REPORT

Opuha Water Ltd

Opuha Dam
Annual Dam Safety Inspection 2011

Report prepared for:

Opuha Water Ltd

Report prepared by:

Tonkin & Taylor Ltd

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Executive summary

The Annual Safety Inspection of Opuha Dam for 2011 was undertaken on 28 March 2011. This report incorporates the inspection on that day and a review of the dam's performance for the period between 1 April 2010 and 31 March 2011. The review is undertaken in accordance with the recommendations of NZSOLD (2000).

The inspection and monitoring data for the period suggest that the dam is operating in a satisfactory manner.

A 7.1 Moment Magnitude earthquake occurred at 4:35 am on Saturday 4 September 2010. The epicentre was located near Darfield and the Geological and Nuclear Sciences website indicates that a maximum acceleration of 12%g (0.12g) was recorded in Fairlie during this event.

Opuha Water Limited carried out a post earthquake inspection of the dam on Saturday 4 September 2010 and, based on visual inspection, no effects from the modest shaking were reported at the dam site. However, as outlined in previous correspondence with OWL[1], a noticeable increase in flow was observed in Drain D21 (the Lower H flume, seepage cutoff wall collection drain) immediately after this earthquake, and the recorded flows from D21 continuously exceeded the alert criteria until late February 2011. Recently recorded flows have been below the alert criteria.

A 6.3 Moment Magnitude earthquake occurred at 12:51 pm on Tuesday 22 February 2011. The epicentre was located 10 km south east of Christchurch City and the Geological and Nuclear Sciences website indicates that a maximum acceleration of 2.2%g (0.022g) was recorded in Fairlie during this event. Opuha Water Limited carried out a post earthquake inspection of the dam on Tuesday 22 February and no effects from the modest shaking were reported in the Fairlie area. The recorded flows from Drain D21 did not indicate any response in flow to this earthquake.

The left hand side conduit anchor block AB2 stressed anchor failed during a proof load test on 24 June 2010. A temporary repair has subsequently been carried out. Preliminary design for a mass concrete overlay has been completed and detailed design of a permanent solution is pending approval by OWL. It is important that this work is completed soon.

The service spillway operated over the 2010-11 New Year period and it is unclear how the Obermeyer gates functioned during this event. The Operator is investigating the matter.

There were no other significant operational incidents during the period.

The Annual Safety Inspection report for 2010[2] provided four recommendations. A further eight recommendations were provided as a consequence of the 2009[3] inspection. These have either been actioned or are in the process of being actioned and the current status of these is reported in Section 10.

A further eleven dam safety related recommendations have been made as a consequence of the 2011 annual inspection. These recommendations are as follows:

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[1] Tonkin & Taylor letter to Opuha Water Ltd titled "*Opuha Dam – Drain D21*" dated 18 November 2010. Ref 51137.004.

[2] Tonkin & Taylor; Opuha Water Limited, Opuha Dam, Annual Dam Safety Inspection 2010; May 2010; Reference 51137.004

[3] Tonkin & Taylor; Opuha Water Limited, Opuha Dam, Annual Dam Safety Inspection 2009; May 2009; Reference 51137.002

- Piezometer calibration and maintenance – Hydraulic piezometer gauge calibration factors to be checked and gauge maintenance works to be undertaken. This matter is the subject of an earlier recommendation and the Operator advises that the work will be undertaken in the near future. Pneumatic piezometer leads to be repaired and rehoused.
- Deformation survey – it is suggested that the outstanding deformation survey occurs soon.
- Dive inspection – Confirm requirements and undertake as soon as practical.
- Anchor block AB2 remedial works – Works required to replace the temporary fix to the damaged anchor bar.
- Service spillway gates – Operation of these gates should to be investigated to ensure that the functionality of the gates is well understood and the gates may be operated in the correct manner.
- Service spillway – Remove tree from the true right cut slope.
- Auxiliary spillway – Clear and maintain fuse plug trigger device clay pipes free of debris.
- Left abutment cut benches – Undertake routine maintenance of the cut benches and bench drains to ensure adequate stormwater control is maintained.
- Downstream weir – Scour damage on true right training wall of downstream weir radial gate to be repaired.
- Downstream weir gate – Remove debris from upstream of gate and maintain gate clear of debris.
- Wet spot on Downstream Weir Overflow Embankment – Ongoing visual monitoring by OWL.

Some general suggestions regarding the performance of the dam have also been provided as summarised below:

- Tower gantry crane lifting unit - Consider servicing this unit and obtain the necessary certifications.
- 450 mm diameter bypass line – Confirm status and operating procedure for the bypass valve.
- Consider improvements to the current access to H flumes to enable safer measurement of manual flows.
- Service spillway chute and stilling basin - Ongoing monitoring of sill and chute erosion.
- Access road - Improve the road drainage between the sharp bend and the power station as this currently does not function well.

A prior recommendation of note that is yet to be resolved relates to investigation of seepage flows emerging from the upper part of the embankment close to drain D16. The seepage has been noted in the past and is not excessive but is persistent.

1 Introduction

The 2011 Annual Safety Inspection of the Opuha Dam was undertaken on the 28 March 2011, by Tim Morris and Dominic Fletcher of Tonkin & Taylor (T&T), together with Ken Roberts and Denis McEntyre of Contact Energy (the Operator), Tony McCormick (CEO of Opuha Water Limited, OWL) and the station attendant William Scott (OWL). The weather for the inspection was fine with no cloud cover. Rain had preceded the inspection the previous day and in places the ground surface was wet. The reservoir water level was at 388.8 m RL.

The inspection took approximately 3.5 hours and progressed along the following route:

- True right abutment and Service Spillway approach channel
- Dam crest and exposed area of the upstream face
- Auxiliary Spillway and true left abutment including abutment benches
- Areas of the embankment downstream face
- Powerhouse
- H flume drains
- Service Spillway flip bucket and Service Spillway including Obermeyer gate structures
- Downstream Weir.

This report incorporates the inspection on that day and reviews the performance of the dam in the period from 1 April 2010 to 31 March 2011 in accordance with the recommendations of NZSOLD (2000). Throughout the report recommendations are made *in italics*. In addition, general comments relating to routine maintenance works have also been made. All recommendations and general comments are summarised in Section 10.

This report covers the following:

- The Dam, comprising the embankment crest and slopes
- Dam instrumentation
- The reservoir, including the intake tower
- The service and auxiliary spillways
- The power station and tailrace
- The downstream weir
- Access roads
- Surveillance and monitoring during the period considered including consideration of any operation incidents of note that occurred during this time.

The following summary of events since 2004 provides relevant background information to the dam.

In 2004 SMEC carried out a Comprehensive Safety Review of the dam. Based on the recommendations from this review, the Canterbury Regional Council (ECan) reviewed and modified Consents CRC950567 and CRC950579.1 to include additional monitoring and a requirement for remedial works to the dam. A programme of remedial design and construction for both abutments and the downstream toe was undertaken. The abutment works and toe works were completed in 2005 and 2006 respectively and the works have been signed off with ECan.

1.1 Canterbury earthquakes

A 7.1 Moment Magnitude earthquake occurred at 4:35 am on Saturday 4 September 2010. The epicentre was located near Darfield and the Geological and Nuclear Sciences website indicates that a maximum acceleration of 12%g (0.12g) was recorded in Fairlie during this event.

Opuha Water Limited carried out a post earthquake inspection of the dam on Saturday 4 September 2010 and, based on visual inspection, no effects from the modest shaking were reported at the dam site. However, as outlined in correspondence with OWL[4], a noticeable increase in flow was observed in Drain D21 (the Lower H flume, and dam foundation rock interface collection drain) immediately after this earthquake, and the recorded flows from D21 continuously exceeded the alert criteria until late February 2011. Recently recorded flows have been below the alert criteria.

A 6.3 Moment Magnitude earthquake occurred at 12:51 pm on Tuesday 22 February 2011. The epicentre was located 10 km south east of Christchurch City and the Geological and Nuclear Sciences website indicates that a maximum acceleration of 2.2%g (0.022g) was recorded in Fairlie during this event. Opuha Water Limited carried out a post earthquake inspection of the dam on Tuesday 22 February and no effects from the modest shaking were reported in the Fairlie area.

To place the earthquakes into perspective it is inferred from the project civil works design report[5] that the Operating Basis Earthquake (OBE) peak ground acceleration used for detailed design was 0.16 g. The acceleration measured in Fairlie in September 2010 was 75 % of the OBE design value. However, due to local amplification effects accelerations near the top of the embankment may have been in excess of 0.12g.

[4] Tonkin & Taylor letter to Opuha Water Ltd titled "*Opuha Dam – Drain D21*" dated 18 November 2010. Ref 51137.004.

[5] Tonkin and Taylor; Opuha Dam Project Design Report for Civil Works Contract undertaked by Doug Hood Ltd; May 1999; T&T reference 13909.

2 Dam instrumentation

2.1 Overview

This section reviews the data for the dam instrumentation for the period 1 April 2010 to 31 March 2011. The layout of the dam instrumentation is presented in Figure 2.1 below. In general, the dam and spillway instrumentation continues to operate satisfactorily.

The instrumentation consists of a series of:

- Drains, including H Flumes with water level recorders for flow measurements from selected drains
- Hydraulic piezometers with gauges in the power house
- Pneumatic piezometers located under the Service Spillway and read when the Service Spillway operates
- Standpipes
- Rain gauge
- Deformation surveys – not undertaken in this reporting period.

The surveillance regime was recently reviewed and updated to reflect current dam performance monitoring requirements[6]. The alarm criteria have been separated into two cumulative level criteria, initial Alert Levels and secondary Trigger Levels, each requiring specific response actions. The intent of each of these criteria is as follows:

- Alert Level – Where recorded data exceeds the normal operational levels requiring further review of observed dam performance.
- Trigger Level – Where recorded data significantly exceeds normal operation and/or design performance levels such that urgent action is required.

[6] Tonkin & Taylor report to Opuha Water Limited titled "*OPUHA DAM: Dam Surveillance and Monitoring Plan 2010*" dated September 2010.

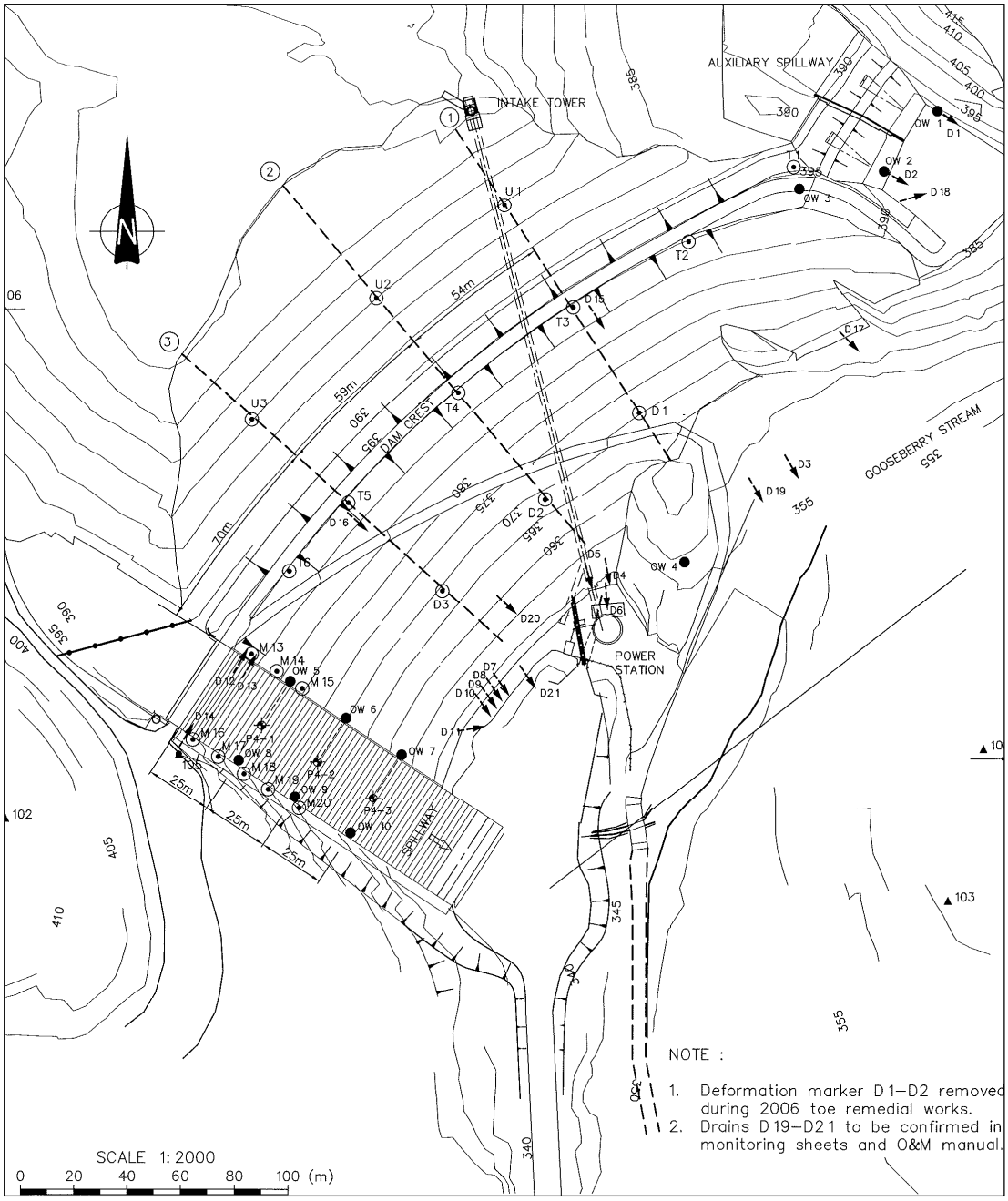

Figure 2.1 Instrumentation layout

2.2 Drains

2.2.1 General

There is a continuous flow monitoring system for the seepage flows from drains D7, D8, D9, D10, and D21. Water levels in these five drains are recorded by data logger and the data is transmitted to Clyde Power Station hourly. Drain flows are also manually read monthly by recording the time taken to fill a container of known volume.

Measured drain flows provide generally consistent and satisfactory results, responding to fluctuations in reservoir level. Of the 21 drainage outflow measuring points, 8 have had measurable flows since the 2010 report:

- the 350 m RL conduit drain (D4)

- the base drainage outlet (D7)
- the outlet from the second diversion channel (D17)
- from the three chimney drain sumps (D8, D9, D10)
- right hand side Auxiliary Spillway fuse plug base (D18)
- the seepage cut off wall drain (D21).

Graphs of flow readings since March 2005 are provided in Appendix A, for:

- drains D7, D8, D9, D10 and D21 on Sheet A1/1 (manual data)
- the sum of D7-D10 on Sheet A1/2
- D4, D17, and D18 on Sheet A1/3.
- drains D7, D8, D9, D10 and D21 on Sheet A1/4 (water level recorder data)

Review of flow rates derived from water level recorder data over the period has highlighted that the water levels in the H flumes are sensitive to the accumulation of algae and other debris. Algae causes water level in the flumes to increase and thus the level recorders incorrectly overestimate flow rates.

The recent Surveillance and Monitoring Regime review has shown that in the case of drains D7-D10 flow rates derived from the manual readings and water level recorders are in good agreement when the flumes are clean. Recorded flow rates diverge when the flumes become dirty. The geometry of the D21 H flume differs from the other flumes and OWL are still collecting manual drain flow data with coincident water level information to allow review of the D21 calibration.

An anti-fouling coating has been in place during the period in the four H-flumes D7-D10. Performance has been satisfactory and has reduced the requirement for cleaning. However, some cleaning has been necessary and ongoing cleaning has damaged the anti-fouling coating. OWL advise that the coating will be replaced in the near future and the coating will also be applied to D21.

The H flumes are regularly cleaned by OWL. Recommendations regarding this matter are set out in the Surveillance and Monitoring Plan review that is reported separately.

Recorded drain flows were within historical bounds during the period, with the exception of flows from Drain D21 as discussed below.

2.2.2 Drain D21

As outlined in previous correspondence with OWL in November 2010[7] and February 2011[8], Drain D21 flow rates exceeded the lower bound Alert Level immediately after the 4 September 2010 Canterbury earthquake. The recorded flows from D21 continuously exceeded the Alert Level criteria from the time of the earthquake until late February 2011. However, recently recorded flows have been below the Alert Level criteria. At all times flows were well below the revised upper bound D21 Trigger Level criteria of 500 l/s for all reservoir levels. Figure A1/4 (Appendix A) illustrates the data. Based on flow rates derived from water level recorder information, surveillance data indicates that the D21 flows departed from the baseline trend when the reservoir level rose after being lowered during

[7] Tonkin & Taylor letter to Opuha Water Ltd titled "*Opuha Dam – Drain D21*" dated 18 November 2010. Ref 51137.004.
[8] Tonkin & Taylor letter to Opuha Water Ltd titled "*Opuha Dam – Drain D21*" dated 21 February 2011. Ref 51137.004.

the latter part of autumn 2010. D21 flow rates increased in response to the rising reservoir level. At least for a time, it appears that the 4 September 2010 Canterbury earthquake influenced the change in D21 flow rate. Indications are that the D21 flow rate has stabilised over recent months and on this basis D21 flows are not considered to be of immediate concern at this time. The 22 February 2011 earthquake did not influence D21 flow rates and it is noted that peak ground accelerations measured in Fairlie in February 2011 were an order of magnitude less than the September 2010 accelerations.

The mechanism for the change in D21 flow rates is presently unclear. Further investigation into mechanisms influencing D21 flow rates would more than likely result in significant uncertainty in conclusions. Given these anticipated uncertainties, we are of the view that the surveillance data recorded during the period is not a sufficient basis to justify further investigation into D21 flow rates at this time. Current flows are in the order of 5 l/s and this flow rate is very much less than the Trigger Level flow of 500 l/s.

However, please note that it may be necessary to revise this advice should the D21 flows increase relative to reservoir level or become discoloured at some future point. It is important that the current surveillance is maintained and any changes in the surveillance data promptly assessed. We also note that the recent electronic readings for D21 have been influenced to some extent by rainfall and algal growth in the flume.

Calibration of D21 remains uncertain due to insufficient calibration data being available for higher flowrates. However, we note that further data is currently being collected by OWL and we anticipate calibration will be possible this year. The Alert and Trigger Level criteria for D21 may warrant review following calibration.

2.2.3 Drain D17

The outlet area for Drain D17 was upgraded in June 2008, in accordance with the recommendation of the 2008 report. There was a modest increase in the recorded D17 flow rates following this work that may be attributed to the improved flow collection measurement.

As noted in the 2008 report, the current D17 flows are discharged directly onto the fill embankment below the drain outlet. This fill is spoil placed of as part of the Toe Remedial works in 2006 and is not part of the dam structural embankment. However, any displacement of the fill could affect Gooseberry Stream. Thus, the 2008 report recommended that the discharge be piped to Gooseberry Stream (*RCM 2008-07*).

The fill continues to appear stable with no adverse effect from the drain discharge observed at this time. Given the performance to date, it is suggested that observation of the fill continues in lieu of the pipework previously suggested.

2.2.4 Drain D18

Drain D18 is located at the RHS base of the auxiliary spillway fuse plug and only flows when reservoir levels exceed 390 m RL. This level corresponds to the base of the right hand side auxiliary spillway channel.

Flows were observed and measured between the 15 November 2010 and 3 March 2011, with minor exceedences of the Alert Level criteria recorded between 22 November 2010 and 13 December 2010. All flows within the period were reported to be clear.

2.2.5 Other drains

The recorded flows from Drain D7 exceeded the alert level criteria in one instance on 8 July 2010. We understand that this exceedance flow was due additional flows being diverted from Drain D9 to enable application of the antifouling paint being trialled.

Flows from Drains D4 and D17 were small and within their typical historic ranges. Drain D6 flows are recorded as dripping and are too small to accurately measure.

2.2.6 Drain flow turbidity meter

A turbidity meter was installed on the H flumes to detect changes in sediment concentrations in the drain discharges. However, we understand that turbulence and the consequent entrainment of air into the flow provided false readings. Thus, upon review by the Operator, the use of the turbidity meter ceased some time ago.

Operations staff continue to measure and report the turbidity of drainage flows by way of manual turbidity measurements taken at the time of the manual flow rate recordings. Reported turbidity readings appear to be relatively stable and are reviewed by T&T as part of the ongoing dam surveillance and monitoring requirements.

2.2.7 Access to H flumes

OWL has advised on various occasions that safe access to the H flumes is difficult during wet or icy conditions. Improvements to the current H flume access would improve the safety for OWL staff undertaking measurements, and we suggest that this is considered further.

2.3 Piezometers

2.3.1 General

Graphs of the data since May 2004 are provided in Appendix A2 on 3 sheets. The locations of the three lines of piezometers are shown in Figure 2.1 and the positions of each piezometer in Figure 2.2.

The 2006 remedial works disrupted the piezometer monitoring. The background to these effects is detailed in the 2007 report and is summarised as follows:

- Piezometers P2-5, P3-3 and P3-5 have been decommissioned because they are unresponsive. The readings are still recorded on site but are not reported.
- The gauges for piezometers P1-2, P1-3, P2-6, P2-7, P3-4, P1-4 and P2-8 were being repaired or replaced during early 2007 and readings were restarted on 8th August 2007.
- The remaining piezometers P1-1, P2-1, P2-4, P2-2 and P2-3 recommenced readings on 5th March 2007.

As outlined in the Dam Surveillance and Monitoring Plan 2010[9], four piezometers are considered to be no longer functioning reliably and hence have been excluded from the monitoring requirements. These discontinued piezometers are P1-4, P2-5, P3-3 & P3-5.

The following 10 hydraulic piezometers are currently monitored:

[9] Tonkin & Taylor report to Opuha Water Limited titled "*OPUHA DAM: Dam Surveillance and Monitoring Plan 2010*" dated September 2010.

- Piezometers P1-1, P1-2, P2-1, P2-3, P2-4, P1-3, P2-6, P2-7, P3-4 & P2-8.

These remaining hydraulic piezometers are currently read monthly in accordance with the Surveillance and Monitoring Plan, with provision for additional readings if warranted by specific circumstances.

The pneumatic piezometers under the service spillway are to be read following spillway operation. The service spillway operated during the New Year holiday period and the pneumatic piezometers were not read because of the timing of the spillway discharge.

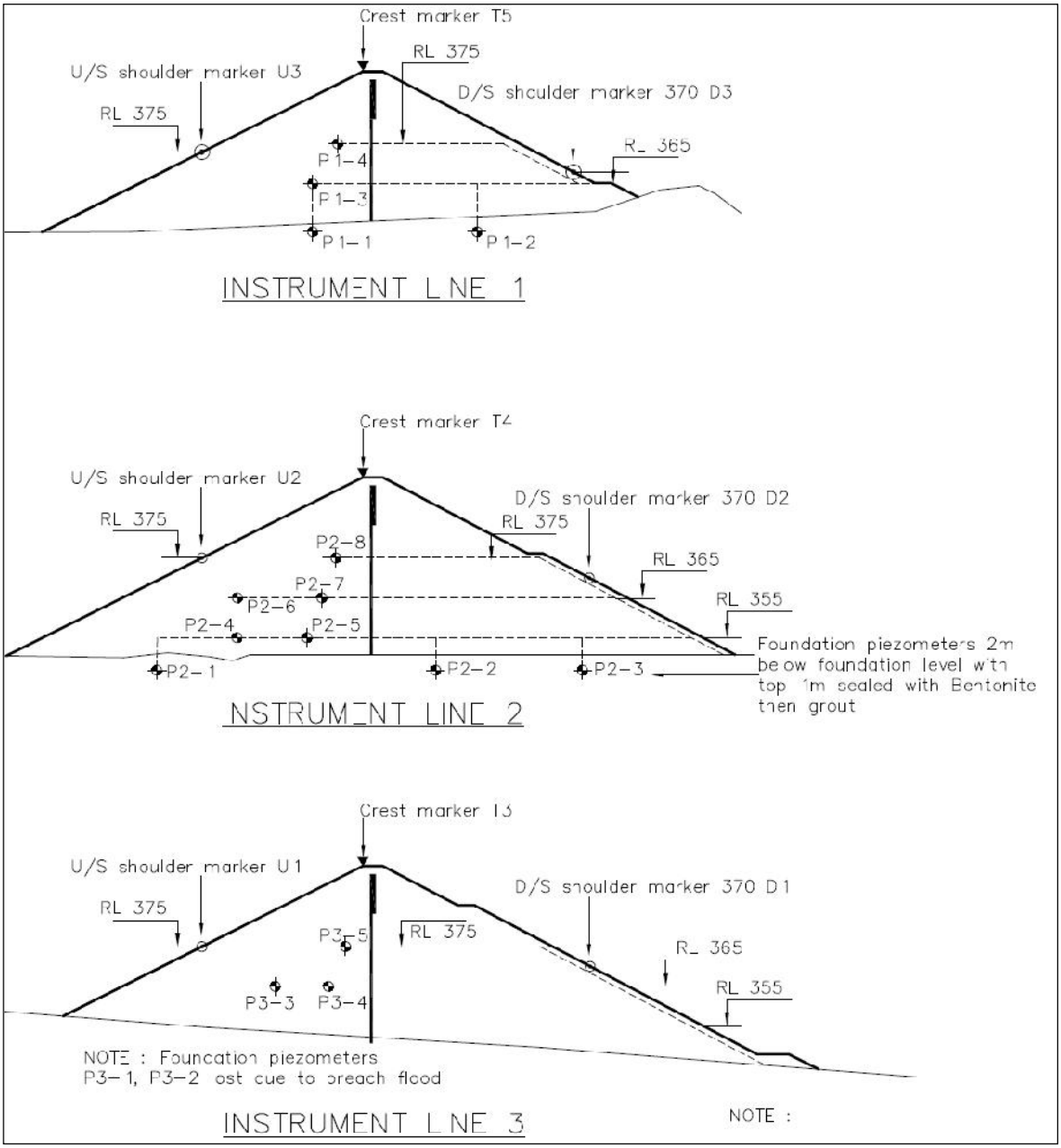

Figure 2.2 Piezometer positions (note P2-5, P3-3 & P3-5 are decommissioned)

2.3.2 Piezometer data

The piezometers were last de-aired by Opus over the period between late November and early December 2008[10]. Since March 2009 piezometer levels have returned to more stable behaviour following a period during which erratic levels were recorded (excluding recordings deemed affected by freezing fluid).

OWL placed frost protection cover material over the exposed hydraulic piezometer leads in late 2009 to prevent freezing of the piezometer lines, and the associated erratic readings. This frost protection measure appears to be working.

The piezometer readings for the reviewed period are generally in keeping with historical readings.

The water level in Piezometer P2-7 rose by 3.5 m between readings on 22nd and 23rd February (Table 3), although the 22nd February reading was taken after the Christchurch earthquake on that date. Subsequently the water level increased slightly. However, from the peak a few days after the earthquake the P2-7 level has been reducing and the reducing trend is continuing. The reducing P2-7 level is yet to reach the pre earthquake levels. Similar trends were observed in other piezometers albeit the trend was less pronounced. After the rise piezometers were monitored daily and then weekly. The February earthquake did not cause any piezometers to exceed their alert levels.

P2-6 exceeded the Trigger Level during the period. The P2-6 Trigger level is set at reservoir level and the exceedance is attributed to inaccuracies with the current gauge calibration factor. This matter is discussed further in the following section.

2.3.3 Piezometer calibration and maintenance

Bourbon gauges are located at the base of the power station to read the hydraulic piezometer tip pressures. It is noted that these gauges have not been calibrated since 2 April 1999. Prior to 2 April 1999, the gauges were calibrated at the end of construction.

Numerous readings from Piezometer P2-6 have marginally exceeded the reservoir water level, which is unlikely to be the case and is most likely due to the calibration factor used (+0.5 m). This indicates that a revision to the calibration factor for the piezometers warranted.

Often hydraulic piezometer gauges are configured to include a control gauge to assist with gauge calibration. It is noted that the Opuha Dam installation does not include a control gauge. Opus[2] also report that the bladder requires replacement and various other minor upgrades are also suggested.

Previously it was suggested that the hydraulic piezometer gauge arrangement is inspected by a specialist and a comprehensive assessment completed to identify all matters where the system could be improved (for example installation of a control gauge) as well as all necessary maintenance works. We understand that the Operator intends to engage Dam Watch Ltd to undertake the hydraulic piezometer maintenance works and that the work will occur this year. These matters were covered by recommendation RCM2010-01 from the 2010 annual inspection report.

We note that the Dam Surveillance and Monitoring Plan will require updating pending the outcome of piezometer recalibration.

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[10] Opus International Consultants report titled "*Opuha Dam Hydraulic Piezometers Maintenance*", dated January 2009.

2.3.4 Pneumatic piezometers

Three pneumatic piezometers are located under the service spillway and are read on the left hand side of the service spillway when the service spillway operates.

In several instances the leads were damaged and should be repaired. Damage of the pneumatic piezometer leads has been an issue in prior years. It would also be prudent to provide long term protection to prevent the damage reoccurring. We understand that the Operator intends to fix these damaged points and install additional protection to reduce the likelihood of subsequent damage.

RCM2011-01: Hydraulic piezometer gauge calibration factors to be checked and gauge maintenance works to be undertaken. Pneumatic piezometer leads to be repaired and rehoused.

2.4 Observation wells

The ten observation wells are all read monthly. These are:

- three in the left abutment area of the dam (OW1 – OW3)
- one near the downstream toe near the power station (OW4)
- six along the sides of the main spillway (OW5 – OW10).

Graphs of these readings since March 2005 are attached at Appendix A in three sheets. The graphs show the 2 or 3 levels at which readings are taken, in individual tubes, for the purpose of checking discrete ground water levels at a range of selected locations and elevations.

Observation well readings for the reviewed period are generally in keeping with historical readings.

As part of the review of the Surveillance and Monitoring Plan, rising or falling head tests were carried out on each of the observation wells. This work was carried out by the Operator on 11 and 12 February 2008. The purpose of this testing was to ensure that they were hydraulically connected to the surrounding ground and therefore capable of responding to changes in local groundwater pressures. All wells showed response to the addition or extraction of water, although the response rate was quite variable. Based on these tests it appears that the wells are recording in-situ ground water levels and therefore should remain in service.

2.5 Rain gauge

Rain gauge data is available from the Environmental Consultancy Services website. Figures A1/1 through A1/4 included in Appendix A illustrate rainfall recorded at the intake tower throughout the period.

2.6 Deformation survey

The bi-annual Type B Deformation Survey was scheduled for February 2010. However, the Operator advises that the overdue deformation survey has not as yet been undertaken, because of issues related to access to the survey pillar, which is on land adjacent to the site owned by others. We understand that the access issue has been resolved and that the Type B Deformation Survey is imminent, albeit that the access agreement is informal for the time being.

As discussed in the 2010 Annual Inspection report, permanent guaranteed access to survey pillars is necessary to fulfil both dam safety compliance obligations and on unpredictable occasions such as immediately following an earthquake. For these reasons it important that OWL and/or the Operator have reasonable rights of access to the survey pillars. The permanent access agreement should anticipate all times that access may be required (including access for planned surveys as well as emergency or unusual occurrence situations).

This matter was the subject of recommendation RCM2010-02.

The downstream row of survey markers, D1, D2 and D3 were replaced in June 2008. The locations of these survey markers will be picked up during the course of the next deformation survey. The Drawings will be amended to include these replaced survey markers when the survey data is available.

A deformation marker has been installed on the conduit anchor block 2 (AB2) since the last deformation survey. However, it was identified at the time of the recent AB2 anchor testing that the deformation marker was damaged and requires refixing and/or replacement. The reinstated marker will be included in the next Type B deformation survey and will provide additional information on the integrity and performance of the anchors.

The 2008 report recommendation RCM2008-15 relates to amending the Surveillance and Monitoring Plan and the Emergency Action Plan to include an additional deformation survey (Type C survey in accordance with the Opuha Dam Deformation Survey Specification[11]) following a significant earthquake event.

Such an event would typically be felt locally or would have triggered an operational response or otherwise be reported upon. The need for a survey should be confirmed with the Dam Safety Consultant following the earthquake event in accordance with the recently updated dam surveillance regime.

RCM2011-02: Outstanding deformation survey be undertaken as soon as practical.

[11] Opus International Consultants; Opuha Dam, Deformation Survey Specification, Issue 1; 2008

3 Dam embankment crest and slopes

3.1 Overview

Visual inspection of the embankment included:

- Upstream face to the extent permitted by the reservoir water level (388.8 m RL at time of inspection)
- Areas of the downstream face
- Crest.

3.2 Upstream face

The upstream slope and riprap appeared in good condition to the extent visible above the 388.8 m RL reservoir water level (Photo 3.1 below).

Photo 3.1 Upstream face from true left abutment

Minimal accumulation of debris was noted. OWL advise that removal of the current debris is programmed for the near future. Periodic debris removal is undertaken and this should continue.

To the extent that it was visible the riprap is robust and sound.

3.3 Downstream face

The downstream face appears to be in a good condition (Photo 3.2 below). Generally spraying continues to control local growth of scrub and bushes to prevent them from penetrating through the riprap into the embankment fill below. A small area of lupins or similar have been overlooked on the right hand side of the embankment. It would be prudent to spray these soon.

During the previous annual inspection period OWL raised the issue of stock tracks on the downstream face of the dam. We understand that the OWL concern related to the potential concentration of stormwater flows by stock tracks. Several stock tracks were observed but no immediate concerns relating to the concentration of stormwater run-off were noted.

Photo 3.2 Downstream face from left abutment

Observations during November 2010 and March 2011 indicate that there may have been a slight amount of movement/slumping of a small area of the Type 1 rockfill behind the power station near the foundation pressure relief well. If deformation of the rock fill has in fact occurred, then the movement is very minor and does not appear to have altered between November 2010 and March 2011. Ongoing visual assessment is warranted.

3.4 Embankment crest

The crest roadway and fence were generally in good condition. However, some slight damage to the fence handrail was observed as per Photo 3.3 below. We suggest that this very minor damage is repaired at a convenient future time.

Photo 3.3 Minor damage to crest fence

We understand that OWL is considering enhancing signage that is intended to assist with exclusion of the public from key areas including motorcycles from the dam crest.

3.5 Drain D16 area on the downstream face

The Operator reports that the historical small wet area on the upper part of the embankment dam face, on the access road and near the D16 drain outlet, has remained unchanged throughout the period. OWL reported in November 2010 that the wet spot may have been responding to rainfall at that time. This wet area is not excessive or extensive and has been noted in the past over a long period.

Drain D16 is a high level connection to the true right base of the thickened chimney drain at 383mRL. The drain exit is adjacent to the dam access road. Prior reports note a wet patch slightly above the drain outlet. The patch is located on the upstream side of the road edge near the outlet to Drain D16. The wet patch is not formally monitored. Nonetheless, anecdotal observations suggest that the damp spot to be generally persistent over a long period (years).

The 2008 inspection report recommended that Drain D16 be investigated by video camera. This investigation was carried out on 31st August 2008 and the video did not identify any discontinuities with the 170mm OD PE drain pipe. However, a low spot is apparent in the pipe close to the upstream end of the pipe. Here there is standing water in the pipe invert.

Previously it was understood that there is no significant response of the damp spot to either heavy rain or reservoir level. It has been suggested that grading the road and road condition changes may obscure the wet patch from time to time. At present the source of this water remains unresolved. It may related to one or more of the following:

- seepage from the chimney drain may be tracking along the outside of the D16 drain pipe
- surface water infiltrating the embankment and exiting at this location
- leakage from the D16 drain pipe.

The 2008 report also recommended a short investigation trench in this area. The objective of this work is to investigate the source of the damp area and install a means to collect and monitor seepage flows. Alternatives to this approach should be considered. Investigation of the source of this seepage was a recommendation of the 2009 Annual Report.

4 Reservoir

4.1 General

The reservoir margin and adjacent slopes in the immediate vicinity of the dam was visually inspected from the dam crest and both abutments. The reservoir level was 388.8 m RL at the time of the inspection.

A small slip of a minor nature occurred on the right hand side of the service spillway approach area in the vicinity of the boat ramp in during the 2010 winter. Slip debris has been removed and the slip has been repaired. Refer to Section 5.2 of this report for additional comment on this matter.

Aside from the slip discussed above, based on the extent of visual inspection from the dam crest there is no apparent sign of slope instability at the margin of the reservoir. In addition, the Operator has not reported any slope instability at the reservoir margin in the period.

4.2 Elver pass

OWL advise that the elver pass is not currently functioning. The cause of this has not been identified yet, however the screen was reported to be blocked. OWL are currently progressing this matter. Further to this, based on site discussions, some routine maintenance of fittings is in order.

4.3 Intake Tower

Photo 4.1 below shows the Intake Tower to the extent that the structure was visible from the dam upstream face of the dam as the time of this inspection.

Photo 4.1 Intake tower from upstream face of dam

A dive inspection of the intake tower was not undertaken during the 2010-2011 year. We understand that this was due to difficulties in scheduling the inspections coincident with low reservoir water level to enable adequate dive time and safe access by divers in accordance with current safety regulations.

Diver inspections are scheduled every two years and the last diver inspection that was scheduled for May 2010 and in now overdue. The dive inspection will provide an opportunity to undertake a more thorough inspection of the intake tower structure.

RCM2011-03: Requirements for the outstanding dive inspection be confirmed, and the inspection undertaken as soon as practical.

A section of access ladder hoop was previously reported to be loose. As-built drawings indicate that the ladder hoops are hinged to allow access to the ladder at varying reservoir levels and that the hinged sections are restrained by chains. It is presumed that the loose hoops are due to the lashing chain coming loose. This matter should be investigated at the time of the upcoming dive inspection.

A number of recommendations from the 2008 report remain outstanding:

- RCM2008-18 – Clarification of the labelling of the guide ropes from the South West tower leg.
- RCM2008-19 - The Operator reports that it is believed that the bulkhead valve handle is located in the powerhouse. This is to be confirmed at the time of the next divers' inspection
- RCM2008-20 - The loose steel bar/plate at the NE tower leg splice should be investigated during the next diver inspection.

We understand that the intake tower hoist/crane unit has not been serviced or operated since commissioning of the dam more than 10 years ago. The intake tower crane is a critical piece of plant necessary to service the conduit screen and/or the bulkhead necessary to seal the conduit. It is suggested that consideration be given to servicing this unit, and testing the functionality of the lifting equipment. It is important to ensure that the crane remains fully operational in the event that it is necessary to operate the crane at short notice.

We note that in addition to the power station crane that is currently being certified, the intake tower hoist also requires Department of Labour certification.

5 Service spillway

5.1 General

We understand that the service spillway operated during this reporting period on 31 December 2010 and continued to operate for several days thereafter.

5.2 Spillway approach

As shown in Photo 5.1 below, the approach was clear of significant debris at the time of inspection. The approach to the service spillway was inspected and was in good condition. The repair to the shotcrete coating on the rock on the right hand side of the spillway is in good order.

Photo 5.1 Approach to service spillway

The structural concrete spillway approach walls are in good condition. The previously recorded 10 mm displacement of the vertical joint between the spillway left side approach wall and mass concrete bridge abutment appears unaltered since the last inspection (refer to the 2006, 2007, 2008 and 2009 Annual Safety Inspection Reports for background detail).

A slip failure of minor significance occurred to the right hand side of the spillway approach channel/road cutting northwest of the service spillway (between the bridge and the boat ramp) during May 2010. Photographs 5.2 and 5.3 taken 28 May 2010 by OWL illustrate the damage). The damage was subsequently repaired soon after and Photo 5.4 illustrates the repair.

Photo 5.2 Road embankment slip (looking south towards service spillway – photo by OWL 28 May 2010)

Photo 5.3 Road embankment slip (looking up from reservoir to road embankment– photo by OWL 28 May 2010)

The recent spillway true right approach slip repair (Photo 5.4 below) was inspected and found to in good condition. However, we note that ponding was observed in the road stormwater drainage upslope from the slip repair. It is desirable that the maintenance works are undertaken to ensure that the road drains correctly function. It is speculated that stormwater ponding at the road side and infiltrating into the slope was a potential contributing factor to the recent slip.

Photo 5.4 Slope protection and stabilisation works on true right of spillway approach

5.3 Obermeyer gates

The Obermeyer gates appear to be in sound condition (Photo 5.3 below).

Photo 5.5 Obermeyer gates from service spillway crest

The exact functioning of the Obermeyer gates during the New Year period when the service spillway operated is not well understood. The Operator reports that the gates failed to respond to the instruction originating from Clyde Power Station Control Room for the gates to lower but that the gates subsequently dropped themselves (timing and trigger uncertain). The Operator also advises that the trigger for the gates to rise was unclear and the gates did not rise as anticipated. This issue is being investigated by the Operator and corrective action is necessary to ensure that the operation of the Obermeyer gates is understood and that the gates correctly function in future. In addition to confirming gate functionality, the Operator advises that a camera will be installed to allow real time observation of the spillway from the Clyde Control Room.

Traditionally a copy of the Obermeyer gate operation and maintenance documentation has been retained in the compressor plant room adjacent to the right hand side of the service spillway. The documentation was not in the compressor plant room at the time of the inspection. The site copy of this documentation should be located and replaced in the plant control room or alternatively at another known location on site (The Operator advises that a copy of this information is retained at Clyde Power Station).

RCM2011-04: Further investigation into the operation of the Obermeyer gates be undertaken to ensure that the gates are operated correctly.

5.4 Stepped spillway chute

The spillway steps appeared to be in satisfactory condition (Photo 5.6 below).

Photo 5.6 Service spillway steps from middle of spillway

As noted in previous annual inspection reports, large rocks thrown from the spillway bridge have broken off step edges in isolated locations. We understand that the Obermeyer gates are similarly targeted by rocks.

In the past rocks thrown onto the spillway have previously been washed into the basin at the toe of the spillway. No substantial accumulation of rocks was observed in the spillway basin at the time of the inspection.

A pine tree has established at the top of the shotcrete above the true right hand side of the stepped chute. The Operator advised previously that this had been sprayed, however we note that spraying has not been successful. It may be necessary to remove the tree by another means if spaying is not successful. This required so that the tree roots do not damage the shotcrete facing. This work is not urgent.

RCM2011-05: Remove the tree from the true right cut slope of service spillway.

5.5 Tailrace and Stilling Basin

As discussed previously in the 2010 annual inspection report, there is a small slip of minor significance on the left bank of the tail race, opposite the spillway. The slip does not appear to have changed significantly and we do not consider further action to be required other than continued visual monitoring.

The spillway basin rock sill was exposed during the inspection. There is minor erosion of the rock sill at the downstream edge of the basin (Photo 5.7 below).

The upper rock cover to the dowel bars had been lost prior to the May 2009 flood. This damage is concentrated at both ends of the sill over a length of approximately 2m on the right and 10m on the left side. In some areas the concrete cover is undermined.

Photo 5.7 Concrete face protection on rock sill

Inspection indicates that the small spillway flows during the period did not erode a significant additional quantity of rock from the sill area. Close monitoring of the sill by OWL will continue. Consequently, the Operator has indicated that works associated with 2008 report recommendation RCM2008-28 will be postponed for the time being. The Operator advises that repair works will be implemented as deemed necessary by the ongoing inspection regime. Based on recent performance this approach is considered to be appropriate.

The concrete facing on the outside of the chute true left wingwall was observed to be undermined near the stilling basin in the vicinity of a crush zone in the rock foundation (Photo 5.8 below). While this does not appear to be of immediate concern, ongoing monitoring of this undermining is warranted.

Photo 5.8 Undermining to concrete face at true left wall of chute near stilling basin

Significant inflows entered the tailrace/downstream weir pondage via Gooseberry Stream during the 24 to 31 May 2010 storm (Photo 5.9 below). Floating debris swept into the tailrace and the downstream weir area was subsequently flushed from the vicinity of the gate structure over the ogee weir. A modest quantity of coarse sediment has been deposited in the power station tail bay area by Gooseberry Stream flows during the flood (Photo 5.10 below). The Operator advises that this material was excavated from the tailrace and removed by truck.

Photo 5.9 May 2010 Gooseberry Stream flood

Photo 5.10 Sediment deposition in the tailrace area after the May 2010 flood

6 Auxiliary spillway

6.1 Fuse plug and channel

The auxiliary spillway appeared to be in a satisfactory condition. The riprap and approach are sound.

Photo 6.1 Downstream face of auxiliary spillway fuse plug

One of the right hand side fuse plug triggering device clay tile pipes is partially blocked (Photo 6.2 below). We suggest that this is cleared and any future blockages removed as they may arise.

Photo 6.2 Partially blocked inlet to clay tile pipe

RCM2011-06: Routine maintenance to ensure that the inlets to the fuse plug triggering device clay pipes are kept clear of debris.

Routine spraying will continue to prevent establishment of vegetation on the fuse plug fill, particularly in the vicinity of the drain outlets.

There was a small puddle on the invert of the auxiliary spillway channel similar in extent to prior years.

Work to improve collection and measurement of the Drain D18 outlet flows has been completed. The drain discharge has been piped below the invert of the Auxiliary Spillway

channel to its downstream extent. The concentrated drain discharge onto the slope below the Auxiliary Spillway does not present any concerns at present.

OWL advises that a surveillance camera may be installed on the right abutment to allow real time remote monitoring of the dam and reservoir water level during an emergency or unusual occurrence situation.

6.2 Left abutment cut slope

The left abutment cut and benches, above the auxiliary spillway, are in good condition. The historical wedge failure downstream of the fuse plug shows no sign of recent movement (Photo 6.3 below). There were no further signs of any significant movement on the slope.

Some minor surficial slipping was observed during this inspection, however this was of a minor nature only. Regular clearing of debris from the cut benches is suggested to avoid prior issues whereby stormwater runoff was concentrating and scouring the fuseplug. No cracking or significant deformation was observed at the top of the cut face.

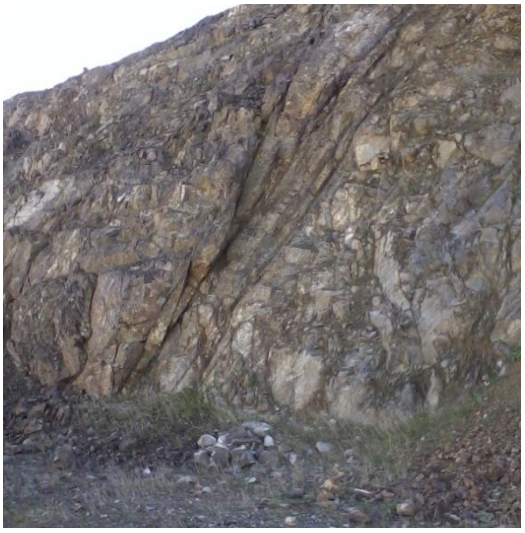

Photo 6.3 Historic wedge failure on true left abutment of auxiliary spillway

During the previous year works have been undertaken to regrade the cut slope benches (Photo 6.4 below) to divert storm water and prevent concentrated stormwater flows affecting the auxiliary spillway fuse plug (Photo 6.5 below).

Periodic spraying of gorse on the benches is also suggested as part of the ongoing maintenance works.

RCM2011-07: Undertake routine maintenance of left abutment cut benches and drains to ensure adequate stormwater control is maintained.

Photo 6.4 Regraded cut slope benches

Photo 6.5 Auxiliary fuseplug edge drain

7 Power station and tailrace

7.1 Powerhouse

The external and internal structure appeared to be in satisfactory and tidy condition. The powerhouse was viewed from the access platform and from around the base of the generator and turbine. No seepage was observed around the penstock pipe penetration through the station wall. Also no other internal leakage into the structure was observed.

The Operator advises that an auxiliary generator is currently being investigated. It is intended that this will allow water to be pumped from the sump at the base of the power station, operation of the lifting equipment and the station control system, and other miscellaneous activities in the event of a power failure.

Subsequent to the inspection, OWL report that a malfunctioning valve was identified in the power station sump and that this has been repaired.

At the time of writing Cookson Engineering advise that the power station crane is in the process of being assessed for the necessary Department of Labour certifications.

7.2 Switchyard

Fencing and security appeared to be in a satisfactory condition.

There are two valves adjacent to the power station that control small diameter pressurised pipelines. The respective pipe alignments are close to the power station and across the dam toe (water supplies to Mr Dave Williams and Allendale stock water supply). These valves are covered by timber lids that are not vandal proof.

It has been identified that there is uncertainty regarding the status of the Allendale stock water pipeline. As-built drawings indicate that the Allendale stock water supply comprises a 100 mm diameter ABS pipeline running along the toe of the dam (length of ABS and other materials unclear). The pipe is connected to the conduit in the vicinity of the Power Station and passes under the lower portion of the Service Spillway.

There is at least one break in the line that is understood to have occurred as a consequence of frost action. The associated leak is visible on the cut slope to the south west of the service spillway when the valve adjacent to the power station is opened (i.e. the identified leak does not pose an erosion risk to the toe of the dam). This valve is usually shut and it is understood that the line is not currently used.

We suggest that the status of the pipe crossing the toe of the dam is clarified in accordance with recommendation RCM2010-04. Subject to the review, recommended outcomes could include repair, decommissioning, or clarification of maintenance responsibility. Additionally, we also suggest that all valves in the vicinity of the power station are secured against tampering by vandals.

7.3 Stoplog

The 2007 report recommended that the stoplog seals be replaced prior to their next scheduled use. The Operator reported that the stoplog seals have been reviewed and are considered to be serviceable at present. The stop log is now stored vertically in a steel cradle adjacent to the Power Station.

7.4 Conduit anchor block AB2

Previously it was recommend that a proof load test be undertaken on the conduit anchor block 2 (AB2) prestressed anchors to verify that the anchors are maintaining the necessary load to perform their design function (no proof load test has been undertaken since the anchors were commissioned). A reduction in prestress can occur over time, for example due to creep within the anchor arrangement, and it is necessary to ensure that this has not occurred. Review of the AB2 design indicates that the stressed anchors are necessary to resist loads imposed by transient pressures within the conduit generated by a generator load rejection scenario.

AB2 contains two anchors comprising 36 mm diameter high yield strength deformed bars. The AB2 right hand side anchor failed on 24 June 2010 during the proof load test, which was undertaken to verify the anchor prestress load and thus prove that the required anchor capacity was still available. The failure comprised a brittle fracture of the bar and occurred well within the bar capacity stated by the manufacturer's advertised specification. A proprietary coupler was added to the bar at the failure location and the anchor was restressed using the test equipment. Subsequently a temporary replacement anchor head arrangement for the true right anchor was installed on 22 July 2010 (Photo 7.1 below).

Following the anchor failure, two deformation surveys were undertaken on the recently installed conduit anchor block deformation markers on the 25 and 29 June 2010 to check for movement of the anchor block AB2, and others report that no measurable displacement was recorded.

The left hand side anchor was not tested given the performance of the right hand side anchor.

A preliminary design has been completed for an AB2 mass concrete overlay to replace the compromised anchors and detailed design of the permanent repair solution is pending approval by OWL.

We strongly recommend that a permanent AB2 solution is undertaken as soon as possible.

RCM2011-08: Undertake works to install a permanent replacement arrangement for conduit anchor block 2

Photo 7.1 Replacement anchor head arrangement

7.5 450 mm diameter conduit bypass

There is a 450 mm diameter bypass system to circumvent the conduit and enable discharge from the reservoir (via the FCD valve) when the conduit is closed (e.g. as would be the case during a conduit inspection). The intake for the 450 mm diameter bypass is 17 m away from main conduit intake to enable safe access to the main conduit.

The 450 mm bypass system is controlled by a valve situated in a valve pit near the power station. We understand that this valve has not been operated for many years and we are not aware of what the status of this valve or the bypass screen is (i.e. open or closed) or the current operational procedure for use of this valve. We suggest that the Operator consider developing an operational procedure for testing and operating this valve. Prior to operation of the valve, it should be confirmed that it is safe to operate within other operating constraints.

8 Downstream weir

8.1 General

The crest, part of the upstream face and downstream face of the right hand closure embankment were inspected. There is no monitoring instrumentation on the downstream weir and appurtenant structures.

The small and isolated areas of gorse that had previously been reported as becoming established on the upstream face of the closure embankment above normal water levels have been sprayed. OWL maintains an ongoing spraying regime to ensure that gorse does not become established on, or in the vicinity or water retaining structures. No significant areas of gorse were observed on the upstream face of the closure embankment at the time of the inspection.

The downstream face appears to be even and is in a satisfactory condition.

8.2 Downstream Weir Overflow Embankment

8.2.1 Recent embankment reinstatement

The Downstream Weir Overflow Embankment (DWOE) is designed to fuse during a five year or greater Average Recurrence Interval (ARI) flood. The estimated five year ARI routed dam outflow is 100 m^3/s. The present DWOE was constructed in 2009.

A green wet spot was observed on the DWOE at the time of the inspection (Photo 8.1 below). OWL advised that this patch has been visible throughout summer but has not increased in size. No visible flow was observed at the surface at the time of inspection.

Photo 8.1 Wet patch on downstream face of overflow embankment

Some minor seepage through the structure may be expected based on previous DWOE structures and prior precedent. Based on observations and advice from OWL regarding the stable nature of the wet spot, we do not consider this seepage to require immediate action. However, we suggest that the wet patch is monitored on a regular basis by OWL and T&T be informed if visible flows, discoloured flows or an increase in the wet patch area is observed.

RCM2011-09: Ongoing visual monitoring be undertaken by OWL of wet spot on DSWOE

The reinstated fusible section of the left embankment was otherwise in good condition at the time of the inspection (Photo 8.2 below).

Photo 8.2 Downstream weir overflow embankment

8.3 Downstream erosion

Some minor erosion has occurred to the armour material on the true right training wall downstream of the radial gate (Photo 8.3 below). The damaged area was previously reinstated in 2009 and erosion in this vicinity appears to be an ongoing issue. While this currently does not pose an immediate concern to the stability of the structure, we recommend that armour material in this area be reinstated as soon as practical to reduce the likelihood of further scour.

Photo 8.3 Observed erosion to TR bank downstream of radial gate

RCM2011-10: Repair scour damage to true right training wall for downstream weir radial gate.

Other than the erosion noted above, the concrete and stone armouring on both banks is generally in satisfactory condition.

It was previously noted that the mass concrete beyond the end of the chute right hand training wall (beyond the toe of the ogee weir) is at least partially undermined (Photo 8.4 below). Ongoing monitoring of this area by OWL is warranted.

Photo 8.4 Partial undermining of mass concrete and end of left training wall

8.4 Weir and control structure

The structure was generally in good condition. Photo 8.5 below illustrates the area in the vicinity of the weir and gate structure.

Photo 8.5 Downstream weir and gate structure (downstream face)

Some accumulation of debris (tree trunk and branches) was noted upstream of the gate structure. This debris requires removal to ensure the radial gate structure is kept clear. OWL advise that the removal of this debris is imminent. We recommend that removal of this debris occurs as soon as practical. We understand that periodic debris removal is undertaken and this should continue. This matter was covered by a previous recommendation in 2008 (RCM2008-37).

RCM2011-11: Remove debris from the upstream side of downstream weir radial gate and maintain clear of debris.

Gabion baskets originally supported the true right hand side of the radial gate approach channel. It was identified that the basket mesh had almost entirely disappeared when the pond drained following the May 2009 DWOE breach. A repair used large diameter rock armour at the time of the DWOE reinstatement. The repaired area was not visible at the time of the inspection because of the high pond level. OWL advises that the repair is performing well.

The concrete weir spillway is in a satisfactory condition. Inspections of previous years identified a number of small continuous horizontal cracks in the spillway face, as well as occasional small surficial spalls. These features do not appear to have significantly changed in the last year.

9 Access roads

9.1 Access to dam

The maintenance of the access road to the dam is the responsibility of the District Council, including removal of slumps from the batters on the west side of the access road leading to the dam. Road access was clear at the time of the inspection.

9.2 Dam road

The dam crest road has a safety barrier on the upstream edge. In addition, public access is restricted by a locked chain with signage.

Access to the powerhouse and the downstream weir was clear at the time of the inspection.

The road drainage between the sharp bend and the power station does not function well and could be improved at some future point, in conjunction with other maintenance work.

10 Recommendations

10.1 2011 recommendations

Dam safety recommendations arising from the inspection of 2011 are collated below in Table 10.1. The recommendations for action on each component of the project are numbered, referenced to the section in this report where they arise and categorised as:

- N (Necessary) to be done as a priority (within 12 months) or regularly
- D (Desirable) to be done at a suitable time before the next Comprehensive Safety Review (CSR).

Table 10.1 Opuha Dam 2011 Annual Review recommendations

Reference	Report section	Recommendation	Category
RCM2011-01	2.3	Hydraulic piezometer gauge calibration factors to be checked and gauge maintenance works to be undertaken. Pneumatic piezometer leads to be repaired and rehoused.	D
RCM2011-02	2.6	Outstanding deformation survey be undertaken as soon as practical.	D
RCM2011-03	4.3	Requirements for the outstanding dive inspection be confirmed, and the inspection undertaken as soon as practical.	D
RCM2011-04	5.3	Further investigation into the operation of the Obermeyer gates be undertaken to ensure that the gates are operated correctly.	D
RCM2011-05	5.4	Remove the tree from the true right cut slope of service spillway.	D
RCM2011-06	6.1	Routine maintenance to ensure that the inlets to the fuse plug triggering device clay pipes are kept clear of debris.	N
RCM2011-07	6.2	Undertake routine maintenance of left abutment cut benches and drains to ensure adequate stormwater control is maintained	D
RCM2011-08	7.4	Undertake works to install a permanent replacement arrangement for conduit anchor block 2	N
RCM2011-09	8.2	*Ongoing visual monitoring be undertaken by OWL of wet spot on DSWOE*	N
RCM2011-10	8.3	Repair scour damage to true right training wall for downstream weir radial gate.	D
RCM2011-11	8.4	Remove debris from the upstream side of downstream weir radial gate and maintain clear of debris.	N

10.2 2011 suggestions

Some general suggestions regarding the performance of the dam have also been provided for consideration by OWL and the Operator as summarised below:

- Tower gantry crane lifting unit - Consider servicing this unit and obtain the necessary certifications.

- 450 mm diameter bypass line – Confirm status and operating procedure for the bypass valve.
- Consider improvements to the current access to H flumes to enable safer measurement of manual flows.
- Service spillway chute and stilling basin - Ongoing monitoring of sill and chute erosion.
- Access road - Improve the road drainage between the sharp bend and the power station as this currently does not function well

10.3 2010 recommendations

Considerable progress has been made in undertaking and completing the recommendations of 2008, 2009 & 2010. The progress is noted in the column under "Current status". Where relevant, outstanding recommendations are discussed in the text of this report.

Recommendations arising from the inspection of 2010 are presented below in Table 10.2.

Table 10.2 Opuha Dam 2010 Annual Review recommendations

Reference	Recommendation	Category	Current status
RCM2010-01	Complete a comprehensive review of the hydraulic piezometer system and identify necessary upgrade and maintenance works (e.g. gauge calibration, consideration of a requirement for a control gauge, review of bladder and the like).	D	Underway
RCM2010-02	Formalise access requirements to all areas of adjacent land where formal access agreements do not exist and access may be necessary for routine activities (eg deformation surveys) as well as during unusual or emergency situations.	N	Completed
RCM2010-03	Clear fuse plug triggering device clay tile outlet pipes and maintain these pipes free from blockage.	N	Completed. Maintenance ongoing.
RCM2010-04	Review status of Allendale water supply pipe line and ensure all valves in the vicinity of the power station are secured against tampering by vandals.	D	To be completed

10.4 2009 recommendations

Table 10.3 below summarises progress with the eight recommendations in the 2009 report (based on advice provided by the Operator 27/4/10).

Table 10.3 Opuha Dam 2009 Annual Review recommendations

Reference	Recommendation	Category	Current status
RCM2009-01	Develop and implement an investigation procedure to determine the source of seepage emerging at the embankment face near Drain D16.	N	To be completed. OWL to consider.

RCM2009-02	The accuracy of the D7 drain flow rate measurements collected using the data logger and manual technique warrants review. Subject to the outcome of this exercise, the alert criteria may require re-evaluation.	N	Completed
RCM2009-03	The accuracy of the D8, 9 and10 drain flow rate measurements collected using the data logger and manual technique warrants review. Subject to the outcome of this exercise, the alert criteria may require re-evaluation (D8 & 10).	N	Completed
RCM2009-04	Review the accuracy of the D21 drain flow rate measurements collected using the data logger and manual techniques and review alert levels given the data now available.	N	To be completed. Data collection underway.
RCM2009-05	Review the de-airing methodology against the erratic behaviour observed and determine if further maintenance is warranted.	N	Completed
RCM2009-06	Investigate and then undertake works to prevent avoidable surface water impinging on the fuse plug embankment as well as prevent progressive damage to the abutment cut slopes.	D	Completed
RCM2009-07	Arrangements for the water pipe offtake and valving for farm water supply, near the switchyard, should be added to the As Built drawings.	D	Completed
RCM2009-08	Spray gorse on the Downstream weir closure embankment	N	Completed. Maintenance spraying ongoing

10.5 2008 recommendations

Table 10.4 below summarises progress with the thirty nine recommendations in the 2008 report.

Table 10.4 Opuha Dam 2008 Annual Review recommendations

Dam			Current status
RCM2008-01	The chain across the crest road should be extended along the downstream side of the crest to make access more difficult for trail bikes and signage should be erected on the chain. (2.2)	D	Complete November 2008
RCM2008-02	The D16 drain pipe should be videoed to check the integrity of the pipe. If the pipe has no visible leakage a short investigation trench should be excavated into the face at the location of the wet patch to try and indentify its source and a drain installed to allow monitoring of the water flow. (2.2)	D	Camera inspection completed June 2008. Refer RCM2009-01.

Dam			Current status
RCM2008-03	The discrepancy between the manual and automatic H flume flow measurements from drains should be investigated and additional on site correlation work carried out. (2.3.2.2)	N	Refer RCM2009-3, 4 &5.
RCM2008-04	The automatic monitoring system should be checked to ensure that it incorporates the correct alert values and, if necessary, changed to reflect the S&M Plan values. (2.3.2.2)	N	Almost complete. D7-D0 complete, D21 pending data from the OWL
RCM2008-05	The D18 drain outlet should be cleaned out and a small concrete bund constructed on the uphill side. (2.3.2.3)	D	Complete June 2008
RCM2008-06	The adjacent seepage flows should be directed into the D17 drain by constructing a concrete wall at the rock/ fill interface. The combined flow should then be recorded as D17. (2.3.2.3)	N	Complete June 2008
RCM2008-07	The D17 flow should be piped from the current outlet to discharge at the base of the fill embankment into Gooseberry Stream.(2.3.2.3)	D	No action warranted, flow drains ok as is, continue to monitor fill for any change - June 2008
RCM2008-08	All drains should be identified by attaching plaques or by painting the drain numbers on headwalls to ensure consistent use of references. (2.3.2.3)	N	October 2008 – substantially complete. Ongoing
RCM2008-09	The H flumes should be regularly cleaned of algae to ensure the depth to flow rate calibration remains applicable. (2.3.2.3)	N	Complete October 2008
RCM2008-10	All weir boards should be kept in a secure location (e.g. the power station). (2.3.2.3)	D	Complete August 2008
RCM2008-11	The leak in the elver pass pipe should be repaired (we understand that this is programmed to take place soon). (2.3.2.3)	N	Complete June 2008
RCM2008-12	The damaged section of piezometer lead pipe should be repaired with a more robust solution (e.g. a split length of PVC pipe between the grey and orange PVC pipes and held together with stainless steel bands and wrapped in Densotape). (2.3.3.3)	D	Complete June 2008
RCM2008-13	The downstream toe deformation markers should be replaced. (2.4.2)	D	Complete June 2008
RCM2008-14	The Opus report includes some recommendations regarding the scope of the surveys which should be considered in the review process. (2.4.4)	D	Complete August 2008

Dam			Current status
RCM2008-15	The Surveillance and Monitoring Plan and the Emergency Action Plan (EAP) should be amended to include the recommendation for an additional survey of the dam following a significant earthquake event. (2.4.4)	D	Surveillance and Monitoring Plan revised
RCM2008-16	A new deformation marker should be installed on the conduit anchor block to allow monitoring of this structure. (2.4.4)	D	Complete June 2008
The Reservoir			
RCM2008-17	The service spillway debris boom should be repaired. (3.1)	N	Complete June 2008
RCM2008-18	The guide rope between the SW tower leg and the bypass valve should be reinstated and the bypass valve then inspected. (3.2)	D	In progress, refer Section 3.2 of the 2009 annual report
RCM2008-19	The location of the bulkhead valve handle should be established or a new handle obtained (3.2)	D	In progress, handle located, to be checked at the time of the next diver inspection
RCM2008-20	The loose steel bar/plate at the NE tower leg splice should be further investigated during the next diver inspection in 2010. (3.2)	D	To be undertaken at the time of the outstanding diver inspection scheduled for May 2010.
Service and Auxiliary Spillways			
RCM2008-21	The undermined shotcrete on the right hand side of the spillway approach should be repaired with concrete to prevent the loss of this protective layer. (4.1)	D	Complete August 2008
RCM2008-22	The gauging board on the right hand side of the spillway approach wall should be repaired. (4.1)	N	Complete June 2008
RCM2008-23	The rust on the Obermeyer gate studs and nuts should be treated before it causes them to seize and the missing nut should be replaced. (4.1)	D	Nuts replaced August 2008 (not painted).
RCM2008-24	The rust spots on the steel gates should be treated and painted. (4.1)	D	Gate now painted
RCM2008-25	The upper nut on the water level bubbler should be tightened and the lower nut should be replaced with a stainless steel nut. (4.1)	N	Complete June 2008
RCM2008-26	The Obermeyer gate operation should be reviewed so that all parties are aware of the system set up and operational responsibilities. (4.1)	D	Complete September 2008
RCM2008-27	The spillway basin should be drained and inspected and if damage has occurred, the rocks should be removed from the basin. (4.1)	N	Complete June 2008

Dam			Current status
RCM2008-28	The damage to the spillway basin downstream sill should be repaired with concrete. The use of mesh reinforcement or alternatively fibre reinforced concrete is recommended to reduce the chance of further damage, preceded by clearing off all loose rock and growth. (4.1)	N	Repair works deferred pending inspection regime.
RCM2008-29	The small tree on the left side of the auxiliary spillway should be removed. (4.2)	N	Complete June 2008
RCM2008-30	The fuse plug crests should be converted back to loose granular material by breaking up the crust and raking back to a smooth even surface. (4.2)	N	Work undertaken June 2008. Refer 2009 Section 4.2.1 for discussion on fuse plug construction.
RCM2008-31	The outlet ends of the two buried pipes should be exposed and all four pipes should be carefully rodded to check for and remove any blockages. (4.2)	N	Complete June 2008.
Powerhouse and Tailrace			
RCM2008-32	The damage to the tailbay concrete should be investigated in greater detail to assess the effects and consequences and determine whether immediate repairs are required. (5.3)	N	To be inspected by divers. 25 May 2010 inspection subsequently postphoned.
RCM2008-33	The conduit anchor block anchors should be tested. (5.5)	N	Testing scheduled for 25 May 2010
Downstream Weir			
RCM2008-34	The weir raising should be extended towards the centre of the structure to improve protection to the gate hydraulic systems (e.g. by metal plates). (6.3)	D	Complete June 2008
RCM2008-35	As noted in the 2007 report, the gate should be cleaned to allow observation of the state of the components and the need for any maintenance. (6.3)	D	Completed.
RCM2008-36	The gate should be closed to allow inspection of the concrete downstream. (6.3)	D	Completed by OWL May 2009.
RCM2008-37	Debris should be regularly removed to prevent it from becoming stuck in the gate. (6.3)	N	Debris removed August 2008. Monitoring ongoing
RCM2008-38	The gabion wall just upstream of the gate should be inspected during a low pond level and, if necessary, repaired or replaced. (6.3)	N	Inspected May 2009 and gabions subsequently replaced by rockfill June 2009

Dam			Current status
RCM2008-39	The void in the instrument shed gabion wall should be filled to prevent the upper basket from settling further and the wall monitored in the 2009 inspection (6.3)	D	Complete August 2008. Void filled with AP20.

11 Conclusions

The Annual Safety Inspection for Opuha Dam was undertaken on the 28 March 2011 in accordance with the NZSOLD Dam Safety Guidelines (2000). The inspection was undertaken by Tonkin & Taylor and accompanied by the Operator and the Owner. The dam is in a satisfactory condition.

The report also reviews the data gathered in the last year from the dam monitoring instruments.

Many of the recommendations from last year's annual inspection report have been actioned or are in the process of being implemented. A further eleven dam safety related recommendations have been made as a consequence of the 2011 annual inspection. These recommendations are as follows:

- Piezometer calibration and maintenance – Hydraulic piezometer gauge calibration factors to be checked and gauge maintenance works to be undertaken. This matter is the subject of an earlier recommendation and the Operator advises that the work will be undertaken in the near future. Pneumatic piezometer leads to be repaired and rehoused.
- Deformation survey – it is suggested that the outstanding deformation survey occurs soon.
- Dive inspection – Confirm requirements and undertake as soon as practical.
- Anchor block AB2 remedial works – Works required to replace the temporary fix to the damaged anchor bar.
- Service spillway gates – Operation of these gates should to be investigated to ensure that the functionality of the gates is well understood and the gates may be operated in the correct manner.
- Service spillway – Remove tree from the true right cut slope.
- Auxiliary spillway – Clear and maintain fuse plug trigger device clay pipes free of debris.
- Left abutment cut benches – Undertake routine maintenance of the cut benches and bench drains to ensure adequate stormwater control is maintained.
- Downstream weir – Scour damage on true right training wall of downstream weir radial gate to be repaired.
- Downstream weir gate – Remove debris from upstream of gate and maintain gate clear of debris.
- Wet spot on Downstream Weir Overflow Embankment – Ongoing visual monitoring by OWL.

Some general suggestions regarding the performance of the dam have also been provided as summarised below:

- Tower gantry crane lifting unit - Consider servicing this unit and obtain the necessary certifications.
- 450 mm diameter bypass line – Confirm status and operating procedure for the bypass valve.
- Consider improvements to the current access to H flumes to enable safer measurement of manual flows.

- Service spillway chute and stilling basin - Ongoing monitoring of sill and chute erosion.
- Access road - Improve the road drainage between the sharp bend and the power station as this currently does not function well.

12 Applicability

This report has been prepared for the benefit of Opuha Water Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

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