IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of applications for resource consents to take and use water in the Waitaki River Catchments

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Memorandum from reporting officer Michael Conrad Freeman for Environment Canterbury

3 June 2010

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1. The purpose of this memorandum is to respond to a direction from the commissioners (23rd Minute, dated 10 May 2010) for a response to the following additional reports:

- Groundwater investigation Pukaki Flats, Mackenzie District, summary prepared for Simons Hill Station Limited and Simons Pass Station Limited report – Aqualinc, 2010 (Pukaki Flats investigation).
- Statement of evidence of David Anthony Horn, GHD dated 21 April 2010 (Horn evidence).
- Statement of evidence of Jose Roberto Romero, GHD, undated (Romero evidence).
- Letter/report from Donna Sutherland, NIWA, titled "Status of Didymo in the Upper Waitaki Hydro-Power Canals", dated 25 January 2010 (Sutherland report).

Pukaki Flats investigation

2. Two reviews have been undertaken of different aspects of the Pukaki Flats investigation: a hydrogeological review undertaken by Simon East, Hydrogeologist, MWH, Dunedin, and a groundwater quality review undertaken by Carl Hanson, Groundwater Quality Scientist, Environment Canterbury.

3. Mr East's summary is detailed below and his full report is attached.

> *"Pukaki Flats groundwater appears to be in variable hydraulic connection with the Tekapo and Pukaki Rivers. Based on broad scale topographical and geological controls I would expect the majority of groundwater from the Pukaki Flats to discharge directly to Lake Benmore. Based on the information presented in the report I consider it likely that there is some groundwater discharge from the Pukaki Flats to the Pukaki and Tekapo Rivers, however the magnitude of this flow gain cannot be quantified with the available information.*
>
> *The actual bulk hydraulic conductivity of the aquifer may be lower than suggested in the report. In turn, aquifer through flow may also be lower. As the methodology used to calculate contaminant mixing (Section 5.3.2 of main report) is sensitive to the aquifer through flow value, I suggest that these calculations should be re-addressed with the potentially lower range of hydraulic conductivity I have described above.*
>
> *Overestimating the hydraulic conductivity value will underestimate the contaminant concentrations in any groundwater that does discharge to surface water.*
>
> *It is apparent that a large proportion of aquifer through flow would have to discharge to surface water to have a significant effect on nitrate-N concentrations in the Tekapo and Pukaki Rivers if the reported mixing distance and groundwater contaminant concentrations (which are based on the estimates of hydraulic conductivity and aquifer through flow) are accepted. However, there is still potential for small scale effects on spring fed streams where groundwater discharge is not diluted by significant surface water flow.*
>
> *The report suggests that groundwater levels are generally below the Tekapo and Pukaki River surface water level. I agree with this conclusion; however, I also stress that in any instance where groundwater levels are above the river level the potential for groundwater discharge to the river exists.*
>
> *As a numerical groundwater model has already been prepared for this area by GHD, it would be prudent to re-run the model after the inclusion of the newly collected field data. A numerical groundwater model supported by adequate field data and an appropriate sensitivity analysis is perhaps the best means of*

> *estimating the likely range contaminant concentrations in groundwater resulting from the proposed irrigation drainage and the quantity of groundwater discharged to surface water. Despite some uncertainties within the report, its broad conclusions appear to be correct, that is; the majority of Pukaki Flats groundwater passes beneath the Tekapo River and discharges directly into Lake Benmore."*

4. Mr Hanson's conclusions, on groundwater quality matters, are detailed below and his memorandum is attached.

> *"Many of the samples discussed in the report have high ion balance errors and therefore are not suitable for comparison with other samples. The only reliable conclusion that can be drawn from the data is that the groundwater chemistry beneath the middle of the Pukaki Flats is somewhat different from the chemistry of the Tekapo River water, but this does not indicate one way or the other whether the groundwater contributes to this stretch of the river."*

5. After Mr Hanson's memorandum was completed (in response to my request) ECan officers were provided with copies of the laboratory results for the groundwater quality analyses. These laboratory results showed that there had been some errors involved in transcribing and applying the results in the Aqualinc report. Mr Hanson reports on these matters in an additional attached memorandum dated 31 May 2010. The applicants' representative was contacted on a number of occasions and asked to comment on these matters. However, as at 3 June 2010, no response has been received.

6. Mr East's and Mr Hanson's reports underline the potential for a proportion of drainage from the Pukaki Flats area to enter the Tekapo and Pukaki rivers. The extent of the potential impact of an unknown proportion of drainage water entering these rivers is uncertain. The additional investigations have not provided any compelling evidence that drainage water would not enter these rivers. It is accepted that the evidence indicates that for the majority of time it is likely that a majority of drainage water would pass under these rivers. However, conversely, at times some drainage water is likely to enter these rivers.

7. It is possible that the effects would be less than minor. However, I consider that the level of uncertainty warrants appropriate monitoring and trigger/response conditions to ensure that firstly, monitoring of groundwater and surface water quality is undertaken to check any potential adverse effects and secondly, to have clear and robust trigger/response conditions that would require appropriate responses to ensure that any significant adverse effects are addressed in accordance with my recommended condition framework.

Horn evidence

8. Dr Horn's evidence focuses on mixing and residence times for Lake Benmore. Dr Horn concludes, "*Since the water quality of the Ohau C Canal is relatively unaffected under any of the proposed development scenarios, the water from the Ohau C will continue to dilute the Ahuriri Arm, mitigating potential impacts from increasing nutrient concentration.*"

9. This conclusion implies that the Haldon Arm waters dilute the entire Ahuriri Arm. This is clearly incorrect. The evidence of Dr Spigel shows that there is at times movement of Haldon Arm water into the Southern-most part of the Ahuriri Arm. However, this

movement clearly only reaches into a portion (length, breadth and depth) of the Ahuriri Arm. Dr Spigel's report outlines his understanding of the inter-relationships between the two arms in his report in paragraphs 72 – 76. These are detailed below.

> *"72. Differences between the Haldon and Ahuriri Arm have been accounted for by use of a three-dimensional grid and a hydrodynamics model that simulates water movements and temperatures as affected by bathymetry; inflows; and momentum, heat and mass exchange between the lake surface and the atmosphere. Nutrient loads and inflows have been specified independently for each basin. The inflows, and the nutrients they carry, enter the lake in grid cells at the head of each basin (Figure 1) and are then transported through the lake by the currents predicted in the hydrodynamic simulation. The user can specify atmospheric data (wind speed, solar radiation, air temperature, etc) separately for each basin as well, if such information is available, but that was not the case for the Benmore application.*
>
> *73. The model variables for concentrations of chlorophyll-a, nutrients, dissolved oxygen and temperature are fully three-dimensional and are calculated separately at each time step at every model grid cell (paragraph 59). Configuring the model for two groups of phytoplankton, with differing responses to light, temperature and nutrient availability, also allows differences between arms to be expressed in model results.*
>
> *74. The model can also account for exchange of water between the Arms. Exchange occurs as a result of temperature stratification and differences in temperatures between the Arms, caused mainly by differences in inflow temperatures, and the density variations associated with the temperature variations. For example, the Ahuriri River has a wider range of temperatures than the Ohau C Canal, being colder in winter and warmer in summer. In summer, Ahuriri River water tends to overflow water from the Haldon Arm as the flows enter the Lower Benmore basin. At the same time, cooler water from the Haldon Arm can penetrate upstream for some distance at depth in the Ahuriri Arm. In winter the pattern can be reversed. In spring and summer the interactions can be quite complex because of thermal stratification, with water from one arm penetrating into the other at intermediate depths.*
>
> *75. These interactions were predicted by Pickrill and Irwin (1986) based on profiles of temperature and suspended sediments that they made along transects through both Arms of the lake. The interactions are consistent with temperature, conductivity and dissolved oxygen profiles that were measured at the three lake sites during the 2008-2009 monitoring.*
>
> *76. The interactions are clearly illustrated in animations of model predictions for passive "tracers" that were inserted into each inflow for the purpose of tracking the water movement of that inflow. I would like to present two animations to the Hearing now, one for each Arm, each showing a transect along the length of the Arm from the river inflow at the head of the Arm to the dam. There are three panels in the animation for each Arm, the top showing temperature, the second showing tracer concentration from the Ohau C Canal inflow (Tracer 1), the third showing tracer concentration from the Ahuriri River inflow (Tracer 2). A tracer concentration of 10 in a grid cell indicates that 100% of the water in that cell is carrying that tracer, while a concentration of zero indicates that none of the water in the cell is carrying the tracer. In watching the animations, note particularly:*
>
> - *the cold underflow of Ahuriri River water in winter all the way to the dam;*
> - *the overflow of Ohau C water into the Ahuriri Arm in winter;*
> - *the interflow of Ohau C water into the Ahuriri Arm in summer;*
> - *the much weaker penetration of Ahuriri River water into the Haldon Arm."*

Romero evidence

10. Dr Romero's evidence is a comprehensive review of nutrient loading to Lake Benmore, the consequential nutrient concentrations and TLI results for the lake. Dr Romero concludes:

> *"The over-arching conclusion in my view is that the GHD (2009) threshold remains valid for most of the reservoir even though I have not accepted their baseline nutrient load estimates. Confirmation of the nutrient baseline loads in my view is one part of the overall issue here, the second critical part is the nutrient load increase from the proposed development, in which I have taken the GHD (2009) as a credible estimate. Combining both of these analyses (ie. establishment of baseline load and plausible nutrient load increases from development) was the basis for my increased nutrient load assessment in Table 12. This analysis indicated that the proposed 'nutrient discharge allowances' remain valid for both the Ahuriri Arm and the Northern Arm, namely:*
>
> *(a) Adoption of the GHD (2009) TLI threshold of 2.75 as the summer epilimnetic threshold is appropriate for the Northern Arm and lower Lake Benmore. As shown in Table 12, the proposed nutrient loads, with mitigation, are predicted to maintain this sector of the Lake in an oligotrophic status.*
>
> *(b) This threshold value will possibly be exceeded in some high flow years in the Ahuriri Arm, in my view from 'natural' variability. Hence, it is recommended that the proposed development implement a strategy to not increase loads to the Ahuriri Arm as outlined in Scenario 2 with 'mitigation' in GHD (2009). As stated in paragraph 7.11, it is my opinion that given the proximity of the current TLI of the Ahuriri Arm to the oligotrophic mesotrophic boundary, the proposed scenario 2 with mitigation is appropriately conservative and precautionary."*

11. The vast majority of Dr Romero's evidence is accepted as a comprehensive and objective review of the technical information. However, I do not agree with the following specific conclusion (paragraph 3.16) "*Hence selection of an appropriate period to assess the trophic status of the lake from a regulatory perspective that diminishes hydrologic-induced variability in the TLI ought to be considered. I suggest an appropriate period is from 1 January to 1 April*."

12. Dr Horn considers that because there was a relatively high Ahuriri River discharge in December 2008, which was followed by an elevated TLI, and because in the following year, the Ahuriri River flows were lower and the subsequent TLI was lower, December should not be included in the summer period for trigger response controls. I accept that significant flow variability can effectively result in changes to TLI and its component parts. However, the fact that a high river flow could result in an increase in TLI does not mean that months where high flows may be more likely to occur should be excluded from a trigger response regime. I consider that the primary focus should be on ensuring that significant adverse effects do not occur.

13. The critical issue is the actual water quality and the measures needed to avoid, remedy or mitigate adverse effects that could occur over the sensitive summer period. Therefore, in my view since December is part of the summer high use period it should be included in a trigger response condition suite. Any significant short-term fluctuation in water quality that is not reflected in actual significant adverse effects can be taken into account by using an appropriate averaging period for a trigger response condition suite. I have recommended that the appropriate trigger response regime should be based on the mean of monthly samples over the December to April (inclusive) period. I suspect that Dr Romero did not fully appreciate that the proposed trigger response regime would take account of any short-term change in TLI.

14. Dr Romero's views are reflected in Mr Whata's closing legal submissions on behalf of Mackenzie Water Research Limited where the MWRL position is summarised in Appendix A as agreeing to a summer mean but only for a January to April period.

Sutherland report

15. Ms Sutherland's letter/report describes the results of recent sampling for *Didymosphenia geminata* (Didymo) in the Upper Waitaki hydro canals. Ms Sutherland states:

> *"Didymo continues to proliferate in areas that are more likely to be subjected to increased nutrient inputs into the canals. For the Tekapo Canal, this area is at, and downstream of, the Salmon Farm. This is consistent with initial observations of growth in the Ohau C Canal, where higher biomass was found just downstream of the Salmon Farm in the first two years post introduction. Similarly, didymo growth in the Ohau B Canal appears to favour areas of potentially higher nutrient inputs, such as the true right side of the canal which is most probably receiving additional nutrients from both the Salmon Farm and the Wairepo Arm."*

16. The implication of these statements is that increases in nutrient concentrations in these canals could potentially lead to more widespread and significant increases in didymo biomass. While the role of nutrient concentrations in determining didymo biomass is currently not well understood, initial studies have indicated that nutrient concentrations can be important. Larned *et al* 2007, concluded "...*it appears that D. geminata is nutrient-limited across most of its current range in New Zealand."* (Larned *et al* 2007, Ecological studies of *Didymosphenia geminata* in New Zealand, 2006-2007, NIWA Client Report: CHC2007-070, December 2007, NIWA Project: MAF07507). Therefore while specific nutrient water quality standards have not yet been identified for didymo, minimising any significant increases in nutrient concentrations is likely to assist in limiting the proliferation of didymo.

Mike Free

Mike Freeman

Environment Canterbury reporting officer

3 June 2010

MWH
BUILDING A BETTER WORLD

13 May 2010

Environment Canterbury
PO Box 345
CHRISTCHURCH, CANTERBURY 8140

Attention: **Anita Warnock**
Consents Project Leader - Waitaki

Dear Anita,

Peer Review: Aqualinc, 2010, Groundwater Investigation - Pukaki Flats, Mackenzie District, C09073

The scope of this peer review is outlined in email correspondence (Anita Warnock - Simon East, 4 May 2010) and the Contract for Services between Canterbury Regional Council (ECan) and MWH (6 May 2010). Specifically the agreed scope includes:

> ***'Review data gathered, (including stream gauging data, aquifer test data and groundwater level data), data analysis and conclusions drawn regarding groundwater flow paths and specifically, the conclusions regarding the flow path of the proposed irrigation drainage water and the receiving waters for that drainage water.'***

The Aqualinc report "Groundwater Investigation – Pukaki Flats, Mackenzie District" (the report) was prepared for Simons Hill Station Ltd and Simons Pass Station Ltd (the applicants) and issued in April 2010. It comprises a summary report (summary report) a report (main report) and appendices (appendix).

The purpose of the report is to support resource consent applications made by the applicants to take water from either Lake Pukaki or the Pukaki Canal to provide water for irrigated agriculture on 4,022 ha of land on the Pukaki Flats between the Pukaki River and the Mary Range. These applications are currently part of the joint Upper Waitaki hearing, which is to hear and decide 110 resource consent applications in the Upper Waitaki Catchment.

The key issue addressed in the report is whether groundwater from the Pukaki Flats discharges to the Pukaki and Tekapo Rivers or flows beneath these features. Irrigated agriculture on the Pukaki Flats has the potential to increase nutrient concentrations in groundwater. Submitters and ECan staff are concerned about the potential for these increased nutrient concentrations in groundwater to impact upon water quality in the Tekapo and Pukaki Rivers. It appears to be generally agreed that the assimilative capacity of the Haldon Arm of Lake Benmore is sufficient that water quality impacts arising from discharge of nutrient enriched water from the Pukaki Flats would be less than minor. I have not explored the validity of this premise in my review.

GHD (2008) undertook preliminary numerical groundwater modelling to address these questions and concluded that the majority of groundwater from the Pukaki Flats would pass underneath the Tekapo River and discharge to Lake Benmore. Little field evidence was available for preparation and calibration of this model at the time. To address the uncertainties within this report additional field data was collected between March 2009 and March 2010. Analysis of this data in conjunction with the GHD (2008) report forms the basis for the report's conclusions.

Monitoring locations

The report assesses groundwater data from 28 wells in Pukaki Flats area. 23 of these wells are located adjacent to the Tekapo River, two adjacent to the Pukaki River, two in the central Pukaki Flats and one on the east side of the Pukaki River. There is a scarcity of data points with the central Pukaki Flats and this has implications for the determination of groundwater flow directions and aquifer parameter estimation.

Aquifer pumping tests

Step pumping tests were conducted on I38/0103 and H38/0261 and a constant rate pumping test on I38/0104.

The constant rate pumping test was relatively short (13.1 hours) and examination of the time-drawdown relationship suggests that a steady state drawdown condition was not reached during the test.

Water levels were monitored in the pumped bore and 5 observation bores. A drawdown response to pumping was observed in I38/0105 and possibly H38/0244. The remaining wells provided data on background groundwater levels.

Bore logs are available for wells I38/0105 (monitoring well at 39.5 m from pumped well) and I38/0104 (pumped well). A clay bound[1] gravel layer was identified in I38/0105 but this appears to be absent from I38/0104. This variation in stratigraphy over relatively small distances appears to be common within sediments of the Pukaki Flats[2] and is indicative of sediments within this geological setting.

A bore log isn’t presented for H38/0244 (3.5 m deep, 152 m from pumped well). Due to the limited lateral extent of sediment layers it cannot be determined if the clay bound gravels identified in I38/0105 exist at H38/0244 and, if they do, whether the well is screened above or below them.

There are inherent uncertainties in describing sediments samples during bore drilling, however the sediments shown in Figure 2 of the report are clearly clay bound. It is possible that the bore log from I38/0104 isn’t representative and the sediments described between 5 and 10 m depth to in fact have greater silt/clay content.

This makes the use of drawdown response data from H38/0244 for aquifer pumping test analysis uncertain. In addition the stratigraphic variation between I38/0105 and I38/0104 may make the selection of an appropriate conceptual model to steer the selection of aquifer pumping test analysis methods difficult.

Static water levels in the pumped well were within 30 cm of those recorded in I38/0105 and these differences are likely to be the result of well efficiency differences due to different well and screen construction techniques used in each well. Static water levels in H38/0244 were approximately 1 m lower than in the pumped well. This is partly explained by this well been down gradient of the pumped well, however well construction and stratigraphic differences may also have an influence.

It is apparent that only data from I38/0105 and the pumped well can be used reliably for aquifer pumping test analysis.

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[1] I have used the colloquial or drillers term “clay bound” but in reality these sediments are likely to have a silt rather than clay matrix.

[2] Refer to Section 8.9.1 of: 2009 GHD, Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Catchment, Prepared for Russell McVeagh on behalf of Mackenzie Water Research Limited.

Drawdown response

During the constant rate test an instantaneous drawdown of approximately 5.17 m in the pumped well occurred and increased to approximately 5.27 m at the end of the test. Review of the graph on page 74 of the appendix reveals that a steady state condition was not reached during the test with drawdown continuing at a minor rate.

In well I38/0105 a maximum of 0.216 m of drawdown was observed. The total depth of the aquifer at the pumping test location is not described, however it is unlikely that the wells are fully penetrating. Well I38/0103, approximately 3.5 km north of the pumping test site was drilled to a depth of 41.7 m. Well H38/0035, approximately 4.8 km west of the pumping test site was drilled to a depth of 118 m. In the absence of other data we must assume the aquifer at the pumping test site maybe significantly deeper than the existing wells. In this case the Hantush (1964) condition for partial penetration is not met for monitoring well I38/0105. This may also explain the unusual drawdown response observed and in some circumstances can produce a very similar response to that observed due to delayed yield.

Analysis

It appears that the aquifer in the vicinity of the pumping test is variably leaky or confined due to the presence of laterally discontinuous impermeable layers. This makes the selection of an appropriate conceptual model for analysis problematic.

Late time data from I38/0105 appears to be influenced by delayed yield or partial penetration effects. There is uncertainty about the causation of the observed “drawdown” in H38/0244 and it would be appropriate to remove this well from the analysis. This leaves early time data from I38/0105 and the pumped well data. The Boulton (1969) solution for leaky aquifers is the most appropriate analysis method presented in the report, however it is important to keep in mind that it doesn’t consider the laterally discontinuous nature of the low permeability layers. It is also uncertain from the report whether partial penetration of the wells has been considered. Table 9 of the report suggests transmissivity values of between 2,240 and 2,692 m^2/day derived from the Boulton solution. Based on the limitations of the aquifer pumping test these values are likely to be the most indicative of those presented in Table 9 of the actual aquifer transmissivity.

Rather than using an average value from the various analysis methods (Section 4.6 of the report) it is more appropriate to select the value from the analysis method which best fits the conceptual model of the aquifer. In this case it is clearly the Boulton solution.

The report has considered the aquifer thickness to be the saturated aquifer thickness above the well screen. In a leaky aquifer it is conventionally the saturated thickness above the bottom of the well screen that is considered the aquifer thickness (b). This would change the aquifer thickness values presented in Table 10 slightly, however not significantly.

An aquifer pumping test generally only provides information about aquifer properties for a discrete area. When looking at aquifer wide processes such as through flow aquifer parameters need to be selected that represent the aquifer as a whole. There appears to be little aquifer parameter data available for the Pukaki Flats apart from the results of the 3 tests presented in the report and for this reason it is essential that a broad range of values is used in any assessment to encompass the likely range of natural variability.

Transmissivity values determined from step pumping tests on wells H38/0261 and I38/0103 were approximately 1,000 and 4,500 m^2/day respectively[3] . When considered with the results of the constant rate

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[3] These values were calculated with the Eden Hazel solution for confined aquifers. I have not assessed the suitability of this solution with respect to the conceptual model of the aquifer at this location. If the aquifer is in fact leaky as observed at the constant rate

test (~2,500 m^2/day[4]) we can suggest that bulk transmissivity of the Pukaki Flats may be within the range 1,000 to 4,500 m^2/day, however insufficient data is available to identify spatial trends in transmissivity and it cannot be excluded that the actual bulk transmissivity may be lower or higher.

Based on the range of transmissivity values from the aquifer pumping tests we would expect hydraulic conductivity to be slightly lower than presented in Table 10. A reassessment of these values is provided in the following table.

Well	Transmissivity (m^2/day)	Saturated aquifer thickness (m)	Hydraulic conductivity (m/day)
H38/0261	1,000	14	70
I38/0103	4,500	13.5	333
I38/0105	2,500	21.7	115

The assessment of aquifer through flow and contaminant transport has used a range of hydraulic conductivity between 233 and 2,330 m/day. Despite the uncertainty in converting the transmissivity values to hydraulic conductivity and the inherent uncertainty in applying results of discrete aquifer pumping tests to the assessment of aquifer scale processes, the range of hydraulic conductivity values adopted are highly conservative in terms of estimating the maximum rate of contaminant transport (i.e. the travel times presented in Table 14 and 15 are likely to be conservative).

However, lower permeability values may result in a decrease in dilution of irrigation drainage and therefore the change in contaminant concentrations (discussed at the end of Section 5.3.2 of the main report) may be underestimated.

The methodology used to assess contaminant mixing (Section 5.3.2 of main report) is highly sensitive to aquifer hydraulic conductivity and I suggest that it would be prudent to re-assess this analysis in light of the potentially lower aquifer hydraulic conductivity values I have described above.

Concurrent stream gauging

The report describes the results of concurrent stream gauging undertaken on the Tekapo and Pukaki Rivers in February 2010 (Section 2.3) and makes comparisons with data from three concurrent stream gauging runs undertaken March and October 2009.

Stream gauging is inherently uncertain due to measurement errors, flow variations during a gauging run and morphological changes in bed structure causing bed through flow and can often lead to errors in excess of 10% of the actual flow.

The gauging data presented in the report confirms that the Tekapo River generally loses water between the Mary Burn confluence and the Pukaki River confluence. However between gauging points T3 and T4 a flow gain of 0.7 m^3/s was recorded on 17 February 2010. It is uncertain whether this same trend was observed during the previous gauging runs or not. The report suggests that the recorded flow at T3 was lower than the actual flow because a proportion of the flow was present as bed flow (and following that if the actual flow at T3 was considered a flow loss would be reported between T3 and T4). This is a reasonable hypothesis but not easily confirmed with the available data. A cross section between D and C would be useful in making this assessment. Bed flow may also be present at other gauging sites, thus bringing into

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pumping test site these results may not be representational. In addition, it is not apparent if the results have been corrected for partial penetration.

[4] Average of reported values

question the accuracy of those measurements. A river morphology survey maybe required to confirm the suitability of the gauging locations.

The available concurrent gauging data suggests that the Tekapo River predominantly loses water to groundwater, however; there is the possibility that there are spatial and or temporal variations to this general trend. With the available data it is not possible to estimate the magnitude of any potential flow gain. Complicating the analysis is the possibility that within a gaining reach of the river flow gains may occur on one bank and losses through the other, and that the river can move from losing to gaining conditions within very short distances. As concurrent stream gauging only examines the net flow differences between two points there is the potential for groundwater contribution from the Pukaki Flats to be underestimated.

No concurrent stream gauging is reported for the Pukaki River. A flow of 0.3 m^3/s was recorded on 17 February 2010, although it is not known if this is more or less than occurring upstream. Cross section B indicates that the groundwater table is at least 4 metres below river level at that point, however it is possible that the observed flow in the Pukaki River just upstream of the Tekapo River confluence when water is not been released from Lake Pukaki is the result of gains from groundwater downstream of cross section B. Additional cross sections downstream of cross section B would be useful in making this assessment.

The presence of at least some gaining reaches of the Tekapo River is confirmed by groundwater levels being higher than river levels in cross sections C1 and C2 although it is not known how far upstream the Tekapo River these conditions continue. Previous gauging runs showed an increase in flow downstream of the Pukaki River confluence of 0.7 m^3/s (15 October 2009), however it is not mentioned in the report if the Pukaki River contributed to this flow. The report also indicates that on 25 March 2009 a flow measured approximately half way between the Mary Burn Stream confluence and Iron Bridge was slightly higher than at Iron Bridge indicating the possibility of a flow gain from groundwater.

Cross sections and vertical hydraulic gradients

Section 2.2.2 of the main report discusses differences between proximal groundwater and surface water level elevation measurements. Table 1 indicates that generally groundwater is below the surface water level with exceptions occurring at Holes 1b, 8 and 9. If the elevation difference between groundwater and the river bed is considered these differences are somewhat less and in some cases groundwater could be shown to equal to or above river level.

Because Holes 8 and 9 are located some distance from the active channel of the Tekapo River cross sections C-1 and C-2 have extrapolated the groundwater level observed in Holes 9 and 8 to the river using the same hydraulic gradient observed between H38/0245 and Hole 9. I am unsure about the suitability of this methodology and would suggest that extrapolating the Tekapo River level towards Hole 9 would be an as equally valid approach. In either case it is clear that there is likely to be some groundwater discharge to the Tekapo River in this area.

I have reassessed the groundwater and surface water level data (Appendix E) used to construct cross section D and suggest that it is possible for groundwater to be discharging to the Tekapo River at this location. Bore I38/0089 shows a significant seasonal level variation of over 4 metres. Groundwater levels at I38/0090 are more constant and the report has assumed that this is the result of it intersecting a perched water table. Nonetheless, when water levels in I38/0089 are high there is potential for water to discharge to the Tekapo River. A lack of long term groundwater level monitoring data makes an assessment of this risk difficult. It is also not apparent whether the assessment in the report has considered the potential worst case increase in groundwater levels in the Pukaki Flats due to irrigation recharge. This has the potential to influence the spatial and temporal occurrence of groundwater discharge to surface water. Reanalysis of the data with consideration of seasonal groundwater and surface water levels fluctuations and increased groundwater levels due to irrigation recharge would be useful.

Through flow

Through flow calculations presented in the report are based on a hydraulic conductivity of 233 m/day. As described above this may not represent the potential low range of possible hydraulic conductivity and to ensure a conservative assessment a broader range of values should be used. The following table compares the aquifer through flow values calculated with a hydraulic conductivity of 233 m/day and 100 m/day.

			Hydraulic conductivity: 233 m/day		Hydraulic conductivity: 100 m/day	
dh/dl	**W (m)**		**Q (m^3/day)**	**Q (m^3/s)**	**Q (m^3/day)**	**Q (m^3/s)**
0.0037	6,000	50	258,630	3	111,000	1
		100	517,260	6	222,000	3
		150	775,890	9	333,000	4
		200	1,034,520	12	444,000	5

If the actual bulk hydraulic conductivity of aquifer is lower than suggested by the report the calculated aquifer through flow will be less. As we can see, if the bulk hydraulic conductivity was in fact 100 m/day and the aquifer thickness only 50 m, the estimated through flow is approximately 1 m^3/s. Groundwater discharge to the Tekapo River may then may be a more significant component of the total through flow.

Groundwater flow direction

Groundwater flow directions have been estimated from the groundwater and surface water level data (Appendix G). Data points are concentrated around the Tekapo River with few available for the area surrounding the Pukaki River and the central area of the Pukaki Flats. For this reason, the orientation of groundwater flow in the central Pukaki Flats cannot be accurately determined. The available data confirms that groundwater flow is approximately to the south in the central Pukaki Flats and to the south west in the vicinity of the Tekapo River.

I disagree with some of Section 4.3 in relation to the inferred groundwater flow directions and suggest that additional groundwater level monitoring points are required adjacent to the Pukaki River and within the central Pukaki Flats to confirm the actual groundwater flow direction. Accurate determination of groundwater flow directions is essential in the selection of appropriate cross section locations and this may be a source of error in the comparison of surface and groundwater level data in the cross sections.

Summary

Pukaki Flats groundwater appears to be in variable hydraulic connection with the Tekapo and Pukaki Rivers. Based on broad scale topographical and geological controls I would expect the majority of groundwater from the Pukaki Flats to discharge directly to Lake Benmore. Based on the information presented in the report I consider it likely that there is some groundwater discharge from the Pukaki Flats to the Pukaki and Tekapo Rivers, however the magnitude of this flow gain cannot be quantified with the available information.

The actual bulk hydraulic conductivity of the aquifer may be lower than suggested in the report. In turn, aquifer through flow may also be lower. As the methodology used to calculate contaminant mixing (Section 5.3.2 of main report) is sensitive to the aquifer through flow value, I suggest that these calculations should be re-addressed with the potentially lower range of hydraulic conductivity I have described above. Overestimating the hydraulic conductivity value will underestimate the contaminant concentrations in any groundwater that does discharge to surface water.

It is apparent that a large proportion of aquifer through flow would have to discharge to surface water to have a significant effect on nitrate-N concentrations in the Tekapo and Pukaki Rivers if the reported mixing distance and groundwater contaminant concentrations (which are based on the estimates of hydraulic conductivity and aquifer through flow) are accepted. However, there is still potential for small scale effects on spring fed streams where groundwater discharge is not diluted by significant surface water flow.

The report suggests that groundwater levels are generally below the Tekapo and Pukaki River surface water level. I agree with this conclusion; however, I also stress that in any instance where groundwater levels are above the river level the potential for groundwater discharge to the river exists.

As a numerical groundwater model has already been prepared for this area by GHD, it would be prudent to re-run the model after the inclusion of the newly collected field data. A numerical groundwater model supported by adequate field data and an appropriate sensitivity analysis is perhaps the best means of estimating the likely range contaminant concentrations in groundwater resulting from the proposed irrigation drainage and the quantity of groundwater discharged to surface water.

Despite some uncertainties within the report, its broad conclusions appear to be correct, that is; the majority of Pukaki Flats groundwater passes beneath the Tekapo River and discharges directly into Lake Benmore.

Yours sincerely

Simon East
Hydrogeologist
MWH New Zealand Limited

Reviewed by: Lee Paterson

Environment Canterbury
Your regional council

14 May 2010 Ref : CO6C/26005

MEMORANDUM

FROM : **CARL HANSON**

TO : **MIKE FREEMAN**
CC : ANITA WARNOCK

SUBJECT: **REVIEW OF PUKAKI FLATS / AQUALINC GROUNDWATER INVESTIGATION REPORT**

I have reviewed Sections 5 and 6 of the report *Groundwater Investigation – Pukaki Flats, Mackenzie District*, written by James Dommisse of Aqualinc Research Limited and dated April 2010. The report is has an Aqualinc number C09073.

Section 5 Pukaki Flats Aquifer

Section 5 of the report is titled “Pukaki Flats Aquifer” and has three sub-sections: 5.1 “Aquitard Vertical Hydraulic Conductivity”, 5.2 “Groundwater Through-flow”, and 5.3 “Groundwater Contaminant Transport”.

The calculations presented in this section are a reasonable first cut for estimating contaminant transport times in the groundwater beneath Pukaki Flats, but they are subject to a great deal of uncertainty. The hydraulic conductivity value of 233 metres per day is probably only reliable to within a factor of 5 or 10, based on results held by Environment Canterbury from aquifer tests that have been conducted in gravel aquifers in various parts of the region. Dispersivity values, taken from published literature, are also subject to uncertainty of at least a factor of 10, based on the information presented in the Gelhar (1986) paper cited by Mr. Dommisse. Effective porosity may vary by a factor of 2 or more (see, for example, Domenico and Schwartz, 1998, page 14). Finally, equations 7 to 9, used to calculate contaminant travel time, are simplifications of real groundwater systems, and therefore they only give approximate values.

The final conclusions of this section, presented at the top of page 25, are not surprising and probably could have been made without the detailed calculations that precede them. Also, it is not correct to say that “the contaminant would arrive sooner than the first groundwater particle”. It would be more correct to say that the contaminant front travels more rapidly than the average groundwater flow velocity.

Section 6 Water Chemistry

The conclusions drawn from the water chemistry are based largely on analytical results presented in Appendix O for samples collected in February 2010. These results are presented as Stiff diagrams on a map in Appendix Q. No copies of laboratory report sheets were provided, so I cannot verify that the data shown in Appendices O-Q were transcribed correctly. The Stiff plots are coloured according to the author’s interpreted chemistry grouping. Table 17 on page 27 of the report also groups the same results by chemistry, but the groupings do not completely match the Stiff plot groupings.

The first thing to point out with these groupings is that some of the chemistry sample results have large ion balance errors, as I show in the following table. In the table, I have converted all of the results from milligrams per litre, as shown in Appendix O, to milliequivalents per litre, as shown in the Stiff plots. The samples with Stiff plots coloured red, green and orange all have considerable ion balance errors. An ion balance error should generally be less than 5%, though with the low ionic concentrations in these samples, an error of 10% is probably reasonable. However, errors greater than this indicate an error in one or more of the individual ion analyses.

Major Ion Chemistry, February 2010, in milliequivalents per litre

Site	HCO3	Cl	SO4	NNN	Ca	Mg	Na	K	Anions	Cations	Ion Balance
Yellow Stiff Plots											
Hole 12	0.56	0.02	0.07	0.00	0.48	0.07	0.11	0.02	0.66	0.69	2.5%
Hole 7	0.61	0.03	0.05	0.00	0.43	0.10	0.17	0.02	0.69	0.72	2.5%
Hole 11	0.49	0.02	0.07	0.01	0.39	0.09	0.13	0.02	0.59	0.62	2.6%
Hole 8	0.44	0.01	0.04	0.00	0.31	0.08	0.13	0.02	0.50	0.54	3.6%
Hole 13	0.48	0.02	0.07	0.01	0.41	0.08	0.10	0.02	0.57	0.61	3.7%
I38/0105	0.51	0.12	0.07	0.01	0.40	0.10	0.25	0.02	0.71	0.77	4.2%
Tekapo River at Hole 9	0.43	0.03	0.04	0.00	0.31	0.08	0.13	0.01	0.49	0.54	4.7%
Hole 9	0.85	0.06	0.05	0.00	0.55	0.21	0.27	0.03	0.96	1.06	4.8%
Tekapo River near Hole 13	0.77	0.03	0.03	0.00	0.70	0.11	0.13	0.03	0.83	0.96	7.5%
I38/0104	0.66	0.05	0.05	0.03	0.49	0.17	0.23	0.02	0.78	0.91	7.8%
Blue Stiff Plots											
I38/0103	0.84	0.06	0.04	0.05	0.55	0.26	0.29	0.02	0.99	1.12	6.2%
H38/0261	0.84	0.07	0.04	0.06	0.55	0.31	0.28	0.02	1.00	1.16	7.4%
Red Stiff Plot											
H38/0244	0.66	0.03	0.06	0.05	0.70	0.20	0.21	0.04	0.79	1.15	18.4%
Green Stiff Plots											
Hole 14	0.41	0.02	0.05	0.00	0.90	0.06	0.11	0.01	0.48	1.09	38.9%
Tekapo River at Hole 2	0.43	0.02	0.04	0.00	0.95	0.08	0.14	0.01	0.48	1.18	41.9%
Orange Stiff Plots											
Hole 5	0.51	0.08	0.04	0.00	1.20	0.63	0.03	0.03	0.63	1.89	49.8%
Hole 2	0.43	0.02	0.04	0.00	0.95	0.49	0.13	0.01	0.49	1.58	52.8%

For example, in the samples from Hole 2 and Hole 5 (orange Stiff plots), it looks to me like the magnesium (Mg) results might be much too high, resulting in high positive ion balance errors. However, it is these magnesium concentrations that distinguish these two samples from the other samples.

Similarly, the samples for Hole 14 and the Tekapo River at Hole 2 are similar to many of the yellow stiff plot samples except for the relatively high calcium (Ca) concentrations. However, given the high positive ion balance errors for these samples, it is possible that these calcium results are in error.

I do acknowledge that the results for the samples from H38/0261 and I38/0103 (the two blue Stiff plots) do have high concentrations of most ions relative to the other samples. These are from two wells in the middle of the Pukaki Flats area and are probably the two samples that most reflect groundwater chemistry rather than the chemistry of an adjacent river.

Ian McIndoe evidence

In paragraph 66 of his Evidence in Reply dated 28 April 2010, Ian McIndoe says that the water chemistry results show a difference between the Tekapo River and the groundwater in the middle of the Pukaki Flats area, and that this difference “supports the assumption that groundwater from the Pukaki Flats is flowing underneath the Tekapo River.”

I do not agree with this conclusion. Even if groundwater makes a significant contribution to a river, I would not expect the river to have the same chemistry as the groundwater, because it would still be a mixture of groundwater and upstream river water.

A better test would be to compare the chemistry of the Tekapo River water upstream of the Pukaki Flats to the chemistry of the river water downstream of the Pukaki Flats. If the downstream chemistry were unchanged, this would provide much stronger support for Mr. McIndoe's argument.

Unfortunately, the data presented in the report does not allow such comparison because the upstream river samples (Holes 2 and 5 and the Tekapo River at Hole 2) have such high ion balance errors that they cannot provide reliable results.

Conclusion

Many of the samples discussed in the report have high ion balance errors and therefore are not suitable for comparison with other samples. The only reliable conclusion that can be drawn from the data is that the groundwater chemistry beneath the middle of the Pukaki Flats is somewhat different from the chemistry of the Tekapo River water, but this does not indicate one way or the other whether the groundwater contributes to this stretch of the river.

Reference cited

Domenico, P. A., and Schwartz, F. W., 1998. *Physical and Chemical Hydrogeology*. Second Edition. John Wiley and Sons, Inc. 506 pages.

Environment Canterbury
Your regional council

31 May 2010 Ref : CO6C/26005

MEMORANDUM

FROM : **CARL HANSON**

TO : **MIKE FREEMAN**
CC : ANITA WARNOCK

SUBJECT: **PUKAKI FLATS / AQUALINC GROUNDWATER INVESTIGATION REPORT – LAB SHEETS**

In a memo dated 14 May 2010, I reviewed Sections 5 and 6 of the report *Groundwater Investigation – Pukaki Flats, Mackenzie District*, written by James Dommisse of Aqualinc Research Limited and dated April 2010 (Aqualinc report number C09073).

In that memo, I commented that no copies of laboratory report sheets were provided with the report, so I could not verify that the data shown in Appendices O-Q were transcribed correctly. I have since received copies of the lab report sheets, and I have found numerous transcription errors. Some of these errors are significant enough to change the conclusions of the report.

The errors included:

- Non-detections reported on the lab sheets were shown in the report as detections at the detection limit. That is, the "<" sign was left off when the value was transcribed. Theferore, all of the DRP results shown in the report as 0.004 mg/L were in fact non-detections, reported on the lab sheets as "<0.004" mg/L. This was also the case for TKN ("<0.10" transcribed as "0.10").
- Rounding errors. It appears that the results were rounded to two significant figures when they were transcribed into a spreadsheet programme, but then the were reported to two decimal places in the table in Appendix O. This was especially true for the February 2010 results. These errors are minor and are unlikely to affect the report conclusions.
- Alkalinity was reported on the lab sheets in units of mg/L $CaCO_3$, but the numbers were transcribed directly to Appendix O as HCO_3^-. These values should have been multiplied by 1.22 to convert from $CaCO_3$ to HCO_3^-.
- Simple transcription errors. I found a number of these in the results for February 2010. For example, for the sample from Hole 2, the calcium concentration was shown in Appendix O as 19.00 mg/L, and the magnesium concentration as 6.00 mg/L. The correct values from the lab sheets were 6.0 and 0.93 mg/L, respectively.

The alkalinity error and the simple transcription errors make some significant changes to the Stiff plots shown in Appendix Q. The table below shows my calcutions of concentrations in milliequivalents per litre and resulting ion balances using the data from the lab sheets. It can be compared to the table in my original memo of 14 May. The values in bold with boxes around them are those that have changed using the lab sheet data. Using the lab sheet data, all ion balances are now less than 10%, which is acceptable.

Major Ion Chemistry, February 2010, in milliequivalents per litre - CORRECTED DATA

Site	HCO3	Cl	SO4	NNN	Ca	Mg	Na	K	Anions	Cations	Ion Balance
Yellow Stiff Plots											
Hole 12	**0.68**	0.02	0.07	0.00	0.48	0.07	0.11	0.02	0.78	0.69	-6.1%
Hole 7	**0.74**	0.03	0.05	0.00	0.43	0.10	0.17	0.02	0.82	0.73	-6.1%
Hole 11	**0.60**	0.02	0.07	0.01	0.39	0.09	0.13	0.02	0.70	0.62	-5.8%
Hole 8	**0.54**	0.01	0.04	0.00	0.31	0.08	0.13	0.02	0.60	0.54	-5.2%
Hole 13	**0.58**	0.02	0.07	0.01	0.41	0.08	0.10	0.02	0.67	0.61	-4.7%
I38/0105	**0.62**	0.12	0.07	0.01	0.40	0.10	0.25	0.02	0.82	0.77	-3.1%
Tekapo River at Hole 9	**0.52**	0.03	0.04	0.00	0.31	0.08	0.13	0.01	0.58	0.54	-3.9%
Hole 9	**1.04**	0.06	**0.04**	0.00	**0.54**	0.21	0.27	0.03	1.14	1.05	-4.1%
Tekapo River near Hole 13	**0.94**	0.03	0.03	0.00	**0.68**	**0.10**	0.13	0.03	1.00	0.95	-2.7%
I38/0104	**0.80**	0.05	0.05	0.03	0.49	0.17	0.23	0.02	0.93	0.91	-0.7%
Blue Stiff Plots											
I38/0103	**1.02**	0.06	0.04	0.05	**0.56**	0.26	0.29	0.02	1.17	1.13	-1.8%
H38/0261	**1.02**	0.07	0.04	0.06	**0.53**	0.31	0.28	0.02	1.18	1.14	-1.9%
Red Stiff Plot											
H38/0244	**0.80**	0.03	0.06	0.05	**0.69**	0.20	0.21	0.04	0.94	1.14	9.9%
Green Stiff Plots											
Hole 14	**0.50**	0.02	0.05	0.00	**0.30**	0.06	0.11	0.01	0.57	0.49	-7.5%
Tekapo River at Hole 2	**0.52**	0.02	0.04	0.00	**0.30**	0.08	0.14	0.01	0.58	0.53	-4.1%
Orange Stiff Plots											
Hole 5	**0.62**	**0.00**	0.04	0.00	**0.38**	**0.08**	**0.13**	**0.02**	0.66	0.61	-3.9%
Hole 2	**0.52**	0.02	0.04	0.00	**0.30**	**0.08**	0.13	0.01	0.58	0.52	-6.0%

Using the lab sheet data, the differences in chemistry identified in the Aqualinc report are all but removed. The samples shown in the report as green and orange Stiff plots are indistinguishable from those shown as yellow Stiff plots. The two wells with blue stiff plots, H38/0261 and I38/0103, still appear to have chemistry distinct from most other wells, but they now appear similar to the sample from Hole 9. It may be possible to make other groupings, but the differences would be very subtle.

Finally, the data suggest that there may be a change in the chemistry of the Tekapo River water in a downstream direction. Most ion concentrations increase in sequence from Hole 2 to Hole 9 to Hole 13, but sulphate concentrations decrease. This would be consistent with an influx of groundwater as represented by the two blue Stiff plots, H38/0261 and I38/0103. Those samples also have relatively high concentrations of most ions, but relatively low sulphate concentrations. However, given the subtlety of the chemistry differences, I would want to see considerably more data before I could make a firm conclusion.