MEMORANDUM

Bay of Plenty REGIONAL COUNCIL

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From: Peter West
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File Ref:

Copy To: Peter Blackwood

Subject: **Lake Okareka; Modelling of Lake Level Management Guideline Options**

Executive Summary

Water balance modelling has been carried out to evaluate the performance of two potential lake level management guidelines for Lake Ōkāreka.

The model was run against two time-history scenarios: a long-term recorded rainfall series from June 1991 to May 2018; and a specific series covering the recent period from February 2017 to May 2018.

The model was also run against a range of synthetically determined design rainfall series relating to the 1% AEP (100 year) rainfall event under various climate change scenarios.

Results for the various scenarios are produced as: time/lake-level graphs; level/duration curves for Lake Ōkāreka; flow/duration curves for Waitangi Stream; tables of maximum and minimum lake levels; and tables of longest periods for minimum flow conditions.

Background

Lake Ōkāreka has no natural surface-flow outlet. Natural drainage is via under-ground seepage. Following high lake levels in the 1960's a pipeline was constructed by the then Rotorua County Council to augment lake outflows. In 2001 BOPRC gained resource consent to operate the pipeline. Conditions of this consent required the use of an operation guideline for managing the pipeline's discharge.

In 2015 part of the 1965 pipeline was replaced and upgraded, increasing the system's discharge capacity. During the winter and spring of 2017 high rainfall lead to very high lake levels requiring additional pumping to avoid damage to houses etc at the lake.

In order to optimise the performance of the lake management systems (the pipleline and pumping), BOPRC is currently reviewing the operation guideline. This report describes water balance modelling undertaken to inform that review.

Method

The BOPRC water balance model for Lake Ōkāreka was run against a range of scenarios:

- A long term time-history scenario with rainfall data from 1 June 1991 to 30 May 2018.
- A specific time-history scenario with rainfall data from 1 February 2017 to 30 May 2018.
- Several climate change scenarios where rainfall was applied from synthetically generated "design storms" at the 1% AEP magnitude[1]. These storms are "nested" in duration out to 500 days. The climate change scenarios were: present day; 2040; and 2090 horizons. The 2040 and 2090 scenarios were run at both mid-range and high-range scenarios in accordance with guidance from MfE (method details on how these storms were generated can be found in West 2017). The lake level starting condition for these scenarios was 353.78mRL: the median lake level in the long-term historical record (1991 to 2018).

Model relationship between rainfall and lake inflows

The water balance model was developed for BOPRC in 2011 and revised in 2013 (see references). One key item of the model is a relationship between rainfall and lake net-inflows. Following the review in 2013 the relationship is:

Lake Inflow (L/s) = 54 x Rainfall rate (mm/day) – 100 x Cosine((Julian day – 55)x 2π /365) – 20

For practical purposes, in the model calculations the rainfall rate is "smoothed" over ten days by a rolling-mean method.

Raingauge Location – inference from historical data

The rainfall rate in the above relationship is the rate recorded at the "Blakely" raingauge at 9 Acacia Road. This is important because rainfall can vary significantly between sites within the catchment. It appears that the previous raingauge location on Wattle Grove received enough additional rainfall that some long-term lake (net) inflows inferred by the model in the period prior to 1991, when the gauge was moved, are more than the pipeline's estimated capacity at that time (i.e. the model "predicts" incorrectly that the lake would have risen uncontrollably through the 1970's and 80's).

I've interpreted this to mean that the Wattle Grove raingauge location received significantly more rainfall than the Acacia Road site and so the model (which is calibrated to the Acacia Road raingauge) is much less helpful for interpreting the rainfall record at Ōkāreka prior to 1991.

However an alternative interpretation is that the pre-1990 period was slightly wetter, but that underground seepages were higher and therefore lake levels were maintained. It is likely that both ideas are at play. The rate of natural seepage has clearly declined since pre 1960 when no pipeline was necessary – it may be an ongoing decline. Either way the model would not be reliable for interpreting rainfall for that period.

The significance of a possible ongoing decline in the natural under-ground seepage flow from the lake should be considered when designing for the long term. The calibrated model relationship suggests that effective seepage is currently about 20 L/s. This works out to be the equivalent of approximately an additional 70mm on maximum lake levels in the high-range 2090 1% AEP climate change scenario. However it must be stressed that there are a number of reasons why the model could not reliably be used in this way. The results in this report do not include the (additional) consideration of a potential future reduction in sub-surface seepage from the lake.

Stream Flows and Spring Flows

[1] 1% Annual Exceedance Probability (AEP) equates to a storm magnitude that is only exceeded over the subject catchment once in 100 years on average.

Waitangi Stream stage has been recorded automatically only since July 31 2017 and the site is rated for flow estimation. However an estimate is presented here for longer term stream flow into Lake Tarawera for the purposes of assessing potential impacts on ecology and recreational values there - without much useful data, this estimate of historic conditions is therefore fairly crude:

This estimate has been based on comparison of the stream flow to pipeline flow especially during pipeline shut-down operations. For the scenarios modelled here, spring flow contribution to the Waitangi Stream has been approximated by a sinusoidal function with minimum (zero flow) on the 55^{th} day of the year (in keeping with the fitted model seasonal factor) and a maximum of 60 litres per second on the 237^{th} day. This is a rather crude method, limited by the available data and will not replicate the stream's response to rainfall, however it should provide reasonable long-term average results for assessing the ecological impacts of the management guidelines.

Operation Guidelines Tested

The existing operation guideline is expressed in the following table. The guideline indicates what the pipeline discharge should be, depending on lake level and season. For this guideline "Summer" is October through March inclusive; "Winter" is April through September.
Note that the maximum discharge in this table is 239 L/s. Our current estimate of actual pipeline capacity that existed at the time of consenting in 2001 is 270 L/s , which would have been the actual fully-open pipeline discharge up until the upgrade works in 2015 (when capacity increased and staff became required to actively limit discharge to the consent limits). I believe capacity was wrongly estimated in 2001 at 239 L/s – and this became the consent maximum discharge condition. The modelling reported here has been carried out with a value of 239 L/s to assess the result of operating strictly to the existing (consented) guideline.

Table 1: Existing Lake Level Operation Guideline

Lake Level (up to)		Pipeline Discharge
Summer	Winter	L/s
353	353	0
353.65	353.55	0
353.75	353.65	50
353.8	353.75	150
354.5	354.5	239
400	400	239

The two tables below express two potential operation guidelines currently being considered by BOPRC.

Table 2: Proposed Lake Level Operation Guideline (Proposed 1)

Lake Level (up to) All year	Pipeline Discharge L/s
353.5	0
353.55	100
353.65	170
353.75	240
353.85	300
353.95	380
354.05	460
400	500

Table 3: Alternative Lake Level Operation Guideline (Proposed 2)

Lake Level (up to) All year	Pipeline Discharge L/s
353.5	0
353.65	100
353.75	170
353.85	290
353.95	380
354.05	460
400	500

Results

Table 4 below shows the maximum and minimum lake levels from the two different time history scenarios, and from the three operation guidelines. It also shows the observed lake level conditions. In addition the table shows the percentage of days outside of the target lake level range. This data is also presented in several graphs in the appendix to this memo.

Table 4: Time-history scenarios – maximum and minimum lake levels; and percentage of time outside of the target range

Period Feb 2017 to May 2018	Min lake level	% below target	Max lake level	% above target
Observed Lake Level	353.52	0	354.56	82
Existing guideline	353.56	0	355.03	91
Proposed Guideline 1	353.51	0	354.11	29
Proposed Guideline 2	353.52	0	354.13	32
Period June 1991 to May 2018	min lake level	% below target	Max lake level	% above target
Observed Lake Level	353.28	6	354.56	22
Existing guideline	353.60	0	355.09	54
Proposed Guideline 1	353.36	9	354.10	5
Proposed Guideline 2	353.39	4	354.13	7

Table ***5*** below shows the percentage of time below 100 L/s and percentage of time above 400 L/s for Waitangi Stream flow results for the two time-history periods. The "Observed/inferred stream flow" values are inferred from the lake level and rainfall data along with a seasonal spring-flow contribution as described above. It is important to realise that these are not recorded values and the inference is best considered indicative only.

Table 5: Time-history scenarios – stream flow percentage of time

Period Feb 2017 to May 2018	% below 100 L/s	% above 400 L/s
Observed/inferred stream flow	7.4	30.5
Existing guideline	7.2	0.0
Proposed Guideline 1	0.0	37.5
Proposed Guideline 2	0.0	40.4

Period June 1991 to May 2018	% below 100 L/s	% above 400 L/s
Inferred stream flow	18.2	12.9
Existing guideline	8.8	0.0
Proposed Guideline 1	9.6	9.8
Proposed Guideline 2	4.1	14.5

Table 6 and Table 7 below show the longest periods (and when) in the time history scenarios for low-flow conditions in the stream and the pipeline. Only the longer period is shown (from 1991 to present). The shorter more recent period was a high rainfall period not suitable for inspecting low flow conditions.

Table 6: Time-history scenarios – Longest period with stream flow less than 100 L/s

Period June 1991 to May 2018	Number of days	Date of last day
Inferred stream flow	68	15/04/2013
Existing guideline	106	21/04/2008
Proposed Guideline 1	93	22/04/2013
Proposed Guideline 2	72	22/04/2013

Table 7:Time-history scenarios – Longest period with pipeline flow at zero L/s

Period June 1991 to May 2018	Number of days	Date of last day
Inferred pipeline flow	20	5/02/1998
Existing guideline	21	3/04/2000
Proposed Guideline 1	93	22/04/2013
Proposed Guideline 2	72	22/04/2013

Table 8 below shows the maximum lake levels resulting for each of the climate change scenarios at 1% AEP magnitude. The cells have been coloured to show orange if the lake level exceeds the building freeboard level (354.5 mRL); and red if the lake level exceeds this and the lowest existing dwelling's floor level (354.94 mRL at 67 Acacia Road). Please note: these numbers are not provided for the purposes of setting building floor levels. Graphs of these model outputs over time are shown in the appendix.

The level shown here for "building freeboard level" is BOPRC's previously advised building floor level minus the required freeboard to account for waves, estimate imprecision, and building tolerances.

Table 8: Design Scenarios – Maximum 1% AEP Lake Level

	Present day	2040 mid-range	2040 high-range	2090 mid-range	2090 high-range
Existing guideline	**354.98**	**355.06**	**355.42**	**355.34**	**356.51**
Proposed Guideline 1	**354.34**	**354.38**	**354.50**	**354.48**	**354.83**
Proposed Guideline 2	**354.33**	**354.37**	**354.51**	**354.47**	**354.84**

References:

West P, December 2008, *Lake Ōkāreka Outlet Structures; High Lake Levels; Pipeline Capacity*, BOPRC Memorandum to Mangala Wickramanayake BOPRC Engineering Manager.

West P, January 2012, *Lake Ōkāreka Outlet Pipeline; Water Balance Modelling for Pipeline Design*, BOPRC Memorandum to Colin Meadowcroft BOPRC Engineering Manager

West P, March 2013, *Lake Okareka Outlet Pipeline; Review of Operating Guidelines*, BOPRC Memorandum to Clive Tozer Acting Engineering Manager

West P, November 2017, *Lake Okareka; Design of Pipeline Capacity; impacts on Lake Level management,* BOPRC Memorandum to Andy Bruere

New Zealand Ministry for the Environment, *Preparing for Climate Change, a Guideline for Local Government*, MfE pub, no. 891