL 279.805 m, maximum is RL 280.11 m and minimum is RL 279.5 m. For Lake Rotoiti the target level is RL 279.116 m ± 75 mm, the maximum level is RL 279.406 m and minimum level RL 278.856 m. Full details of the current operating regime for the Okere Gates are given in the Resource Consent Conditions included in Appendix A.

It should be noted that prior to 30 November 2005 the target level for Lake Rotoiti was RL 279.15m. The change to RL 279.116 m was made due to datum adjustments.

3.4 Stoplog Removal Record

In 1989 a submerged weir structure was constructed at the upstream end of the Ohau Channel replacing the gabion baskets there at the time. The weir was designed to incorporate the insertion or removal of stoplogs allowing some control of Lake Rotorua levels. Table 3 below details the record of dates of stoplog removal in the Ohau Channel. This was taken from the comments sections of Rivers and Drainage daily lake levels record.

Table 3: Ohau Channel Stoplog Installation/Removal Dates.

Year	Removed	Installed
1998		
1999		
2000	30-August	24-October
2001	15-May	16-July
2001	19-December	
2002		28-February
2002	20-June	3-September
2003		
2004		
2005		
2006		
2007		
2008	12-August	19-November

4. Methodology

4.1 General Approach

The general approach was to use historical gauge data of lake levels and outflows to derive inflow hydrographs to Lakes Rotorua and Lake Rotoiti for the 10 year period 1998 to 2007. (This period includes significant floods and droughts.)

This approach is based on the equation: $\Delta S = I - O$ which says the change in storage of the lake (which can be measured by changes in lake level) is equal to the total inflow minus the total outflow.

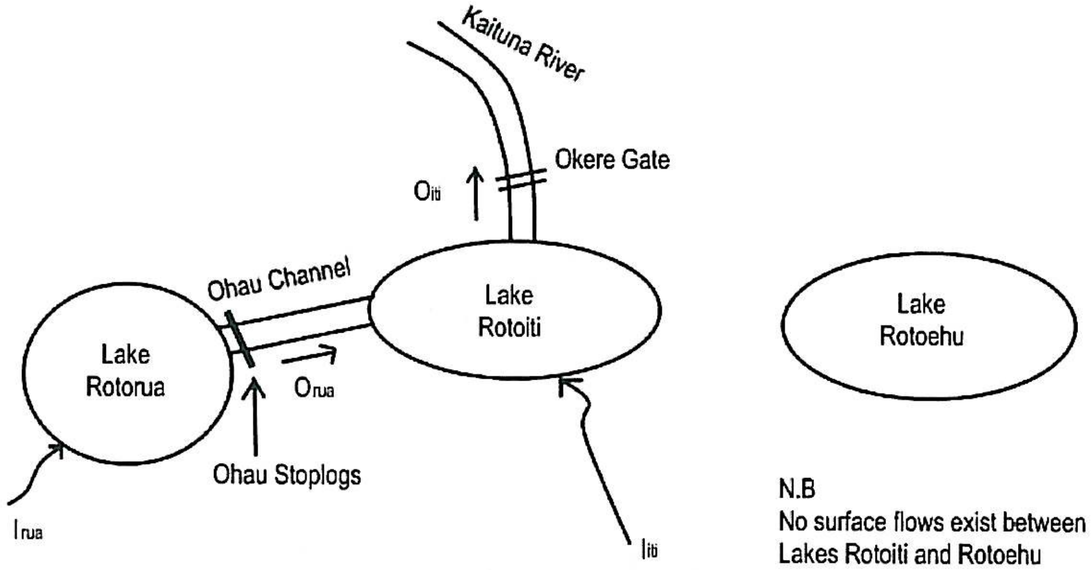
Having derived inflow hydrographs to both Lake Rotorua and Lake Rotoiti, a Mike-11 model was set up of the two lake system linked by the Ohau Channel.

To achieve the objectives of this study, alternative outlet structures from Lake Rotoiti were tested on the Okere outlet channel for this 10 year period and lake levels modelled and compared with the 10 year historical record.

4.2 Methodology details

The sketch below shows schematically the relationship between the lakes:

Drawing 1 – Model setup



I_{rua} – Inflows to Lake Rotorua
O_{rua} – Outflows from Lake Rotorua to Lake Rotoiti via Ohau Channel
I_{iti} – Inflows to Lake Rotoiti (excluding those from Ohau Channel)
O_{iti} – Outflows from Lake Rotoiti to Kaituna River via Okere Gate

Step 1 – Flows in Ohau Channel

The Ohau Channel Mike-11 model from Phil Wallace was used to generate a 10 year record of O_{rua}. The model was set up with the averaged daily Lake Rotorua levels (refer section 2.2) measured at Mission Bay (refer Figure 1 in Appendix B) at the upstream end, and the averaged daily Lake Rotoiti levels measured at Okawa Bay (Okere corrected for drawdown prior to June 2001) at the downstream end. The Mike-11 model was run in two different states – stoplogs in or stoplogs out – according to the dates in Table 3.

Step 2 – Flows into Lake Rotorua

Daily values of I_{rua} were calculated from $\triangle S_{rua} = I_{rua} - O_{rua}$ where O_{rua} was calculated in step 1 and $\triangle S_{rua} = \triangle Z_{rua}. A_{rua}$

$\triangle Z_{rua}$ = daily change in Lake Level at Mission Bay

A_{rua} = Area of Lake Rotorua = 8047 ha (from www.envbop.govt.nz/water/Lakes/Lakes - Statistical - Information.asp). Changes in the area of the lake due to water level variations are minor and considered negligible.

Step 3 – Flows into Lake Rotoiti

Daily values of I_{iti} were calculated from $\triangle S_{iti} = I_{iti} + O_{rua} - O_{iti}$ where O_{rua} was calculated in step 1.

O_{iti} was taken from daily averaged values at the Taaheke gauge.

$\triangle S_{iti} = \triangle Z_{iti}. A_{iti}$

$\triangle Z_{iti}$ = daily changes in Lake Level at Okawa Bay (or Okere corrected for drawdown prior to June 2001)

A_{iti} = Area of Lake Rotoiti = 3370ha (from www.envbop.govt.nz/water/Lakes/Lakes - Statistical - Information.asp). Changes in the area of the lake due to water level variations are minor and considered negligible.

Step 4 – Setting up 2 Lake Mike-11 model

The Mike-11 model of the Ohau Channel was extended upstream with dummy sections to represent Lake Rotorua. To correctly represent the area of Lake Rotorua a channel was made in the Mike-11 model 8.047 km long by 10km wide.

Similarly the model was extended downstream with dummy sections representing Lake Rotoiti by a channel 3.370 km long with sections 10 km wide.

Downstream of Lake Rotoiti an Okere Channel branch was added to the Mike-11 model. Cross-sections were taken from the bedrock excavation design levels shown on the Murray North 1978 survey.

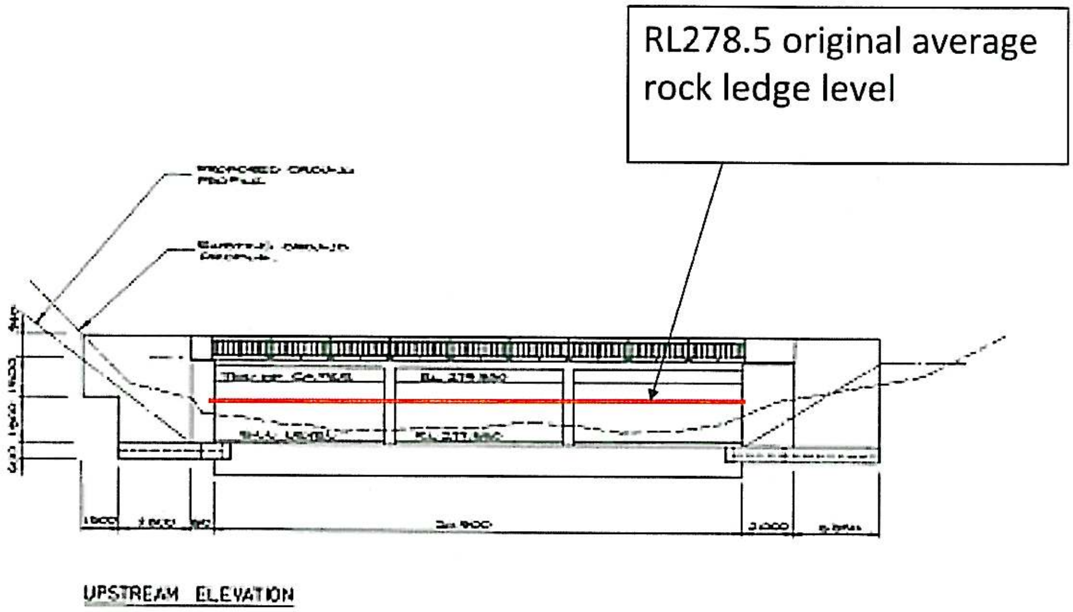
The cross-sections in the lower portion of the Okere Channel are not consistent in their cross-sectional area or conveyance. To improve model stability the more restrictive sections were removed. Photos from the site show rapid white water flows in this section implying that backwater effects are unlikely and hence inaccuracies in survey here are unlikely to affect model results. However if any options for alternatives to the current Okere Gate structure/operation were to proceed to detailed design it is recommended that full survey and modelling be undertaken to confirm this assumption. Any impacts of the new Ohau diversion wall (likely to be minor) would also need to be surveyed and modelled.

Step 5 – Option 1 – Replicating pre-excavation bed levels with uniform weir.

There have been some calls from the community to remove the Okere gates structure and return the system to its 'natural state'. As shown in the Murray North design plans (refer Appendix C) construction of the Okere gate structure also involved excavation of bed rock. Examination of the survey cross-sections show that prior to this excavation, the outflow from Lake Rotoiti was controlled by a rock ledge about 35 m downstream of the present gate structure (Peg No 2/80). Detailed levels are not given on the Murray North drawings but by scaling off the drawings it can be approximated that this rock ledge formed a natural weir about 20 m wide at about RL 278.5 m.

An option to replicate this is to insert stoplogs into the Gate structure themselves up to RL 278.5 m. The radial gates could be either removed or left fully open. This was modelled in Mike-11 by placing a 20 m wide weir into the model on the Okere Channel branch set at RL 278.5 m.

Drawing 2 – Option 1 Schematic



RL278.5 original average rock ledge level

Step 6 – Option 2 – Replacing gates with a stepped weir

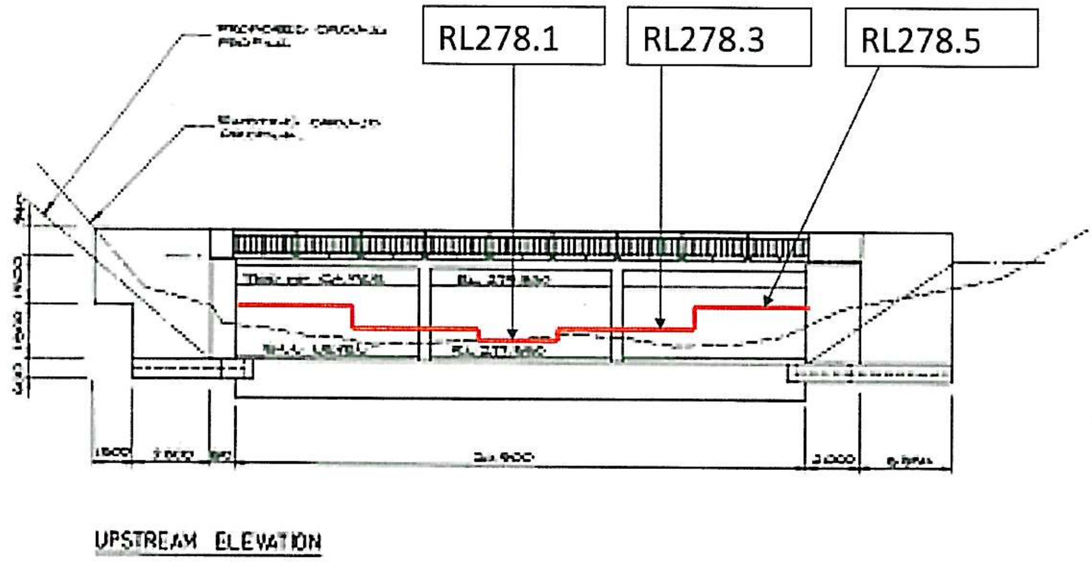
A second option modelled in Mike-11 was replacing the current gate structure with a stepped weir. A stepped weir has different lengths at different levels. The 'advantage' of a stepped weir is that it allow a reasonable flow depth over the lowest section of weir for low flows, but still utilises the full width of channel available for high flows.

The weir trialled in Mike-11 had the configuration set out in Table 4.

Table 4 – Option 2 – Stepped weir details

Level (m RL)	Width (m)	Total width (m)
278.1	3	3
278.3	12	15
278.5	5	20

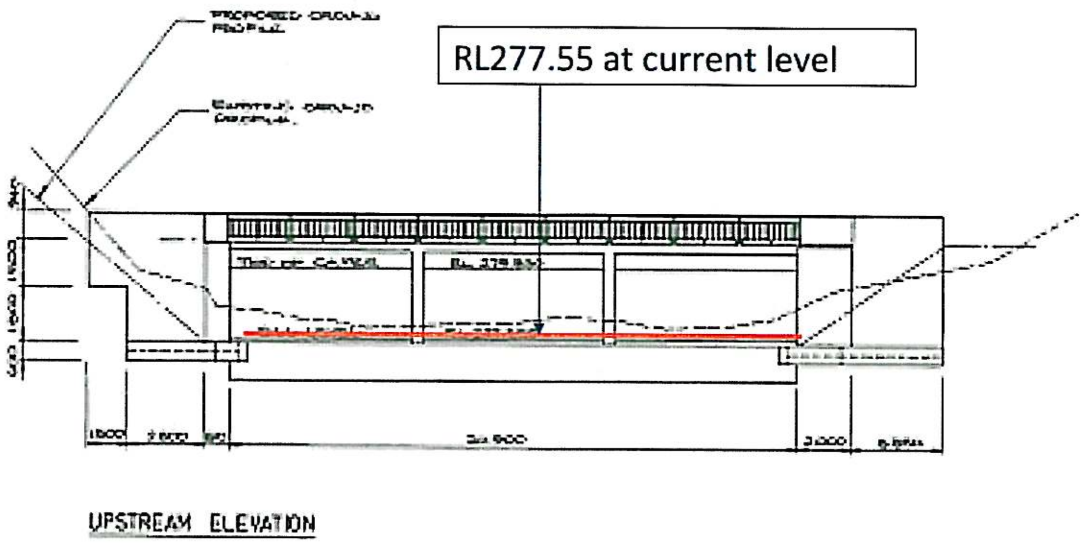
Drawing 3 – Option 2 Schematic



Step 7 – Option 3 – Keeping the radial gates fully open

A third option modelled in Mike-11 was keeping the gates permanently fully open. The sill level of the gates as shown on the Murray North design plans is RL 277.55. If the gates are fully opened this sill would effectively operate as a weir. This option was therefore modelled in Mike-11 by a 20m wide weir at RL 277.55 m. When modelling this option it was found that the level of Lake Rotoiti was lowered significantly (refer the following results section for more details). It was found that this lead to modelling instabilities at the downstream end of the Ohau Channel branch. These instabilities occurred at chainage 12250 and referring to Phil Wallace's Draft report Hydraulic Modelling of Ohau Channel 2002 this represents the very shallow water over the delta formed by the Ohau Channel as it enters Lake Rotoiti. With lower Lake Rotoiti lake levels the water in this section became even shallower causing numerical instabilities. In reality if Lake Rotoiti levels did reduce significantly the channel through the delta would respond and naturally cut itself down lower too. Hence for option 3 the section at chainage 12250 on the Ohau Channel was lowered by 1m.

Drawing 3 – Option 3 Schematic



Methodology uncertainties

The results of the modelling are discussed in the following sections. However it is prudent first to discuss inherent uncertainties in the assumptions and methodology that was employed.

i) Lake levels used to calculate the inflows to the lakes are subject to the following factors:
   a) Wind waves and run-up
   b) Drawdown assumptions at the Okere Gates gauge (refer 2.2.1)
   c) Datum level changes (refer 2.2.2)

ii) Outflows from Lake Rotorua via the Ohau Channel are dependent on:
   a) Lake levels (see above)
   b) Survey of cross-sections (dates from 2002 – refer 2.1.3)
   c) Stoplog weir was input to model from design drawings not as-built survey (refer 2.1.3)
   d) Calibration factors in model for weir and cross-sections (refer Phil Wallace's report)

iii) Historic outflows from Lake Rotoiti were taken from Taaheke which is about 1 km downstream of Okere and includes an extra 2 km^2 of catchment, and will hence tend to overestimate flow from Lake Rotoiti. These outflows are also dependent on the accuracy of NIWA's rating curve at Taaheke.

iv) Modelled outflows over alternative structures at Okere have the following uncertainties
   a) They are theoretical flows and not calibrated. (Figure 11 of the Titchmarsh report by way of example, shows the difference between theoretical and observed flows for the current gate structure)
   b) No reliable survey of channel downstream of gate structure is available to confirm the assumption that backwater effects are not applicable (refer 3.2)
   c) Uncertainties as to what level a weir should be set at to replicate the pre-gate conditions, due to uncertainties around historic (1978) survey data (refer 3.2)
   d) The sill level for the gates permanently open option were taken from design drawings not surveyed as-builts.

v) The Ohau Channel diversion wall has only just been recently constructed (2007/2008 – completed July 2008) and was therefore not included in the modelling of the period 1998 to 2007 analysed in this study. (Impacts from this wall however are likely to be minor).

Despite all of the above factors, many of them apply to both the options and the historic record. Any relative differences will be consistent between the existing gate and alternative outlet models. Hence there can be some reasonable confidence in the results, especially in the broad trends and relative differences between the options.

5. Results/Discussion

The objective of this study is to model alternative structures to the current Okere gates and compare their impacts on:

i) Lake levels of Lake Rotoiti
ii) Lake levels of Lake Rotorua
iii) Outflows into the Kaituna River

Results for the above levels and flows are compared for the 10 year period 1998 to 2007 inclusive for;

i) Historic recorded values for the current gate operating regime
ii) Option 1 – Levels and flows that would have occurred in this 10 year period if the gate had been replaced by a uniform weir at RL 278.5 m (this being the approximate level of the natural rock weir that existed prior to excavation for construction of the gate structure)
iii) Option 2 – A stepped weir with levels as per Table 4 that targets a mean lake level for Lake Rotoiti – similar to the current gate operating regime.
iv) Option 3 – The gates left permanently open, with water discharging over the current sill of the gates at RL 277.55 m.

5.1 Impacts on Lake Rotoiti lake levels

Graph 3 in Appendix D shows the lake levels in Lake Rotoiti. This shows that the weirs trialled in the 3 options give a much wider range of lake levels than the current gate operating regime which has effectively kept lake levels between around RL 279.1 to 279.4 m for the 10 year period 1998 to 2007. In contrast the levels for option 1 range approximately from RL 279.1 to 279.8 m, for option 2 they range from RL 278.8 to 279.6 m, and for option 3 they range from RL 278.2 to 278.9. The difference between options 1, 2 and 3 is predominantly governed by the level of the respective weirs – RL 278.5 m for option 1 stepped between RL 278.1 m and 278.5 m for option 2 and RL 277.55 m for option 3.

Table R1 in Appendix D shows the percentage of time that each option keeps the lake level within different height bands. EBOP's flood warning manual (July 2008) gives a minimum and maximum level for Lake Rotoiti of RL 278.856 and RL 279.406 m respectively. It can be seen that between 1998 and 2007 the actual level was kept between RL 278.9 m and 279.4 m. 100% of the time, but for options 1 and 2 this figure is reduced to 69% and 92 % respectively. For option 3 the lake level is almost always below the current minimum level of RL 278.856 m. Bar Chart 1 in Appendix D presents this table more visually and shows how options 1, 2 and 3 have levels spread over a much wider range of values.

The aim of option 1 was to provide a weir at the approximate level of the natural rock weir that existed prior to excavation for construction of the gate structure. Figures 2 and 3 from a report by NIWA (Water Level Fluctuations in Lake Rotoiti and their Ecological Implications – 2003) show the Lake Rotoiti water level since 1905 and are included in Appendix E. This shows that prior to the gate operation fluctuations of lake levels were much greater than at present. It also shows that the lake levels were generally higher than the current target level. The trends shown in Graph 3 for option 1 are consistent with these historic pre-gate lake levels.

In order for a weir structure to provide a narrower range of lake levels, similar to that maintained with the current gate operating regime, the weir structure would need to be considerably longer than 20 m. This would require locating the weir upstream from the present gate structure to where the Okere Channel is wider. However, additional assessment would be required to confirm that at such a location the weir would still operate as a free overflow and not backwater up from the downstream channel flow. Alternatively a longer weir at the current gate location could be obtained by zig-zagging it across the channel.

5.2 Impacts on outflows to the Kaituna River

Graph 4 in Appendix D shows the outflows to the Kaituna River. It shows that while the results are highly similar for the three options, these are very different from the historic gauged flows at Taaheke. In general the outflows for the three options are less extreme. The maximum flow for the first two options is around 43 m^3/s and 45 m^3/s for option 3 compared to the historic maximum gauged flow of 46 m^3/s. The minimum for the three options is around 11 to 12 m^3/s compared to 9 m^3/s for the historic gauged readings.

Table R2 in Appendix D shows the percentage time that different flow bands are achieved for each option. It can be seen that the range 13 to 26 m^3/s, which is suitable for rafting on the Kaituna River downstream of Okere, was obtained 75% of the time under the current radial gate structure. The weir structures result in this flow range around 77 to 80% of the time. This table is presented visually in Bar chart 2 in Appendix D

The reason that flows are more peaked with the current operating regime is related to lake level control. With the current narrow operating regime of levels there is little scope for storage within the lake and hence attenuation. The radial gate openings are modified frequently (sometimes daily) to control level by modifying flow.

The weir options by contrast have a much wider range of lake levels, giving more additional storage in the lake and more attenuation of flows, resulting in less variation in flows.

5.3 Impacts on Lake Rotorua lake levels

Graph 5 in Appendix D shows that lake levels for Rotorua are similar for both the historic data and options 1 and 2 but are slightly lower for option 3. EBOP's flood warning manual (July 2008) gives a minimum and maximum level for Lake Rotorua of RL 279.5 and RL 280.11 m respectively. From Table R3 in Appendix D It can be seen that between 1998 and 2007 the actual level was kept between RL 279.5 and 280.1 around 97 to 99% of the time for both the historic gauged data and the three options.

Further analysis of the data in Table R3 and Bar Chart 3 in Appendix D shows levels more frequently in higher bands for option 1. It was found that option 1 gives an average lake level about 25 mm higher than that for the historic record or option 2. Option 3 has an average lake level around 65mm lower than the historic record.

The reason for this is because option 1 gives around 200 mm higher levels in Lake Rotoiti than the historic gauge or option 2. The backwater effect from this affects the efficiency of the stoplog weir in the Ohau Channel. This has a small but measurable effect on levels in Lake Rotorua (about 25mm). Similarly option 3 gives around around 700 mm lower levels in Lake Rotoiti than the historic gauge. The backwater effect of this lowers the average lake Rotorua level by around 65mm.

Lowering the level of the stoplog weir in the Okere Channel in option 1 would result in an equivalent drop in Lake Rotoiti levels and this would decrease the 25mm impact on Lake Rotorua levels. (Although modelling hasn't been undertaken to confirm this it seems likely that a reduction in weir level in option 1 of around 200mm to RL 278.3 m would be required to remove this 25mm impact on Lake Rotorua.)

5.4 Summary of results

i) The range and variability of lake levels in Lake Rotoiti **increase** significantly if the current gate operating regime is replaced with a weir – Refer Appendix D, Graph 3.

ii) The average level of Lake Rotoiti with a weir outlet is dependent on the level the weir is set at. Option 1 therefore gives a significantly higher average Lake Rotoiti level than option 2, or the historic gauged levels - Refer Appendix D, Graph 3. Similarly option 3 gives a significantly lower average Lake Rotoiti level

iii) The range and variability of outflows from Lake Rotoiti to the Kaituna River **decrease** significantly if the existing control gate is replaced with a weir structure. Refer Appendix D, Graph 4.

iv) If average levels in Lake Rotoiti are increased significantly (such as by 200 mm in option 1) this causes a small but measureable (about 25 mm) increase in the average level of Lake Rotorua (Refer Appendix D, Graph 5). Similarly a significant (700mm) lowering of average Lake Rotoiti levels in option 3 gives around a 65mm decrease in the average level of Lake Rotorua.

6. Discussion of impacts

6.1 Consultation

A letter was sent out to stakeholders on the 9th February 2009 asking what priorities they have for any future control structure and its operation such as controlling lake levels and river flows or returning to a more natural regime. A copy of the letter and the list of stakeholders it was sent to is included in Appendix F. Responses received are also included in Appendix F.

Responses received so far include:

Joe Tuhuna	–	Would like to see return of beaches around Lake Rotoiti
WBOPDC	–	Concerned about impacts on flooding of Kaituna and dependent catchments in Te Puke / Papamoa areas
Te Arawa Lakes Trust	–	Meeting held on 2nd March 2009. EBOP attended. Draft minutes of meeting included in Appendix F
Lakes Rotorua and Rotoiti Ratepayers Association	–	EBOP attended the meeting and explained the purpose of the Okere Gate review in light of the consent renewal deadline of 30 June 2010. Letter received from Association dated 5 May 2009 and included in Appendix F.
Fish & Game New Zealand	–	Letter received from F& G dated 9 April 2009 and included in Appendix F.

6.2 Positive and negative impacts

The potential positive and negative impacts of both the current gate operating regime and the three options are discussed below. Bearing in mind the scope and objectives of this study and the early stages of consultation this discussion is mainly of a qualitative nature. It may need to be refined when further consultation has been undertaken. Further modelling or separate studies may also be required if particular issues/concerns need a more definitive discussion.

Stakeholder – Bay of Plenty Energy (BOPE) - Future hydro generation		
	Benefits	**Negative Impacts**
Status Quo	• Flow can be controlled • Flows could be discharged at peak demand periods • Gates potentially give BOPE the ability to control storage volume in Lake Rotoiti (although this is limited by the current narrow target range for levels)	• Greater fluctuation of flows from day to day
Option 1	• More uniform flow from day to day	• No ability to control flow or storage in Lake Rotoiti
Option 2	• As per option 1	• As per option 1
Option 3	• As per option 1	• As per option 1

Stakeholder – Cultural Values		
	Benefits	**Negative Impacts**
Status Quo	• More able to maintain minimum flows in Kaituna River in drought times	• Manmade controls preventing nature taking its course • Ecological impacts • Lack of depth range at edges result in greater weed growth and lack of beaches
Option 1	• More natural regime for Lake Rotoiti and Kaituna River	• Unable to maintain minimum flows in Kaituna River in drought times
Option 2	• As per option 1	• As per option 1
Option 3	• As per option 1	• As per option 1

Stakeholder – EBOP Flood Management of Lakes Rotoiti and Rotorua		
	Benefits	**Negative Impacts**
Status Quo	• Ability to control Kaituna River flows in flood emergencies • Ability to control Lake Rotoiti levels	• Cost of maintenance of structure • Cost of monitoring lake levels and adjusting gates to suit. • Political pressure. Trying to reconcile demands from different groups that are in conflict with each other.
Option 1	• Greatly reduced operating/maintenance or monitoring expenses • No political pressure or perception that EBOP is favouring one group over another. Letting nature take its course • If gates are retained but left fully opened EBOP will retain ability	• No ability to control day to day Kaituna River flows • No ability to control Lake Rotoiti levels

	to restrict Kaituna flows in flooding or drowning emergencies	
Option 2	• As per option 1 but without ability to close gate in emergency	• As per option 1
Option 3	• As per option 1	• As per option 1

Stakeholder – Ecological Factors		
	Benefits	Negative Impacts
Status Quo	• Can maintain a minimum flow of at least 7.9 m^3/s in Kaituna River that is required by biota	• Refer Niwa Report "Water Level fluctuations in Lake Rotoiti and their ecological implications (2003) – This states that "A very stable level regime is likely to result in a narrower and less diverse band of lake margin wetlands than an unstable one with corresponding impacts on the invertebrates, fish and birds that exploit the zone". • Larger range of flows in upper Kaituna River may continue any erosion problems that currently occur
Option 1	• Larger range of Lake Rotoiti levels should result in "a wider and more diverse band of lake margin wetland"	• Cannot maintain minimum flow of 7.9 m^3/s in Kaituna River as required by biota (however in 10 year simulation flow was always >10 m^3/s anyway)
Option 2	• As per option 1	• As per option 1
Option 3	• As per option 1	• As per option 1

Stakeholder – Kaituna River Scheme (managed by EBOP's Rivers and Drainage Group)		
	Benefits	Negative Impacts
Status Quo	• Potential control of Kaituna flows in flood emergencies	• Increased daily variation in flows increasing erosion. (Flow from Okere as % of total flow in Kaituna in lower catchment is small however)
Option 1	• Reduced daily variation in discharges reduces erosion along downstream banks of Kaituna River.	• No potential control of Kaituna in flood flows. As discussed by Titchmarsh (p42) the Okere Falls contributed only 55 m^3/s of the 376 m^3/s 1962 flood at Te Matai on the Lower Kaituna. However this may still be enough to be the difference between stopbank overtopping or not
Option 2	• As per option 1	• As per option 1
Option 3	• As per option 1	• As per option 1

Stakeholder – Lake users		
	Benefits	Negative Impacts
Status Quo	• Boat ramps are accessible at all times • No unsightly mudflats	• Lack of depth range at edges result in greater weed growth and lack of beaches
Option 1	• Less weed growth and more beaches	• Nil

	• More beaches will provide smelt spawning areas which is beneficial to Trout fishery	
Option 2	• As per option 1	• Boat ramps may not be accessible when lake levels are low
Option 3	• As per option 1	• Permanent lowering of Lake Rotoiti lake levels will cause significant boat ramp accessibility issues.

Stakeholder – Property owners adjacent to Lake Rotoiti		
	Benefits	**Negative Impacts**
Status Quo	• Narrow range of lake levels means boat sheds can be used most days. • No unsightly mudflats. • No flooding issues or inundation of septic tanks	• Lack of depth range at edges result in greater weed growth and lack of beaches.
Option 1	• Less weed growth and more beaches.	• Raised water levels may cause flooding concerns. Potential inundation of septic tanks. Variable lake levels private boat ramps may not always be usable.
Option 2	• As per option 1	• Variable lake levels means private boat ramps may not always be usable. • Unsightly mudflats at times of low lake levels
Option 3	• As per option 1	• Permanent lowering of Lake Rotoiti lake levels will cause significant private boat ramp accessibility issues. • Unsightly mudflats at times of low lake levels

Stakeholder – Property owners adjacent to Lake Rotorua		
	Benefits	**Negative Impacts**
Status Quo	• Nil	• Nil
Option 1	• Nil	• Slightly raised water levels (~25 mm) may be a minor concern for some.
Option 2	• Nil	• Nil
Option 3	• Nil	• Slightly lowered water levels (~65mm) may be a minor concern for some

Stakeholder – Rafting companies		
	Benefits	**Negative Impacts**
Status Quo	• Have potential to control flows to required limits (13 to 26 m^3/s) to suit rafting days (e.g Sundays) and times (e.g. 9am to 5pm). • EBOP can warn rafting companies prior to any changes in flow.	• Current regime leads to fewer days within required range than options 1 and 2.
Option 1	• More days within required range of flows (15 to 25 m^3/s).	• No potential to control flows on required days/times - at nature's mercy.

		• No potential to stop flows in case of accidents/drownings. • No warnings about changes in flow (although with lake storage changes in flow over weir will tend to be gradual)
Option 2	• As per option 1.	• As per option 1.
Option 3	• As per option 1.	• As per option 1 but radial gates can may still be closed to stop flows in emergencies

Stakeholder – RDC		
	Benefits	**Negative Impacts**
Status Quo	• Narrow range of Lake Rotoiti levels means boat ramps do not need to extend into lake for dry periods	• Lack of depth range at edges result in greater weed growth and lack of beaches.
Option 1	• Less weed growth and more beaches on Lake Rotoiti.	• Increased lake levels in wet periods, may cause localised flooding issues around Lake Rotoiti and potential inundation of septic tanks. Additionally very small increase in Lake Rotorua levels may cause minor stormwater pipework discharge capacity reductions.
Option 2	• Less weed growth and more beaches on Lake Rotoiti.	• Increased lake levels in wet periods, may cause localised flooding issues around Lake Rotoiti and potential inundation of septic tanks. • Boat ramps may need to be extended to cover periods of low levels in Lake Rotoiti.
Option 3	• Less weed growth and more beaches on Lake Rotoiti. • Permanent lowered lake levels may reduce localised flooding issues around Lake Rotoiti and potential inundation of septic tanks.	• Permanent lowering of Lake Rotoiti lake levels will cause significant boat ramp accessibility issues. Boat ramps will need to be extended.

Stakeholder – WBOPDC		
	Benefits	**Negative Impacts**
Status Quo	• Potential control of Kaituna flows in flood emergencies	• Greater daily variation in flows and associated increased bank erosion potential
Option 1	• More uniform day to day flow and less bank erosion	• No control of Kaituna flows in flood emergences
Option 2	• As per option 1	• As per option 1
Option 3	• As per option 1	• As per option 1

7. Further Alternative Options

This report has considered three options. All options result in a larger range of Lake Rotoiti levels than the current consented gate operating regime, with a corresponding decrease in range of flows in the Kaituna River (refer section 4).

Other alternatives that may wish to be considered are:

i) Maintain the manual operating regime of the gates but with a larger target lake level range.

ii) Maintain the manual operating regime of the gates but with another stakeholder such as EBOP's Lakes Management group or some other agency such as Bay of Plenty Energy (for their proposed hydropower scheme) or river rafting companies taking control. (However very careful consultation and rules would need to be put into place to make sure other stakeholders were not disadvantaged)

iii) Optimise gate operations by developing a flow forecasting model that provides early warnings on expected flows and required gate operations. (This could be incorporated into either a manual or automated algorithm operating regime).

iv) If the wish is to replace the gates with a weir, but to maintain a narrow range of Lake levels then a weir considerably wider than 20 m is required. This would require either zig-zagging the weir or for it to be placed further upstream in the Okere arm. However if the weir was placed further upstream in the Okere arm it is likely that it may then be subject to backwater effects from flow constrictions downstream of the weir.

8. Summary / Recommendations

This report has quantitatively described the impacts of different structures on Lake Rotoiti and Lake Rotorua levels and Kaituna River flows. It has also qualitatively described potential impacts this may have on various factors/groups (eg ecology, boat users etc).

Full consultation is just commencing and it is therefore not feasible to recommend the status quo or any particular option.

It is recommended that the results of this study be used to help inform the consultation process between EBOP and other stakeholders.

It is suggested that if an alternative to the current gate operation is the preferred outcome from the consultation process then the gate structure should not be removed but instead retained, with the gates fully open. In this way there is still the ability to close the gates in the event of a flooding or drowning type emergency.

If the preferred outcome from consultation is an alternative structure to the current gate operation, accurate survey of the Okere Channel and the Ohau Diversion Channel within Lake Rotoiti will be required to refine the modelling and calibration.