BEFORE THE CANTERBURY REGIONAL COUNCIL
AND THE ASHBURTON DISTRICT COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of resource consent applications by Rangitata Diversion Race Management Limited to the Canterbury Regional Council and Ashburton District Council for resource consents for the construction, operation and maintenance of the Klondyke Water Storage Facility, its associated water takes from and discharges to the Rangitata River, and all associated activities.

SUMMARY OF EVIDENCE AND SUPPLEMENTARY COMMENTS OF BAS VEENDRICK

DATED 24 April 2018

Introduction

1. My name is Bas Veendrick. I prepared a statement of evidence for the Klondyke Water Storage Facility Proposal dated 28 March 2018. My qualifications and experience are set out in that statement of evidence and I reiterate my confirmation of the expert witness code of conduct in preparing this summary and supplementary comments.

2. This summary statement addresses:

    (a) The key points of my evidence;

    (b) My supplementary comments in response to the statements of evidence of:

        (i) Mr. Ian McIndoe

        (ii) Mr. Alasdair Keane

        (iii) Dr Murray Hicks

        (iv) Mr Richard Brunton

        (v) Dr. Douglas Rankin

    (c) The key items of disagreement between the experts as identified in the joint witness statements for hydrology and sediment transport and geomorphology.

Summary of evidence

PROPOSAL

3. Rangitata Diversion Race Management Limited (RDRML) is proposing to construct a 53 million cubic metre storage reservoir. The proposal also includes a proposed 10 m^3/s take from the Rangitata River during times of high river flow. In accordance with the flow regime specified in the Water Conservation (Rangitata River) Order 2006 (WCO) this new take will have a minimum flow of 132.6 m^3/s with the full 10m^3/s being available when the flow exceeds 142.6 m^3/s. In addition RDRML is proposing to construct a fish screen at the Rangitata Diversion Race which will replace the Bio-Acoustic Fish Fence (BAFF). RDRML is proposing to divert up to 5 m^3/s for the fish bypass associated with the new fish screen with stepped reductions in take rate depending on flow in the Rangitata River.

SUPPLY - DEMAND MODEL

4. A calibrated supply-demand model was developed in MATLAB to model the supply and use of irrigation water. This model enables the benefits of the proposal to be assessed in terms of irrigable area and required storage volumes. A range of possible future scenarios was considered to provide an indication of the benefits of building storage and the 10 m^3/s flood flow take.

5. The modelling indicates that the proposed Klondyke storage reservoir would allow for developing the currently consented RDRML irrigable area of up to 94,500 ha as well as have the ability to use water for 'other purposes' such as irrigation outside of the RDRML, Managed Aquifer Recharge (MAR) and Targeted Stream Augmentation (TSA). It would also enable RDRML to convert to an irrigation application rate that is closer to current and projected future evapotranspiration rates. The proposed 10 m^3/s high flow take would reduce the required storage volumes or alternatively would ensure that sufficient water is available for these 'other possible uses'.

6. RDRML currently takes water from both the Rangitata River and South Ashburton River at a combined rate not exceeding 35.4 m^3/s. As detailed in section 13 of the Land and Water Regional Plan (LWRP) the minimum flow in the Ashburton River will increase in the year 2023 with a further increase in 2033. This will cause the reliability of supply for the RDRML to reduce and therefore it is anticipated that further storage is required to compensate for these future scenarios where less water from the Ashburton River is available for the RDR.

ASSESSMENT OF EFFECTS

7. In order to assess the effect of the proposed 10 m^3/s flood flow take on Rangitata River flows a model was developed based on daily time series of river flows for the Rangitata River at Klondyke. The reach of the river between the RDR intake and the existing fish bypass return will be affected by both the 10 m^3/s high flow take and the proposed fish bypass diversion (both the take and discharge) of up to 5 m^3/s associated with the new fish screen. The reach of the river downstream of the existing fish bypass return will be affected by the 10 m^3/s high flow take only as the water abstracted at the RDR intake for fish bypass purposes is discharged back into the river by this point.

8. Although there is a small stretch of river that is affected by the proposed fish bypass diversion the majority of the length of the river is only affected by the 10 m^3/s high flow take as the water for the fish bypass will be discharged back into the river approximately 1.4

kilometre downstream of the RDR intake. In the paragraphs below I will therefore focus on this reach of the river. Further details on the effect of the short stretch of river affected by the fish bypass diversion are provided in my primary evidence.

9. Table 6 of my primary evidence shows the summary flow statistics for the existing and modified state for the full modelling period. For comparative purposes the flow statistics for the natural flows (recorded flows for the Rangitata River at Klondyke) are also included.

10. As expected the summary statistics in Table 6 indicate a small reduction in mean river flow in the Rangitata River as a result of the proposal i.e. a reduction in mean flow of 1.4 m^3/s from 61.0 m^3/s in the existing state. The percentage decrease in mean flow (compared to the existing flow) is estimated to be 2.3 %. Flows above 142.6 m^3/s at Klondyke are reduced by 10 m^3/s. Flows below 132.6 m^3/s are not affected by the new proposed take. A flow of 132.6 m^3/s is equalled or exceeded only 16% of the time and therefore for the majority of the time (84 % of the time) there is no reduction in flow as a result of the proposal. The minimum, 7D MALF, 75th percentile, 50th percentile (median), 25th percentile and 20th percentile flows are therefore unchanged compared to the existing state. A full suite of hydrological outputs are included in Appendix F3 and Appendix G3 of my primary evidence.

11. Appendix F3 and G3 of my primary evidence show example hydrographs for wet, dry and average years and flow duration curves. It can be seen that there is a small reduction in residual flow in the Rangitata River and that the duration of time that flows are at around 77 m^3/s increases slightly. The flow duration curve indicates that the duration of time flows are at or around 77 m^3/s increases (on average) by approximately 8 days per annum (approximately 2% of the time). This is a result of the Rangitata River flow regime and the current allocation in the Rangitata River. When flows are at 110 m^3/s a total of approximately 33 m^3/s can be taken from the river reducing the flow to 77 m^3/s. High flow takes (takes with a minimum flow of 110 m^3/s or higher) can be taken on a pro-rata basis and there is currently 22.6 m^3/s of flood flow water allocated. Therefore in the existing state the residual flow in the river is 77 m^3/s whenever the recorded flow at Klondyke is in the flow range between 110 m^3/s and 132.6 m^3/s. With the proposed new 10 m^3/s RDR take in place the residual flow in the river is 77 m^3/s whenever the recorded flow at Klondyke is in the flow range between 110 m^3/s and 142.6 m^3/s resulting in a very small increase in the duration of time that flows are stable at 77 m^3/s. In summary, in my opinion, the flow statistics, hydrographs and flow duration curves indicate only minor changes to the flow regime of the Rangitata River as a result of the proposal. Other experts comment on the significance of these changes on instream values.

12. The 10 m^3/s high flow take has the potential to reduce fresh and flood flows in the Rangitata River. The FRE3 statistic is a measure of the frequency at which flood flows occur on an annual basis. Specifically, the FRE3 statistic is the mean annual frequency at which the mean daily flow exceeds three times the median flow. The FRE3 statistic is closely linked with periphyton growth and invertebrate density as further detailed in the evidence of Dr. Ryder.

13. As expected there is a small reduction in the average annual frequency of these flushing flows as a result of the proposal. Under the existing state the average annual frequency is 4.4 and under the proposed state this reduces to 4.1.

14. As detailed in the evidence from Dr. Ryder the main period that periphyton can grow to nuisance levels is in the low flow summer period (1 November – 30 April). Flushing flow statistics (including accrual time) for the Rangitata River based on this period are included in Appendix H of my evidence. The reduction in the mean number of flushing flows and the

reduction in the mean days per annum the flow exceeds 3 times the median flow (222 m^3/s) for the period November to April is greatest between the natural and existing state. The difference between the existing and proposed state is relatively small. In terms of mean accrual time (mean number of days per annum a fresh of 222 m^3/s is absent for the period November to April) the main increase is between the natural and existing state with a smaller increase in mean accrual time between the existing and proposed state. The maximum accrual time increases from 158 days to 182 days when comparing the natural and existing state and remains unchanged between the existing and proposed state.

15. This Appendix also includes annual flow plots from 1 November to 30 April for the three example years (average, wet and dry). These plots include a line indicating a flow of three times the natural median (222 m^3/s). In these example years there is no difference in the number of FRE3 events over the period 1 November to 30 April between the existing and proposed state. One additional hydrograph (November 1985 – April 1986) is added to show one year where there is a change in the number of events exceeding three times the median flow. In that year the modelled flood peak in early January for the existing state is 228.6 m^3/s which is reduced to 218.6 m^3/s under the proposal.

16. Overall I conclude that the biggest change in flushing flow frequency and accrual time is between the natural and existing state. The change between the existing state and proposed state is small although it will add to the overall decrease in flushing flows and increase in mean accrual time. Further comments on the ecological and water quality significance of these changes in relation to an increase in risk of nuisance periphyton growth are provided in the evidence of Dr. Ryder. From a purely hydrological perspective, however I consider this to be a minor (very limited) change.

17. In summary the hydrological assessments I have undertaken indicate that the changes to the flow regime in the Rangitata River both for the reach of river between the RDR intake and the existing fish bypass as well as for the reach of the Rangitata River downstream of this point are small. I am of the opinion that any adverse effects on the hydrology of the Rangitata River will be at worst, minor. The hydrographs and flow duration curves provided in my evidence confirm this conclusion. Other experts have used these results to inform their assessments and provide comments on the significance of the hydrological alterations on instream values.

18. Based on the assessments undertaken and presented in my evidence I consider the adverse effects of the proposal on wetted area, depth and velocity, water levels in the Rangitata River downstream of the proposed discharge, existing users, sediment transport and river morphology, river mouth behaviour and local drainage to be small to the point that they can be defined as less than minor in the context of the RMA. The section 42A Officer report generally agrees with these findings and conclusions.

19. However, I note that cumulative effect concerns have been raised (by submitters and ECan (S42A officer's report)) regarding bedload transport capacity and the reduction in flushing flows. I understand from Ms Hamm and the planning team advising RDRML that an assessment of cumulative effects of the current proposal should look at effects which will occur over and above the currently consented environment. Historic water takes from the Rangitata River have reduced the bedload transport capacity and flushing flows of the river since at least the 1940's (when RDR started abstracting water from the Rangitata River) so alterations to the flow regime of the Rangitata River have occurred for at least 70 years. Irrespective of these consideration, if the commissioners are of the view that cumulative effects should be assessed against the natural state then I note that in my view the changes

as a result of the proposal are so small that they do not materially add to the reduction in bedload transport capacity and flushing flows already experienced on the river by the existing abstractions. In other words, in my view the changes in bedload transport capacity does not modify the bedload transport capacity already experience on the river by the existing abstractions in a meaningful way. I note that the significance of the cumulative reduction in flushing flows on the ecology of the Rangitata River is addressed in the evidence of Dr. Ryder.

Supplementary comments

MR. IAN MCINDOE

20. In paragraph 21 to 44 of Mr. McIndoe's evidence he comments on the **'derogation issue**' raised in the Rangitata Water Limited (RWL) submission which was also recorded as a point of disagreement in the hydrology joint witness statement (refer to Appendix L of my primary evidence). I have provided some comments on this matter in paragraph 9.38 of my primary evidence.

21. In summary RWL hold a consent (CRC134810) which allows RWL to take RDRML water when it is not (fully) exercising its consent (CRC011237). Conversely RDRML can take RWL water when it is not 'fully' exercising its consent. Mr. McIndoe's view is that the taking of water into (the proposed Klondyke) storage has the potential to reduce the amount of water that can be taken under consent CRC134810.

22. As an expert hydrologist, it is not appropriate for me to offer an interpretation of the applicable resource consents. In that regard I leave the interpretation of these consents to Ms Hamm and Mr. Greaves, which I believe is appropriate given the obligations imposed via the expert code of conduct.

23. Mr. McIndoe in paragraph 38 to 41 of his evidence comments on analyses undertaken by Dr. Ayaka Kashima (Aqualinc engineer) using flow data for the period between 1 June 2016 and 31 May 2017 to calculate the amount and percentage of water sourced from unused RDRML water (under consent CRC134810). These analyses are subsequently used to calculate the impact on supply reliability in that year. He also comments in paragraph 41 that if the unused RDRML water was limited to early May the RWL ponds would only be filled in 75% of years and reliability would be increased by just 0.5%.

24. The analyses described in Mr. McIndoe's evidence compares the reliability of the RWL scheme for the existing state with a state where the partial unused water from RWL is removed. I understand from the evidence of Mr. Greaves that the RWL consent to take unused RDRML water (CRC134810) is a 'subservient' consent and therefore the current quantities of 'unused RDRML water' are not guaranteed. Analysing the difference in storage refill and reliability based on the current amount of unused RDRML water versus the amount of unused RDRML water with the Klondyke storage in place is, in my view, not a reliable basis for RWL to plan their water management. Rather it should be viewed as an opportunistic supplementary flow that cannot always be relied on.

25. In paragraph 43 and 44 Mr McIndoe comments:

'Hydrologically, I have no doubt that adding 53 million m^3 of storage into the RDR system will reduce the availability of water to RWL. While I am not in a position to make a call on whether this needs to be considered from a planning or legal sense, I am of the opinion that

such an assessment could be carried out using historical RDR take data and consented data and comparing the situation with and without storage.

At this point in time, I cannot quantify the potential effect of RDR's proposal. However, my opinion is that there will be a difference in the amount of water taken under the storage proposal versus the current situation that could lead to an adverse effect on the availability of unused water for the Rangitata South Irrigation Scheme'

26. Although I agree that there will be a change in the amount of water available to RWL by introducing 53 million m^3 of storage near the top of the RDR I disagree that this could lead to/represents an adverse effect for RWL as the unused RDRML water is not guaranteed irrespective of whether the Klondyke Storage proposal will proceed. The amount of unused RDRML water that can be taken by RWL depends on a number of factors including shut down of the RDR for maintenance as well as the capacity of one of the existing RDR syphons. The maintenance regime from RDRML and the capacity of the syphon may change over time and as such the available amount of unused RDRML water may change as well. I note that Mr. Ben Curry in paragraph 8.8.9 of his primary evidence points out other reasons for a likely reduction in the availability of unused RDRML water in the future.

27. In other sections Mr. Ian McIndoe comments on **reasonable use**. In paragraph 49 he comments on the assumption that everything is assumed to be piped and comments (in the final sentence of this paragraph) '*where are the RDR losses?'*.

28. The RDR losses are described in the final paragraph of section 5.2.1 of the hydrology report which states:

'*Based on data provided by RDRML it was assumed that 900 L/s is lost to groundwater as water flows through the RDR from the intake to the end of the race at highbank. The total combined water taken from the Rangitata and Ashburton is reduced by this amount before considering available water.'*

29. For modelling purposes we have assumed a future scenario assuming all three schemes are fully piped and as such minimal losses within the distribution network of MHV and ALIL.

30. In paragraph 59 he comments that there is virtually no information provided regarding the overall model, climate and soils data, efficiency factors etc. The model details Mr. McIndoe is referring to are provided in section 5.1 and 5.2 of the Hydrology Assessment for the Klondyke Storage Pond (PDP, July 2016). Section 5.1 provides details of the overall model (model setup) and section 5.2.2 and 5.2.3 provides a detailed description of the climate, land-use, soils data and efficiency factors used. I also note that these sections of the Hydrology Assessment describe the range of crop, soils and climate data used for the modelling and as such also address the comment in paragraph 54 of Mr. McIndoe's evidence.

31. In paragraph 56 Mr. McIndoe comments that the proposed **changes to the Ashburton River minimum flows** have not been modelled. This is correct in terms of the original document in the AEE, however I have now quantified the amount of storage required based on the increase in minimum flow in the Ashburton River as detailed in section 13 of the LWRP. A description of the changes to the Ashburton River flow regime is provided in paragraph 7.17 to 7.20 of my primary evidence. In summary the main change to the reliability of supply for the RDRML will be when the minimum flow is raised to 10,000 L/s at State Highway 1 (SH1) in 2033. The hydrological analyses undertaken to provide a natural flow series for the

Ashburton River at SH1 that can be used to estimate the reduction in water supply to the RDR in 2033 is provided in Appendix A of my supplementary evidence.

32. Table 1 below provides an indication how much storage would be required to maintain the current level of reliability based on the flow regime for 2033 both with and without the 10 m^3/s high flow take based on the current maximum consented irrigable area of around 94,500 ha.

Table 1: Storage Volume Required to Irrigate 94,486 ha [1]			
	Scenario 1: Future irrigation water demand based on current irrigation application rate (0.41 – 0.48 L/s/ha)	**Scenario 2:** Future irrigation water demand based on assumed increase in irrigation application rate to 0.52 L/s/ha	**Scenario 3:** Future irrigation water demand based on assumed increase in irrigation application rate to 0.6 L/s/ha
Scenario	**Storage Volume Required to irrigate 94,486 ha (Mm^3) [2,3]**		
No 10 m^3/s high flow take and current Ashburton River minimum flow	22	49	78
No 10 m^3/s high flow take and increased minimum flow for Ashburton River (2033)	39	71	98
10 m^3/s high flow take and current Ashburton River minimum flow	14	39[4]	55[4]
10 m^3/s high flow take and increased minimum flow for Ashburton River (2033)	29	57	74

Notes:
[1] All scenarios have been modelled to meet a target reliability of approximately 99% which represents the current reliability with 75,000 ha of irrigable area.
[2] 94,486 ha is the current maximum consented irrigable area.
[3] All scenarios assume that the storage volume available at Carew is 6 million m^3 and the total storage is only varied by changing the amount of storage available at Klondyke
[4] In light of (some of) the submissions received RDRML has decided that provided that the 10 m^3/s flood flow take is granted then consent CRC134808 (left over RWL water) will be surrendered. Therefore these numbers differ slightly from Table 9 in the (July 2016) PDP hydrology report.

33. As detailed in Table 1 the reduction in the available amount of Ashburton River water (due to the increase in the minimum flow in 2033) significantly impacts on required storage volumes. For example, based on an irrigation application rate of 0.52 L/s/ha the required storage volume increases from 49 to 71 Mm^3 in order to maintain the existing level of reliability based on a scenario when no 10 m^3/s flood flow take is available. With the 10 m^3/s high flow take in place the required amount of storage for the 2033 flow regime increases from 39 to 57 Mm^3.

34. The table can also be used to quantify the reduction in required storage volumes when the 10 m^3/s high flow take from the Rangitata River is available for RDRML. For example the required storage volume for the 2033 flow regime will reduce from 71 Mm^3 to 57 Mm^3 when

the 10 m^3/s high flow take is available for the same scenario with an irrigation application 0.52 L/s/ha.

35. In summary the analyses above further demonstrate the significant benefit of the 10 m^3/s high flow take to offset the impact of the increased minimum flow in the Ashburton River. The analyses also indicates that under a moderate increase in application rates to 0.52 L/s/ha the required amount of storage to irrigate the currently consented irrigable area of 94,500 ha is close to the 53 Mm^3 of storage as proposed by RDRML. I.e. 57 Mm^3 minus the storage volume at Carew of 6 Mm^3 means that 51 Mm^3 of storage is required at Klondyke to retain the current level of reliability at an irrigation application rate of 0.52 L/s/ha under the 2033 Ashburton River flow regime.

36. In paragraph 51 and 60 Mr McIndoe comments on the increase in **irrigation application rate** to 0.52 and 0.6 L/s/ha for two of the model scenarios. In paragraph 60 he comments:

‘*I cannot tell from the data presented whether the additional water applied for is justified, but I am certain that 0.6 L/s ha would not be justified over the whole scheme. For me to be able to comment on the justification of the additional take, I will need substantially more information on the MATLAB model than has been provided to date* ’

37. I am very surprised about the comments regarding the increase in irrigation application rate especially in light of the irrigation application rates provided in the Irrigation Reasonable Use Database (Aqualinc, 2014-2015)[1] which provide rates greater than 0.6 L/s/ha for the ALIL and MHV command areas. The typical rates for pasture under pivot irrigation in the ALIL and MHV command area provided by the Irrigation Reasonable Use Database is 0.61 L/s/ha (5.3 mm/day). I note that this rate does not allow for further projected increases in evapotranspiration under climate change as further detailed in paragraph 6.11 to 6.23 of my primary evidence.

38. As detailed in Table 5 (page 18) of the hydrology assessment the vast majority of the scheme is irrigated pasture (86.2% of the total area). This database is used by Environment Canterbury to determine reasonable and efficient use.

39. I also note that I acknowledge in my primary evidence (paragraph 6.9) that whether the full increase to 0.6 L/s/ha for the consented RDRML command area will occur depends on economics and that this was the reason for modelling two scenarios which allow for an increase in irrigation application rate to 0.52 L/s/ha (scenario 2) and 0.6 L/s/ha (scenario 3).

40. In my view an increase in irrigation application rate is realistic based on the relatively low irrigation application rates within the irrigation schemes supplied by RDRML and the projected increase in evapotranspiration rates under climate change.

41. In summary in my opinion a detailed description of the irrigation model has been provided with the application and I consider that the 10 m^3/s high flow take sought is reasonable and represents the efficient use of water.

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[1] Aqualinc Research Limited (2014-2015). Irrigation reasonable Use Database: **http://mycatchment.info/**.

ALASDAIR KEANE

42. In Table 2, paragraph 34 Mr. Keane provides **flow statistics** downstream of the RDR take and downstream of all takes. I agree with the modelling undertaken by Mr. Keane and the flow statistics presented in Table 2. The flow statistics, hydrographs and flow duration curves presented in his evidence for the natural, existing and proposed state are very similar to those presented in my primary evidence and provide a similar (small) reduction in flow between the existing and proposed state.

43. I note however that there appears to be a minor error in the statistics provided for the upper quartile (25th percentile) flow in the tables presented in his evidence. The reason I point this out is that it is important to make it clear that for the majority of the reach of the Rangitata River downstream of the RDR intake flows below the 16th percentile are not affected as a result of the proposal. In other words for 84% of the time there is no reduction in flow as a result of the proposal. In paragraph 53 Mr. Keane states:

'*The flow statistics for all regimes are the same below the <u>upper quartile flow</u> because the high flow abstraction occurs above this flow'*

44. Whilst this statement is correct, it does not tell the full picture of the extent to which flows do not change. A more complete statement would say:

'*The flow statistics for all regimes are the same below the <u>16th percentile flow</u> because the high flow abstraction occurs above this flow*'

45. From paragraph 40 onwards Mr. Keane comments on **alternatives to proposed bulk flow extraction** and has modelled two additional scenarios (scenario 2 and scenario 3 as described in paragraph 44 of his evidence). Scenario 2 proposes 1:1 flow sharing for the 10 m^3/s high flow take. 1:1 flow sharing essentially means that the same amount of water is left in the river as the amount of water take from the river. For example under 1:1 flow sharing when the river flow is 142.6 m^3/s (which is 10 m^3/s above the flow at which the extra proposed take can occur) a total of 5 m^3/s can be taken and 5 m^3/s will be left in the river. Under the RDR proposal (which is based on standard pro-rata restrictions) the full 10 m^3/s high flow take can be abstracted when the river is flowing at 142.6 m^3/s. For the 1:1 flow sharing scenario the full 10 m3/s flow is available when the river (at Klondyke) is at or above 152.6 m^3/s.

46. Scenario 3 ('*Recession &1:1 flow share*') described in Mr. Keane's evidence proposes no take of water on the rising stage of the hydrograph with RDRML only taking water on the river recession (falling limb of the hydrograph) on the basis of 1:1 flow sharing. The rising stage of the hydrograph is illustrated in red in an example hydrograph in Appendix B of my supplementary evidence.

47. Figure 2 to Figure 9 of Mr. Keane's evidence provides hydrographs and flow duration curves for the natural, existing, proposed RDRML take as well as scenario 2 and 3 described above. Comments on the difference between the proposed RDR take and scenario 2 and 3 are provided in paragraph 48 – 54 of his evidence. My review of the flow statistics, hydrographs and flow duration curves presented by Mr. Keane is that there is very little difference between the proposed RDRML take and the two alternative scenarios. For example in the hydrographs presented in Figure 2 – Figure 7 most of the time the lines for the proposed RDRML take, 1:1 flow share (scenario 2) and recession and 1:1 flow share (scenario 3)

overlap indicating that there are either no differences or that the differences are so small that they are indiscernible on the hydrographs.

48. As acknowledged in the evidence of Mr Keane (paragraph 49 (f)) the two alternative scenarios will result in less flow volume being available compared to the RDRML proposal. I have therefore modelled these two alternative regimes to quantify the reduction in average annual available flow volume for RDRML with regard to the 10 m^3/s high flow take. Under scenario 3 (Recession and 1:1 flow share regime) the average annual flow volume is reduced by 34% which represents a significant reduction in the volume of water available to RDRML. Under scenario 2 (1:1 flow share) the reduction in the available amount of water is less at around 7% and this flow regime is therefore likely to have less of an impact on the availability of water to RDRML.

49. These considerations aside, I acknowledge that if the flow regime of a river is significantly altered or impacted on, alternative take regimes (such as those described by Mr. Keane) can be implemented to maintain flow variability and/or flushing flow characteristics of a river. In this case and as detailed in my primary evidence and the evidence of Dr. Ryder and Mr. Greenaway the effects of the proposed 10 m^3/s high flow take on the flow regime are considered to be less than minor. Dr. Ryder concludes that freshes that potentially affect algae accrual and fine sediment accumulation are largely unaltered from the existing state. Mr. Greenaway concludes that the proposal represents a minor (small) change to recreation amenity on the river. Given this, and the limited change that any of the alternative scenarios will cause to the hydrology of the Rangitata River. I consider that the alternative scenarios proposed by Mr. Keane provide little benefit, in terms of mitigating effects that are expected to be very minor.

DR. HICKS

50. In paragraph 19 Dr. Hicks comments on the **LOWESS approach** and the background suspended sediment concentrations in the river at flows just above 140 m^3/s. This is the current discharge threshold associated with flushing the sand trap and he makes the following comments in paragraph 19 and 20:

'For example, if flushing occurs on a flood recession at a river flow just above 140 m^3/s as measured at the Klondyke flow recorder, the background concentration in the river need not be 410 mg/l as considered by PDP but could be anywhere between about 750 and 250 mg/l. In the latter case, the flushing discharge would be conspicuously muddier than the river it was entering, although this would fade in the course of several kilometres downstream as the flush discharge mixed with the river flow.

I conclude that the sand trap flushings could at times be more conspicuous in the river than anticipated by PDP. '

51. Although I haven't made any comments in my primary evidence in relation to the conspicuousness of the sandtrap discharge (this requires consideration of water clarity which has been covered in the evidence of Dr. Ryder) I agree that the background suspended sediment concentration in the river at times could be lower than the average of 410 mg/L extracted from the LOWESS sediment rating curve. The available data indicates that when the river flow is around 140 m^3/s the background sediment concentration can be anywhere between 250 mg/L and 750 mg/L. My understanding from the supplementary evidence of Dr. Ryder is that there is little difference in the visual clarity of the water at SSC concentrations of 410 mg/L and 250 mg/L. I also note that, the background sediment concentration can at

times be greater than 410 mg/L at a flow of 140 m^3/s (up to 750 mg/L) and hence the sand trap discharge will be less conspicuous compared to using the average of 410 mg/L.

52. In paragraph 21 – 30 Dr. Hicks comments on **the Impact of additional take on silt deposition in the river downstream.** In paragraph 25 and 26 he refers to an article written by Jowett and Milhous (2002)[2] and provides a plot (Figure 2) showing the change in suspended sediment concentration with distance down the Rangitata River. In paragraph 26 he comments

'*Jowett and Milhous concluded that if the flow in a river reduces, such as due to water withdrawal for irrigation, water velocities will be generally lower and it will take a longer time for turbid water to progress downstream, increasing the likelihood of settling in dead zones – in other words, the river bed between the intake point and the sea will be a more effective trap for fine sediment*'

53. The key question therefore is by how much are the water velocities reduced and how much longer will it take for turbid water to progress downstream as a result of the proposal. As detailed in my primary evidence (paragraph 9.24) the largest relative reduction in velocity as a result of the proposal is when flows at Klondyke are 142.6 m^3/s. At these flows the mean velocity at Arundel is reduced from 0.745 to 0.716 m/s, a 3.9% reduction and at Ealing the mean velocity is reduced from 0.751 to 0.727 m/s, a reduction of 3.2 %. The increase in travel time between the RDR and the coast will be similarly small (up to 3.9 % increase in travel time). This indicates that there is no appreciable increase in time for turbid water as it flows towards the coast and subsequently I consider it unlikely that settling of fine sediment in dead zones will change appreciably.

54. Furthermore, as commented in the evidence of Dr. Ryder, the plot reproduced from Jowett and Milhous (2002) was undertaken at very low flows in the Rangitata River (flows at around 60 m^3/s at Klondyke) and is therefore not directly comparable with the proposed flood flow take which will occur at much higher flows (and hence velocities).

55. In paragraph 27 and 28 Dr. Hicks uses examples from several studies to demonstrate the effect of flow removal on fine sediment. This includes studies from Jowett (1983)[3] and NIWA (1983a[4] and 1983b[5]) in the Lower Waitaki. Although I agree with the summaries of these studies provided by Dr. Hicks I note that the Lower Waitaki has a highly modified flow regime due to its location downstream of a series of dams which has a significant effect on the flow variability in the lower Waitaki River. Flood peaks are significantly reduced (dampened) and as such the ability of the lower Waitaki River to re-entrain sediment (cleanse any silt deposition) is significantly reduced. The lower Waitaki River is also subject to hydro-power generation. Jowett (1983) in his study notes:

'*In a hydro - electric situation daily flow peaks can cause inflow to shallow pools or backwaters where during the remaining part of the day there is no or little inflow and the suspended sediment settles. This situation was observed in the Lower Waitaki and was probably the most commonly occurring method of heavy silt deposition*'.

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[2] Jowett, I., Milhous, R. (2002). Why rivers get clearer as they flow downstream. Water & atmosphere 10 (1).
[3] Jowett, I.G. (1983), Siltation of the Lower Waitaki River bed. Power Division, Ministry of Works and Development.

[4] NIWA (2003a). Project Aqua: environmental study – aquatic ecosystems: physical and chemical water quality.

[5] NIWA (2003b). Project Aqua: Lower Waitaki River geomorphology and sediment transport.

56. As detailed in the NIWA (1983b) study the proposed Project Aqua hydropower development was to involve the removal of up to 340 m^3/s from the river so leaving a residual flow in the range of 100-140 m^3/s. The NIWA report also states that broadly speaking the minimum river flow approximately halved and that the main impact of Project Aqua (with regard to suspended sediment) would be on the capacity of the residual river to dilute and flush away the tributary suspended sediment. It was expected that under this project the suspended material would settle into substrate and drape the bed of backwaters. At flows less than 300 m^3/s the Waitaki riverbed tends to 'absorb' more suspended sediment than it yields from bank scour.

57. In summary the Lower Waitaki represents a much different situation than the Rangitata River in that the flow regime of the Lower Waitaki is heavily modified by upstream dams and hydro-electricity generation. In addition the quantum of flow proposed to be removed under Project Aqua was to be much greater than proposed under the RDRML proposal.

58. I certainly do not disagree with Dr. Hicks that the removal of a significant amount of flow potentially results in deposition of fine sediment however I do not think that, for the reasons outlined above, the Lower Waitaki (and Project Aqua) is comparable with the Rangitata River and the RDRML proposal to take an additional 10 m^3/s of water. The key question at hand is whether the 10 m^3/s proposed take is likely to result in a noticeable/measurable increase in the rate of fine sediment deposition into dead zones in between floods (capable of re-entraining fine sediment) and whether the proposal represents a material decrease in these flood flows to re-entrain deposited fine sediment.

59. In addition to my comments in paragraph 53 regarding settling of fine sediment in dead zones I note that for the vast majority of the time between floods there is no increase in sediment deposition compared to the existing state as the high flow take is only taken at flows above 132.6 m^3/s which occurs only 16% of the time. As detailed in my primary evidence (and the hydrographs in Appendix F1- F3) the proposal does not materially alter the floods and freshes currently experienced in the Rangitata River and as such the ability to re-entrain deposited fine sediment is retained. On that basis, in my view, monitoring fine sediment deposition in low energy environments downstream of the RDR intake is not required.

60. In addition I note that I'm not aware of any such monitoring requirement for other (similar) run-of-river takes from the Canterbury Alpine Rivers which indicates to me that this matter is generally not considered to be an issue for run-of-river takes. For example the applications for Central Plains Water which proposed to take water from the Rakaia and Waimakariri River the s42A report from Mr. Duncan[6] states (his paragraph 75):

'It is unlikely that suspended sediment concentrations will reduce downstream of the extraction points. The suspended load is largely washload (silt and clay) and is supply limited, so diverting part of the flow into a canal will not alter the concentration in the water left in the river. There is some evidence for a gradual reduction in suspended sediment concentration in the downstream direction as it gets trapped in the boundary layer but this is not flow dependent. Not a big issue, though.'

61. Another example is Hurunui Water Project which obtained consents to abstract up to 49.2 m^3/s from the Hurunui River. The effect of this proposal on the flow variability of the river

[6] Section 42A Officer's Report, Report of Maurice John Duncan, 25 February 2008.

(periods of prolonged low flow and freshes and floods) is far greater than for the proposed 10 m^3/s take for RDRML and no such monitoring was considered to be required.

62. In paragraph 31 to 35 Dr. Hicks comments on the minimum flow for **sand trap** flushing. I agree with Dr. Hicks (his paragraph 32) that dispersion of the discharged sediment down the river will continue after the actual sand-trap flushing ceases, and therefore it is important to consider the size of the residual river flow after its augmentation by water returned with the flushing has ceased.

63. The main concern from Mr. Hicks is the increased risk of sand deposition on the riverbed near the sand trap discharge point during or immediately after sand-trap flushing due to a smaller residual flow in the river as a result of the 10 m^3/s take. He states in paragraph 34:

'*This risk would be mitigated by raising the minimum river flow for sand trap discharge to compensate. Since Fish & Game have advised me that they consider that the 140 m^3/s limit under the status quo has not appeared to produce adverse sedimentation effects, then this state would be preserved by increasing the sand trap flushing limit to 150 m^3/s should the 10 m^3/s take be consented. An alternative mitigation would be to not take the extra 10 m^3/s on the recession of an event when the sand trap was flushed.'*

64. I consider the risk of increased sand deposition on the riverbed near the sandtrap to be small due to the relatively small decrease in velocities induced by the proposal (refer to paragraph 53 above). In other words due to the very small change in the velocity of the residual flow the dispersion of the sand deposition is unlikely to be much different than the sand deposition that currently occurs following a sand trap discharge. However, I agree with Dr. Hicks that from a purely theoretical point of view the status quo would be retained with his proposed mitigation to increase the sand trap flushing limit to 150 m^3/s.

65. I note that the alternative mitigation proposed to not take the extra 10 m^3/s on the recession of an event when the sand trap was flushed would significantly reduce the availability of the high flow take to RDRML. The falling limb of the hydrograph is generally much longer than the rising limb and sandtrap flushes occur on a regular basis. As such the amount of time that no high flow water can be taken based on this proposed mitigation would be significant.

66. In paragraph 36 to 42 Dr. Hicks comments on the **Optimal timing of water take and flushing during high flow events.** In paragraph 41 Dr. Hicks comments:

'*On that basis, I conclude that restricting water takes and sand trap flushes to falling stages would not mitigate the risk of fine sediment deposition in dead zones downstream. In contrast, flushing and taking water only during rising stages would mitigate this risk by providing more competent flows and more time for dispersing the flushed sediment and residual river sediment downstream during recessions.*'

67. I understand from paragraph 34 of Dr. Hicks evidence that Central South Island Fish & Game have advised that the current 140 m^3/s limit for sand trap flushing has not appeared to produce adverse sedimentation effects. Appendix J of my primary evidence shows a plot of the sandtrap discharges for 2013 – 2014. This plot indicates that sandtrap discharges currently occur on both the rising and falling stages of the hydrograph. Based on this information I do not see a need to change the sandtrap flushing to only the rising stages of the hydrograph. In other sections of my supplementary evidence I have commented on the risk of fine sediment deposition in dead zones as a result of the proposal. In my view the

proposal does not result in a material change to fine sediment deposition on the Rangitata River downstream of the take.

68. In paragraph 48 and 49 Dr. Hicks comments on **Sediment effects associated with the fish bypass**. Dr. Hicks considers it possible that sand and fine gravel discharged directly to the river may form a transient fan-delta at the discharge point which could hinder fish connection with the main river channel. In paragraph 68 and 69 he recommends monitoring the connectivity of the proposed fish bypass channel with the Rangitata main channel at the discharge point and the use of earth-moving machinery to ensure connectivity should monitoring show any adverse consequences for the river environment. I agree with the proposed monitoring from Dr. Hicks and RDRML have now proposed consent conditions to address this.

69. In paragraph 50 – 66 Dr. Hicks comments on the effects on **bedload transport and channel morphology**. This relates item 7(b) of the sediment transport and geomorphology joint witness statement. In summary Justin Cope (ECan S42a officer) is in agreement with my view that the effect of the 10 m3/s take on bedload transport capacity in the Rangitata River downstream of the RDR intake is leass than minor. Dr. Hicks is of the view that the effect of the 10 m^3/s take should not be assessed without taking into account the effect of existing abstractions on the river since he expects that the cumulative effects of all takes should be having some effect on channel substrate and morphology. In paragraph 51 Dr. Hicks states:

'while the effect of the extra 10 m^3/s might be viewed as having little significance because of the marginal change from the status quo, Fish and Game have asked whether this effect should be viewed in the context of cumulative effects of all takes, particularly if the extra 10 m^3/s may push the river over some morphological threshold – in other words, could it be the proverbial ''straw that breaks the camel's back''?

70. When answering this question in paragraph 63 (conclusion) he states:

'*While I do not expect that the relatively small additional reduction in transport capacity associated with the 10 m^3/s take will be enough to result in some morphological threshold being exceeded - in the sense of a change in morphological type - it will, nonetheless, help drive the river along its present slow course of morphological adjustment involving a reduction in the average size of gravel on the river bed surface and lower relative relief of channels and braids. Moreover, this morphological adjustment may lead to some "tipping point" in its value to river users such as paddlers.'*

From this, I infer that Dr. Hicks agrees with my conclusion that the effect of the proposal (in isolation) results in minor morphological changes. It also appears from his conclusion that from a purely morphological perspective the 10 m^3/s high flow take is not the straw that breaks the camel's back.

71. The comments that this adjustment may lead to ''some tipping point'' for river users such a paddlers are vague. Mr. Greenaway in his supplementary evidence expects that a tipping point for river users such as paddlers would be for example long lengths of wide and/or multiple shallow braids, a lack of hydraulic features (such as short rapids currently available between the RDR intake and above Peel Forest), or a proliferation of weeds and willows encouraged by a lack of flood flows.

72. I do not expect material changes to these characteristics as a result of the proposal. In other words the morphological characteristics (and morphological adjustment) of the river

important for river users such as paddlers (as described by Mr. Greenaway) are unlikely to be much different compared to the morphological adjustment the river undergoes as a result of the existing abstractions already occurring on the river. As detailed in paragraph 9.49 to 9.51 of my primary evidence it is the changes in bedload transport capacity and the frequency of larger floods that are important for re-organisation of the riverbed and on-going development of braid channels and island geomorphology. The changes to the bedload transport capacity as a result of the RDRML proposal are very small and the 10 m^3/s take will have a negligible effect on the magnitude of these larger floods.

73. On that basis I do not agree with the monitoring proposed by Dr. Hicks in paragraph 64 – 66 including periodic surveys of channel morphology and bed material size grading downstream of the RDR intake. In my view the monitoring proposed is not very meaningful. Due to the very small anticipated morphological change associated with the 10 m^3/s take it is unlikely that the results from the monitoring can distinguish between the morphological changes as a result of existing abstractions on the river and those associated with the 10 m^3/s high flow take. As such the adaptive management response proposed in paragraph 68 and 69 would not be practical or meaningful to implement. I certainly agree with Dr. Hicks that monitoring the ongoing morphological changes in the Rangitata River would assist with any potential future regional Plan change however this is not occasioned by this consent application.

RICHARD CLARKE BRUNTON

74. Evidence is provided by Mr. Brunton on behalf of Ashburton Lyndhurst irrigation Ltd (ALIL). I have read his evidence and agree with its conclusions.

DOUGLAS RANKIN

75. In paragraph 88 – 103 Dr. Rankin comments on the effect of using mean daily flow from the previous day measured at 12:00 pm (midday) and assumes that is **the ''protocol'' used by ECan to impose restrictions**. He subsequently uses that ''protocol'' to show and comment on the changes of the 10 m^3/s take on hourly flows in a hydrograph (Figure 4, page 21 of his evidence).

76. I agree that this 'protocol' is generally used by ECan to impose restrictions at times of low river flow, however for high flow takes from the Rangitata River this is not the case. For example RDRML exercise consent CRC154670 held by Cumberland Dairies. This water is taken through the RDRML intake and Cumberland Dairies take this water from the RDR just downstream of the sand trap. This is a high flow take of 1.5 m^3/s from the Rangitata River similar to the RDRML proposed 10 m^3/s take. The minimum flow for this consent is 131.1 m^3/s with the full 1.5 m^3/s take being available at flows above 132.6 m^3/s. RDRML manages the take of water on behalf of Cumberland Dairies based on the hourly river flows posted on the ECan website and not the 24hr average irrigation restriction. RDRML have indicated that their system is sufficiently responsive to manage the 10 m^3/s take on the same basis. The '*24 hour period'* has now been removed in the proposed consent conditions for the 10 m^3/s high flow take (CRC170654) to be consistent with the wording in CRC154670 (Cumberland Dairies).

77. In paragraph 150 – 156 Dr. Rankin comments on **Possible Mitigation measures should the consent be granted**. He suggests the following possible mitigation measures:

- Option 1: No taking of the 10 m^3/s take during daylight hours.

- Option 2: No taking of up to 10 m^3/s of water at flows up to 290 m^3/s during daylight hours.

78. Both of these proposed mitigation measures would significantly reduce the availability of the 10 m^3/s high flow take to RDRML. The average number of daylight hours is 12 hours and the availability of the 10 m^3/s would therefore halve based on option 1 above. The flow duration table for the Rangitata River at Klondyke indicates that flows are above 290 m^3/s for only 3% of the time and above 132.6 m^3/s for approximately 16 % of the time. Therefore for option 2 the proposed mitigation not to take water during daylight hours when flows are above 290 m^3/s would restrict the 10 m^3/s take to night time only for the vast majority of the time when flows at Klondyke are above 132.6 m^3/s. The expected reduction in water availability for the 10 m^3/s take under option 2 would be in the order of 40%.

79. Based on the assessment by Mr. Greenaway, the effects of the take do not warrant the further restrictions proposed by Dr. Rankin.

Bas Veendrick
24 April 2018

Appendix A

Flow Regression Memorandum for Ashburton River at SH1

TECHNICAL MEMORANDUM

Flow Regression for Ashburton River at SH1

18/04/2018

Introduction

An analysis was undertaken to develop a naturalised synthetic flow record for the Ashburton River at the State Highway 1 (SH1) flow recorder site.

The naturalised synthetic flow record was constructed in two steps, including:

1. Creating a naturalised flow series at the SH1 recorder site; and
2. Completing a regression of upstream flow recorder sites located within the Ashburton River Catchment against the naturalised flow series at SH1.

The analysis uses historical flow data from five flow recorder sites and flow data of existing abstractions and discharges within the Ashburton catchment.

The natural flow record for the Ashburton River at SH1 developed in this analysis has been used for modelling the future reliability of irrigation schemes which will be subject to the 2033 flow and allocation regime in the Ashburton River at SH1 flow recorder site.

This memorandum describes the data, methodology and results of the analysis.

Flow Data

The analysis uses flow data from three flow recorder sites located within the Ashburton River catchment. The locations of the flow recorder sites are shown in Figure 1 attached to this memo. All mean daily and instantaneous flow recorder data was provided by Environment Canterbury (ECan) in .csv format. Table 1 presents a summary of the flow recorder data provided including station number and available record period.

Table 1: Flow Recorder Site Summary

Name	ECan Station I.D.	Available record period
Ashburton River at SH1	68801	21/Jun/1996 to 13/Mar/2018
North Ashburton River at Old Weir	68810	7/May/1982 to 25/Feb/2018
South Ashburton River at Mt Somers	68806	28/Apr/1967 to 13/Mar/2018

The catchments for the North Ashburton River at Old Weir and South Ashburton at Mt Somers drain the majority of the hills in the Ashburton Catchment. There are three other permanent recorder sites in the Ashburton Catchment being Taylors Stream at SH72, Bowyers Stream at SH72 and Pudding Hill Stream at Mt Hutt. The catchment areas at these recorder sites is relatively small and the available record period for these recorders is relatively short. Therefore these flow recorders were not used in the analysis.

The Ashburton River upstream of the SH1 flow recorder site is significantly modified by a number of existing water takes and discharges. The Rangitata Diversion Race (RDR) takes water from the South Ashburton River downstream of the Mt Somers recorder site. At times, the RDR also spills water back into the North and South branches of the Ashburton River. The location of the RDR is shown on Figure 1.

The Ashburton District Council (ADC) takes stockwater at a number of intakes within the Ashburton River and its tributaries. There are 15 metered stockwater intakes within the Ashburton River catchment upstream of SH1 that are relevant to this analysis.

Table 2 presents a summary of the flow data obtained for the RDR and ADC stockwater takes.

Table 2: Existing Takes/Spill Data		
Name	**Available record period**	**Source**
RDR take from the South Ashburton River	23/Sep/2009 to 14/Mar/2018	Boraman Consultants
RDR spill into the North and South Ashburton Rivers	7/Mar/1997 to 4/Jan/2018	Boraman Consultants
Asburton Stockwater Takes	27/Jun/2012 to 31/Mar/2018	Ashburton District Council

In addition to the above takes and spills, there are a number of other consented takes from the Ashburton River and its tributaries. All existing consents within the Ashburton River catchment were obtained from ECan for the analysis.

Methodology

The naturalised synthetic flow record has been constructed in two steps, including:

1. Creating a naturalised flow series at the SH1 recorder site; and
2. Completing a regression of the upstream flow recorder sites located within the Ashburton River Catchment against the naturalised flow series at SH1.

Constructing Naturalised Flow at SH1 Recorder Site

Mean daily flows were calculated from the instantaneous data for the available record period for each flow recorder site. Note: A review of concurrent flow gaugings from the recorder sites provided insufficient data for a regression using gauging data. Therefore, mean daily flows were used for the regression analysis.

Mean daily flow for the Ashburton River at SH1 were offset to allow for the flow travel time (approximately 11 hours) between the upstream recorder sites and SH1. The approximate travel time was calculated by comparing recorded flood peaks between Mt Somers and North Ashburton at Old Weir for a number of small flood events. Including travel time in the analyses resulted in an improvement for the regression analysis.

A review of all existing ECan take consents from the Ashburton River and its tributaries found that the majority of takes occur during the irrigation season (1st September to 30th April). As many of these existing takes have no available flow data all days inside the irrigation season were removed from the regression analysis.

The future 2033 flow and allocation regime for the Ashburton Catchment is defined in Section 13 of the land and Water Regional Plan (LWRP). Under this regime the minimum flow in the Ashburton River is 10 m^3/s as measured at SH1 with a total A- and B-block allocation of 20.1 m^3/s and a gap of 4 m^3/s between the A- and B-block. Therefore a naturalised flow series is required for flows up to 34.1 m^3/s at SH1 (i.e. 10 m^3/s minimum flow plus 20.1 m^3/s allocation plus a 4 m^3/s gap). As such the target flow range (for the Ashburton River at SH1) for the regression analyses are flows up to 34.1 m^3/s. Flows above 34.1 m^3/s were therefore not used in the regersssion analysis.

At times, the RDR spills water in the South and North Ashburton Rivers. Boraman Consultants have indicated that spills in the spill flow record below 150 L/s are likely to be a result of inaccuracies at the bottom end of the rating and not real flow. Based on this information all days where the spill into the North and/or south

Ashburton River was greater than 150 L/s were excluded from the regression analyses.

ECan comment files for all recorder sites were reviewed to assess the quality of the flow record. Data coded as 'poor' were removed from the analysis. Two periods of data were found to be "poor" including: SH1 flow recorder for 15/May/2014 to 8/June/2014 and 22/August/2015 to 31/August/2015.

A review of the stockwater intake data provided by ADC found that complete intake data records are available from 2014 to 2016. Other years were reported to have missing data for a number of intakes and so do not provide an accurate representation of the actual amount of stockwater taken from the Ashburton Catchment. The mean daily stockwater take for 2014 to 2016 was added to the recorded flow at the SH1 recorder site. Because the stockwater take data was only available for 2014 to 2016 all flow data outside of this period was removed from the analysis.

The mean daily RDR intake flow from 2014 to 2016 was added to the recorded flow at the SH1 recorder site.

A review of other consented takes from the Ashburton River and its tributaries found that during winter, there is an approximate take of 20 L/s upstream of the SH1 recorder site. This take can be mainly attributed to non-irrigation uses during the winter such community supply bores with a stream depleting effect. This 20 L/s was added to the flow at SH1.

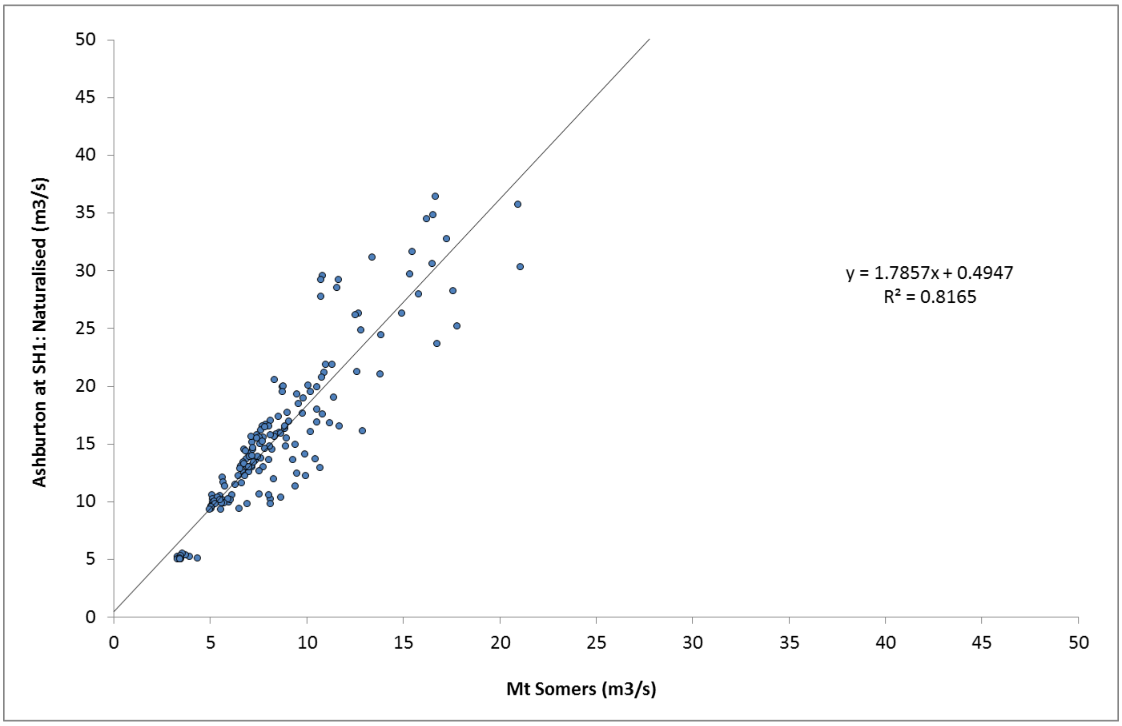
Regression

Once the naturalised flow at the SH1 recorder site was obtained a regression was completed against the upstream flow recorder sites for the following scenarios:

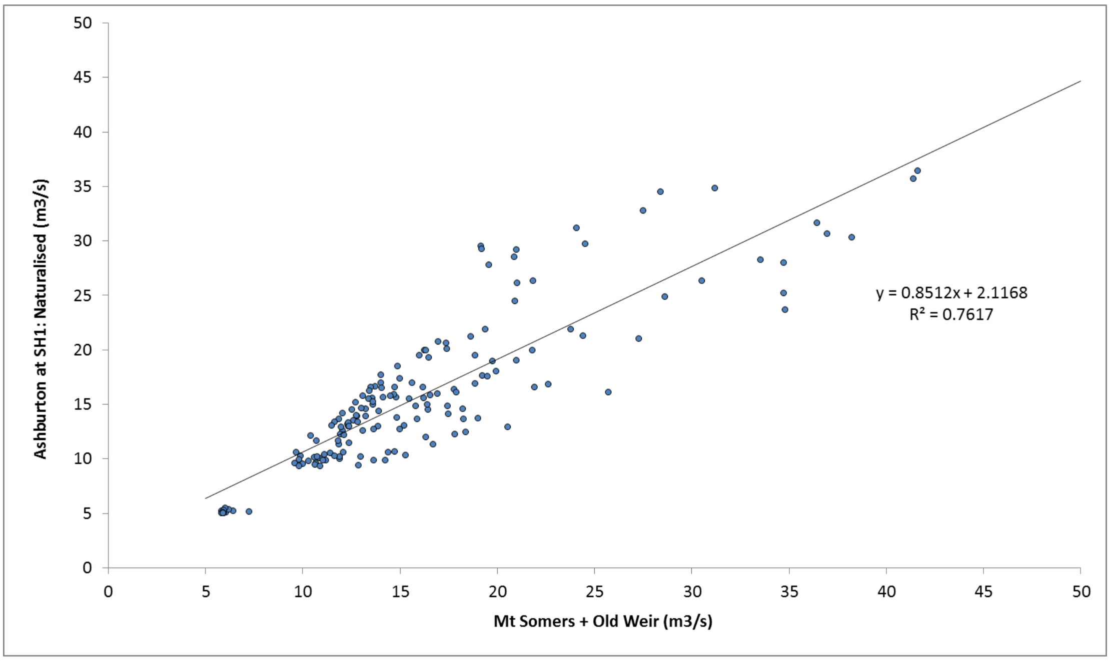
- South Ashburton River at Mt Somers vs. Naturalised Ashburton River at SH1.
- South Ashburton River at Mt Somers + North Ashburton River at Old Weir vs. Naturalised Ashburton River at SH1 vs.

The plots below show the resulting regression plots.

Plot 1: South Ashburton River at Mt Somers vs. Naturalised Ashburton River at SH1



Plot 2: South Ashburton River at Mt Somers + North Ashburton River vs. Naturalised Ashburton River at SH1



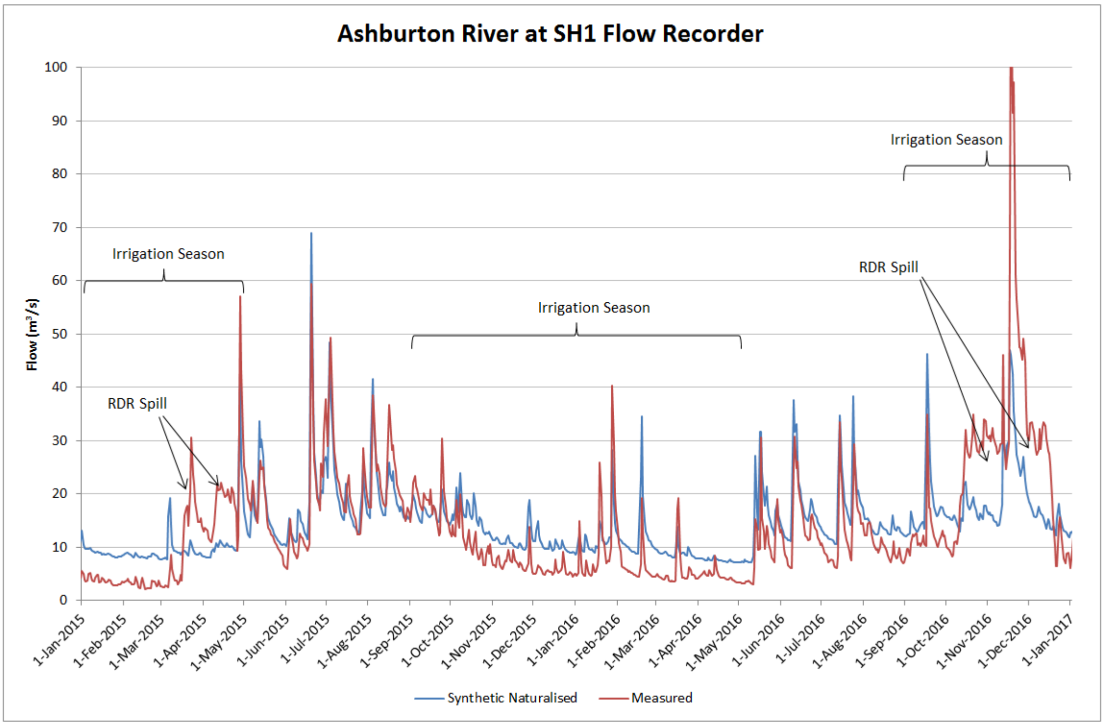
The regression plots show a reasonable correlation between the upstream flow recorders and the naturalised flow at SH1. It is recognised that there is a reasonable 'amount of scatter' in the regression plot. However, the long term synthetic flow record produced from these regression plots is considered to provide a reasonable estimate for natural flows in the Ashburton River at SH1 and as such, can be used to provide an indication of the likely storage requirements under the 2033 flow regime for the Ashburton River.

Results

To generate the final naturalised synthetic record, the regression equations shown in Plots 1 and 2 were applied to the upstream recorder sites. Based on the available record period for the recorder sites (refer to Table 2) regression plot 1 (Mt Somers vs. Ashburton River at SH1) was used to create a natural flow record for the period 1971 – 1982. For the period between 1982 and 2018 when flow data is available for both the North Branch at Old Weir and the South Branch at Mt Somers plot 2 was used to create a natural flow series for SH1.

Plot 3 shows an overlay of the naturalised synthetic record and recorded flow at the SH1 recorder site.

Plot 3: South Ashburton River at Mt Somers + North Ashburton River vs. Naturalised Ashburton River at SH1



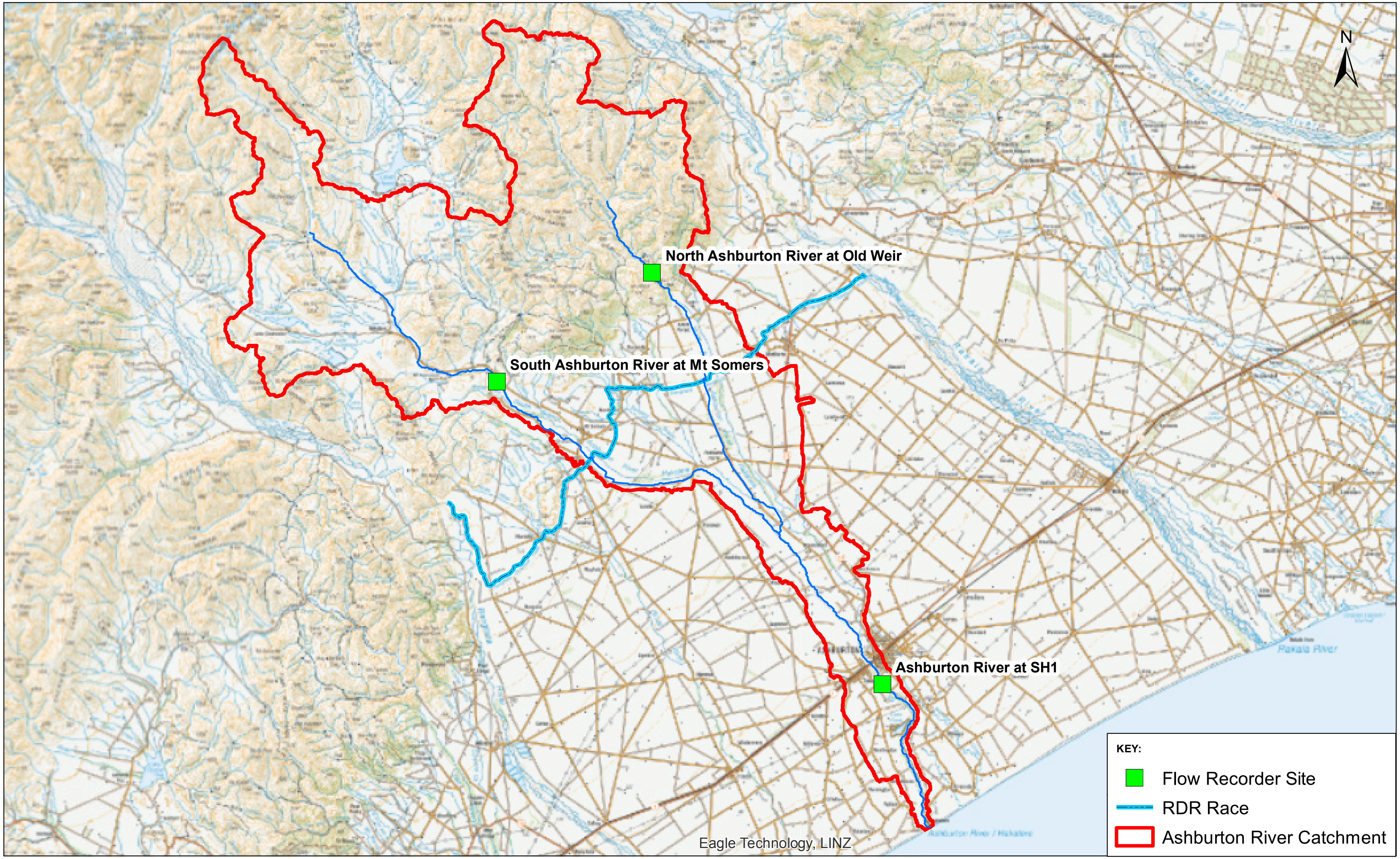
Stockwater Takes

An estimate of the future 2033 ADC stockwater take has been completed for modelling purposes. As discussed above a review of the stockwater intake data provided by ADC found that complete intake data records are available from 2014 to 2016. Table 3 shows the average stockwater take for the 2014 to 2016 period.

Table 3: ADC Stockwater Flows for Intakes in Ashburton River and Tributaries above SH1

Year	Average Yearly Stockwater Take (m^3/s)
2014	2305
2015	2050
2016	2049

ADC has indicated through discussion that a 5% reduction in stockwater take per year can be expected into the future. Based on an assumed existing stockwater take of 2049 L/s, and the 5% yearly reduction, the 2033 stockwater is calculated to be approximately 950 L/s.

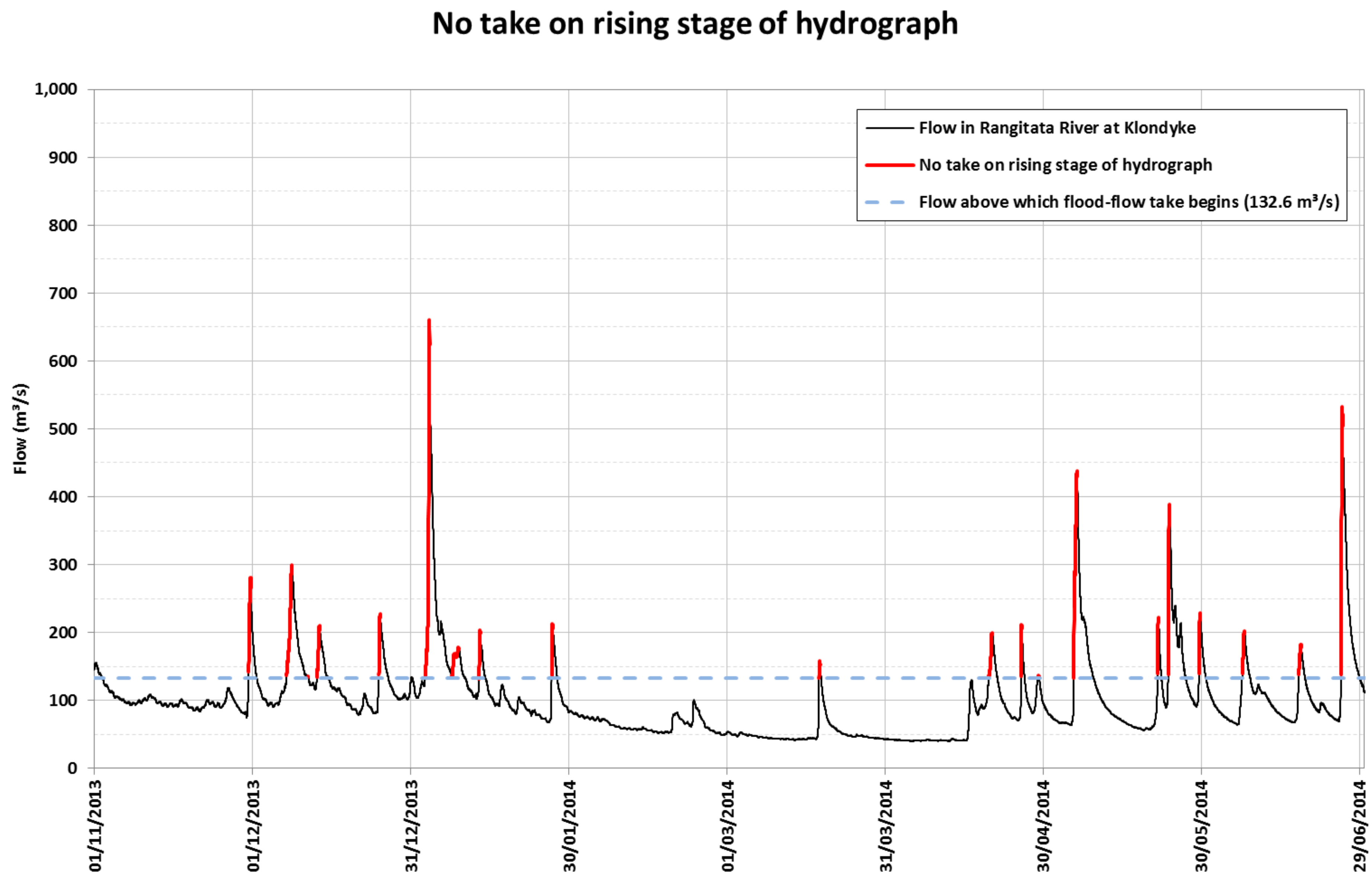


SOURCE:
1. TOPOGRAPHICAL INFORMATION
AND INSET DERIVED FROM LINZ DATA.

FIGURE 1 : ASHBURTON RIVER CATCHMENT, FLOW RECORDER SITES AND RDR

Appendix B

Example hydrograph 2013 – 2014: Rising stage of hydrograph



No take on rising stage of hydrograph
Flow in Rangitata River at Klondyke
No take on rising stage of hydrograph
Flow above which flood-flow take begins (132.6 m³/s)
Flow (m³/s)
1,000
900
800
700
600
500
400
300
200
100
0
01/11/2013
01/12/2013
31/12/2013
30/01/2014
01/03/2014
31/03/2014
30/04/2014
30/05/2014
29/06/2014