Otago Regional Council

Document Id:

MEMORANDUM

To: Tom Dyer

From: Jason Augspurger

Date: 03/10/2023

Re: Taieri Water Balance Memo

Purpose

The purpose of this memo is to provide a "stock/balance" approach to determine potential allocation pressure, data issues, and highlight potential risks of altering the existing flow regime without further information.

Context

Traditionally, allocation pressure on water bodies is assessed by ORC through modelling and/or measuring the natural flow regime and then assessing the impacts of current and proposed flow alteration. In the Taieri catchment, a number of factors make this difficult including:

1. Highly variable rainfall throughout the catchment
2. Complex water movement throughout the catchment
3. Numerous on-farm storage ponds
4. A dam in the upper catchment
5. Inter-catchment transfers
6. Significant lag times

ORC has pursued a bespoke hydrology model for the Taieri catchment capable of generating naturalised flow statistics and time-series. A robust, fit for purpose, hydrological model capable of delivering these outputs is the most robust and appropriate way to determine the potential allocation pressure and ecological impacts within the Taieri catchment.

Along side this information, a water "stock" or "balance" approach developed from ORC's in progress water accounting system can be used to inform data issues and potential allocation pressure at key points in the catchment. This approach investigates the proportion of the catchments total water take supplied by Logan Burn Reservoir by subtracting the water abstracted from that released from the Logan Burn Reservoir. A positive number indicates a water "surplus" from Logan burn (i.e. the stored water from logan burn is not all taken). From a mainstem perspective[1] this means flows are higher than natural. A near zero number indicates mainstem flows at that point are approximately same as they would be naturally and thus while stored water is taken, no run of river water is taken. Therefore, the realised primary allocation is small. A negative number indicates a deficit where all of the water released by Logan Burn is abstraced and additional “run of river” water is also being abstracted. Running a “deficit” does not necessarily lead to unacceptable environmental outcomes. Some level of run of river abstraction is likely to be considered acceptable.

Methods

To determine realised primary allocation pressure, the Logan Burn water meter (WM0966) was used as its discharge record. Logan Burn has a high-flow by pass which is not measured through this meter. At times of high flow, logan burn often shows a metered reading of 0. Two evaluations were used to remove the potential “high flow” records. First, winter months were removed leaving November-April inclusive. Second, the median flow at a natural flow site (Taieri at Canadian Flat) was calculated. To confirm that flows below the median represent when Logan Burns discharge occurs, the Logan Burn discharge was plotted against the Taieri at Canadian Flat flow record and visually inspected. Records above this value (flow of approx 1.6 m^3/s at Canadian flat) were then removed. To enable assessment at periods of low flow, records when Taieri at Canadian Flat is below its 7-dMALF (<0.800 m^3/s) were selected.

To evaluate a potential balance, two approaches are were used. The first approach simply aggregates all metered water-take data above Waipiata and then between Waipiata and Outram. This approach has a number of large caveates listed below. “Blind” metered water-take accumulation in this catchment is likely to over-estimate abstraction and, while potentially indicative of allocation pressure, requires additional context to better understand the water meter records. The accumualted water abstracted is subtracted from the Logan Burn discharge to provide a water balance figure for Waipiata. The water demand above Outram, but below Waipiata, is then subtracted from this figure to provide the Outram balance figure. To provide summary statistics, descriptive statistics (percentiles, mean, median) are calculated for each irrigaiton year (1 July to 30 June) and the mean of the annual statistic is then calcualted.

[1] The concept of spatial scale is important to consider. On a tributary scale, a Logan Burn “surplus” does not mean there is no run of river abstraction. Logan Burn does not supplement tributaries, solely the mainstem. As a result, a mainstem surplus does not indicate there are not localised areas of high allocation pressure in tributaries.

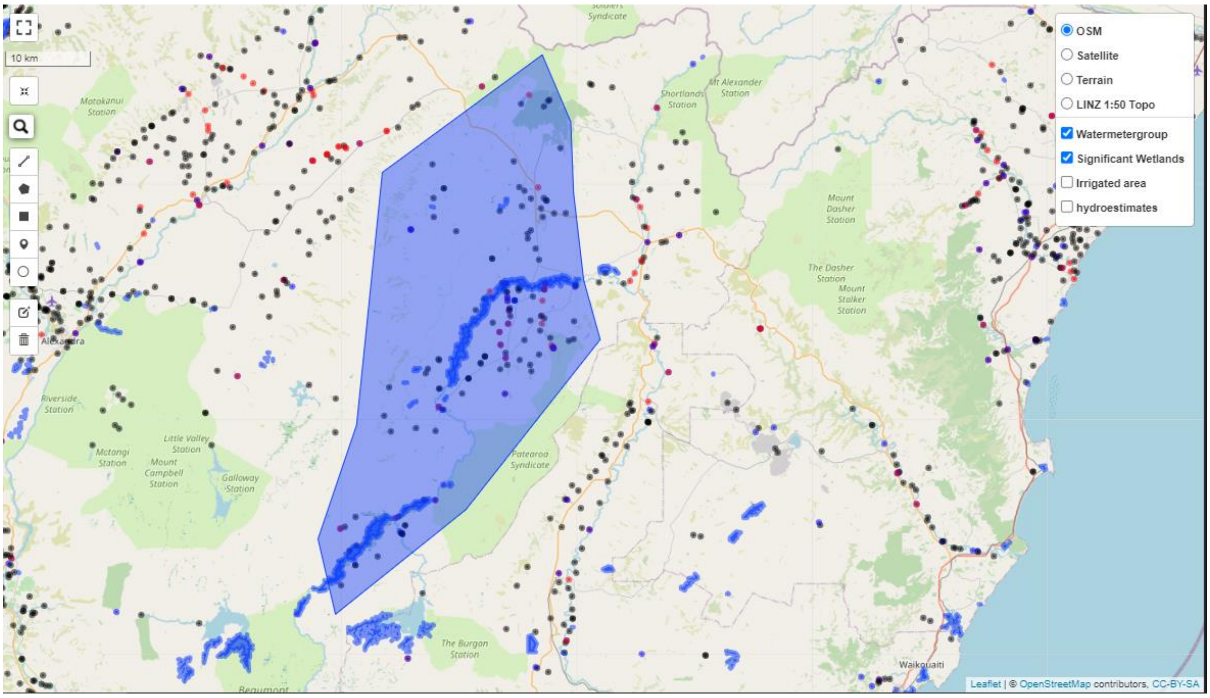

Figure 1: Selected water takes above Waipiata

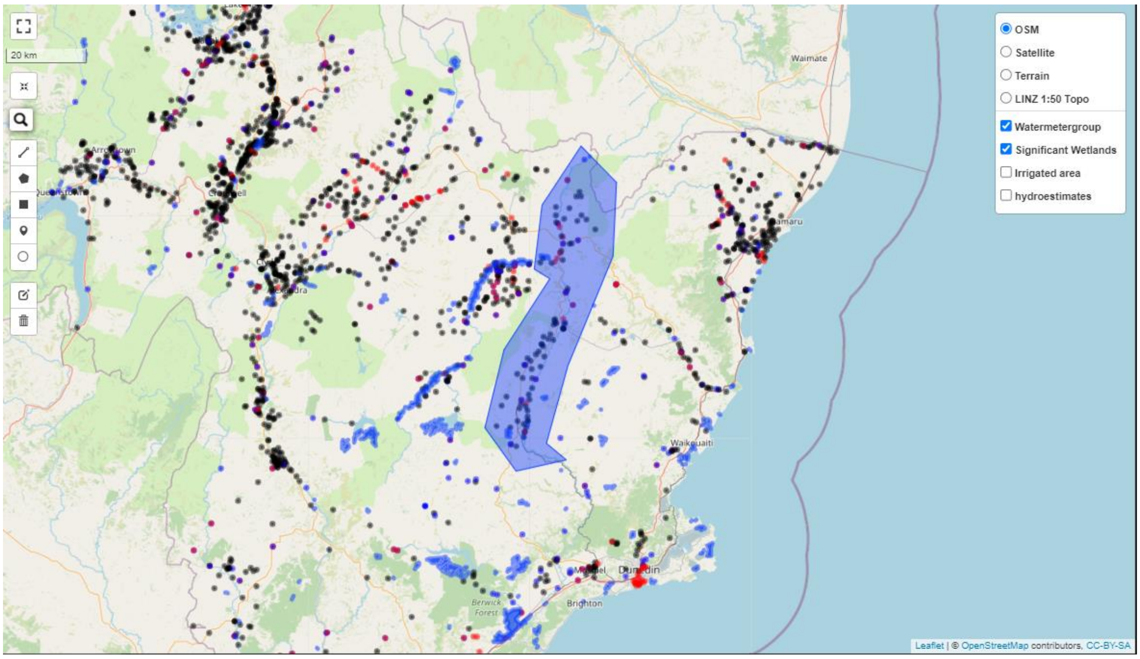

Figure 2: Selected water takes above outram

Water meter caveats

Water metering data was used in this analysis due to the convience of its aggregation and general link to demand. However, water-metering data has many significant potential issues:

1. Water movement and historic irrigation systems often result in water meters re-measuring water (i.e. re-take/double accounting). Re-takes have not been accounted for nor removed from this analysis. Simliarly, outlier and other common take issues

have not been addressed. As such, the analysis takes all of the meters in the selection range and "blindly" accumulates them.

2. Water meter records often have "gaps". This analysis auto fills the gap by using the existing record, calculating the Julian day of the year starting on July 1st and then using a spline through the resulting data such as that below. Splines have not been audited nor manually adjusted to provide a better fit for the gap they are filling. The percent of data gap-filled (i.e. modelled) vs. measured is provided.
3. Water meters often have insufficient validation and therefore records can be very dubious. However, they do represent a reconsenting reality and so should not be totally excluded from consideration.
4. Lag times naturally occur between Logan Burn and when water is taken downstream. These are not accounted for in anyway; a "same day" relationship is applied across a catchment. Lag times in this catchment can be multiple days.
5. The Taieri catchment is supplied from the Mt Ida Water Race which brings in water from the Manuherikia catchment. Meters near Naseby were excluded. However, this should be further queried in a future analysis[2].

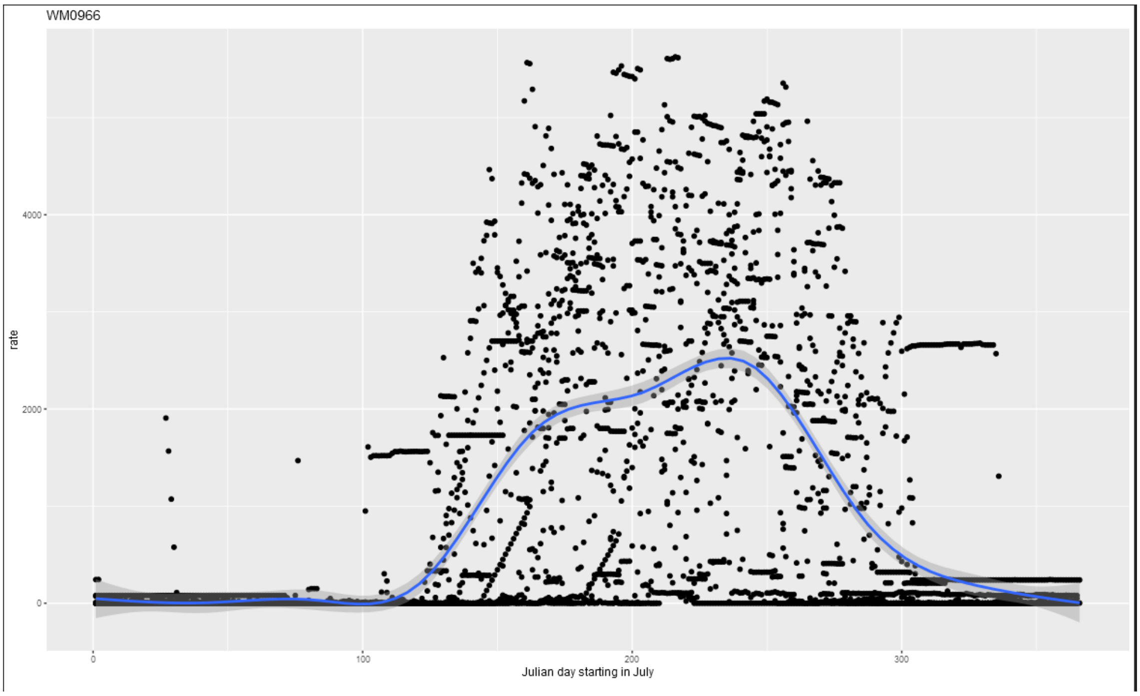

Figure 3: Example of gap filling spline

Irrigation Demand

The second approach used is to estimate irrigated demand upstream of Waipiata and between Waipiata and Outram. To calculate irrigated demand, Aqualinc's Update of Reasonable Water Requirements for Pastoral Land Uses (Kashima 2022) was applied on ORC's mapped irrigated area (Dark and Kashima 2021). The weighted (by land use) average daily demand (mm/d) was converted into a daily mean abstraction rate (m^3/s). Generally, demand figures exceed the

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[2] There are additional caveats around water meters not discussed here as these caveats are sufficient for the purpose of this memo.

actual water applied. However, ORC's irrigation mapping is incomplete and therefore the demand must be interpreted as such.

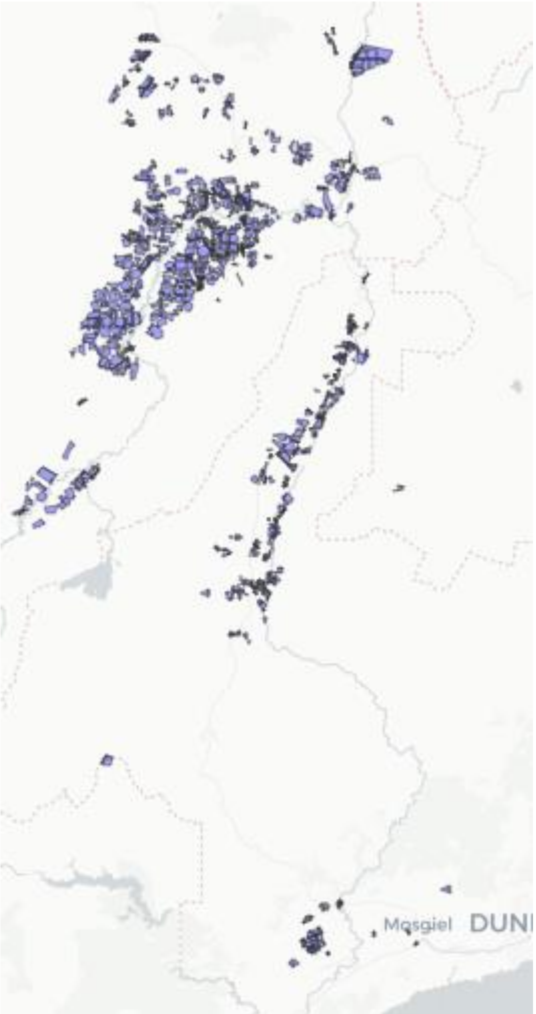

Figure 4: Mapped irrigated area in the Taieri Catchment

For simplicity, existing spatial polygons were used to determine demand which cover the area upstream of Waipiata, but exclude the area around Patearoa, and a polygon which encompasses the entire Taieri catchment. These do not directly align with the water-takes upstream of Waipiata and upstream of Outram. However, they are likely to give a general idea of potential water demand.

Bracketing

To reconcile the differences in water demand and metered summer water take, a bracketing a approach is used. The lesser of the water demand and lower quartile of metered summer water take is used as a lower bound and the greater of demand and upper quartile of metered summer water take is used as an upper bound. Additional middle increments were added as required.

Ecological interpretation

Ecological interpretation was completed by comparing ORCs advised default allocation guidelines (Hayes et al. 2021) based on the presumptive flow standard for flow alteration

(Richter et al. 2012). To determine a low flow statistic, the NIWA River Maps MALF at Waipiata (2 m^3/s) and Outram (5 m^3/s) were used .

Additional limitations

This analysis assumes the release from Logan Burn Reservoir is comprised entirely of stored water and contain no “run of river” water. This assumption is false as prior to impoundment a natural flow regime would have occurred. As a result, a temporally variaible component of the release is not stored water. In the absence of naturalised flow timeseries for the Logan Burn, the NIWA Rivermaps MALF estimate is 0.184 m^3/s (Booker and Woods 2014). Natural flows of this order of magnitude should be considered when interpretting the balances.

Results

Logan Burn Discharge

The Logan Burn discharge shows a pattern of discharging approx. 2-2.5 m^3/s in summer with values as high as 6 m^3/s.

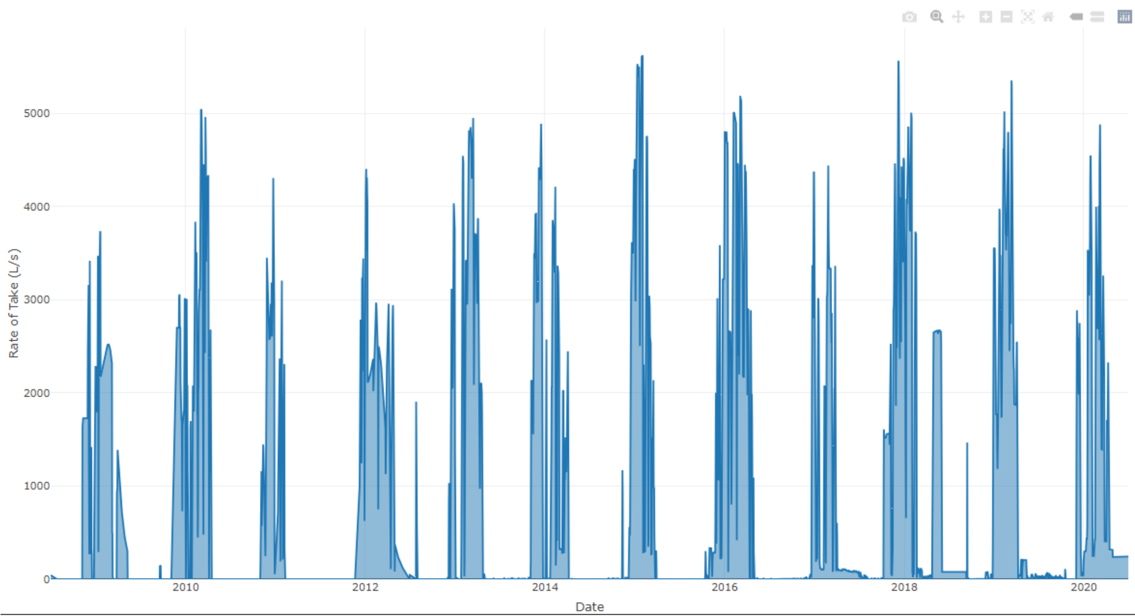

Figure 5: Logan Burn discharge record.

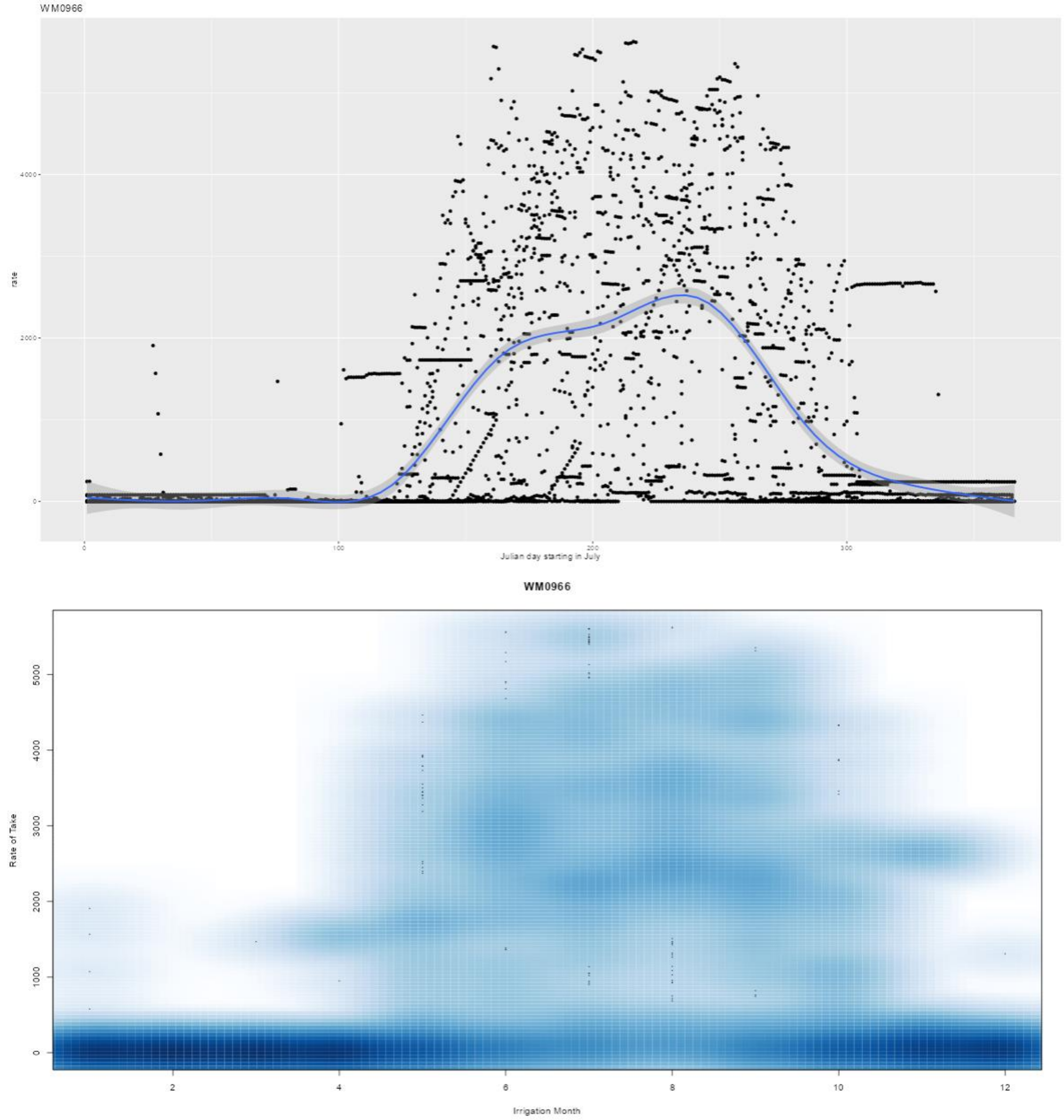

Figure 6: Logan Burn discharge (WM0966) visualised as a meter time series, Julian day with gap-fill spline, and point cloud on Julian day.

Above Waipiata takes

Of the water meter data selected, the majority of meters supply records from 2015-2020. Prior to 2015, a large portion of the meter data is filled using the gap fill splines. Takes above Waipiata often take approximately 5 m^3/s during their summer peaks with higher pulses.

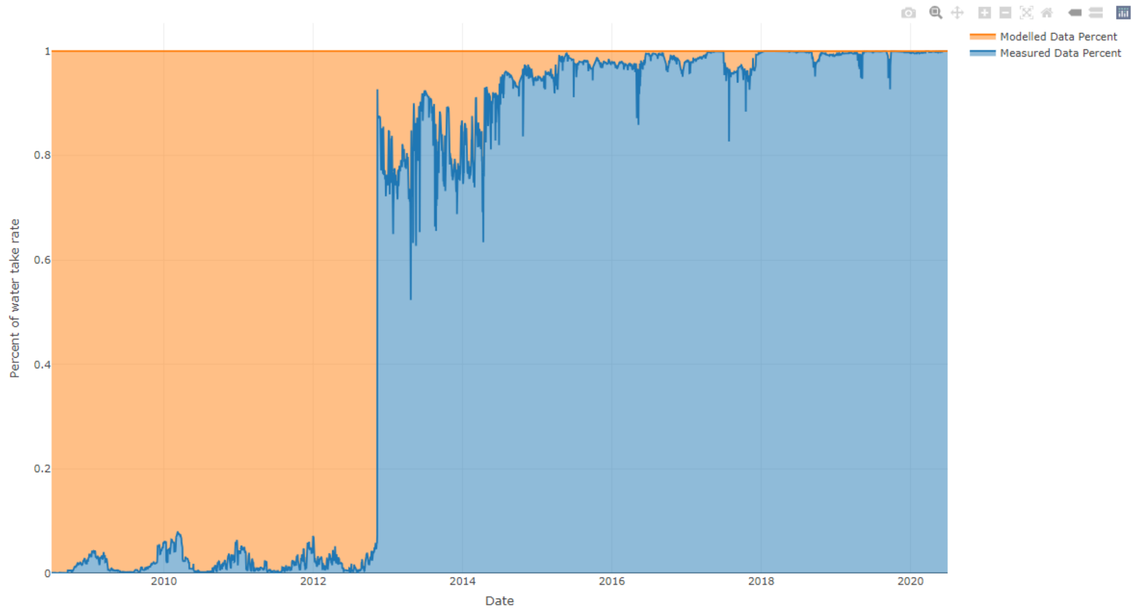

Figure 7: Modelled vs. metered data for the water-takes above Waipiata. Post 2013, the majority of meters selected are reporting values.

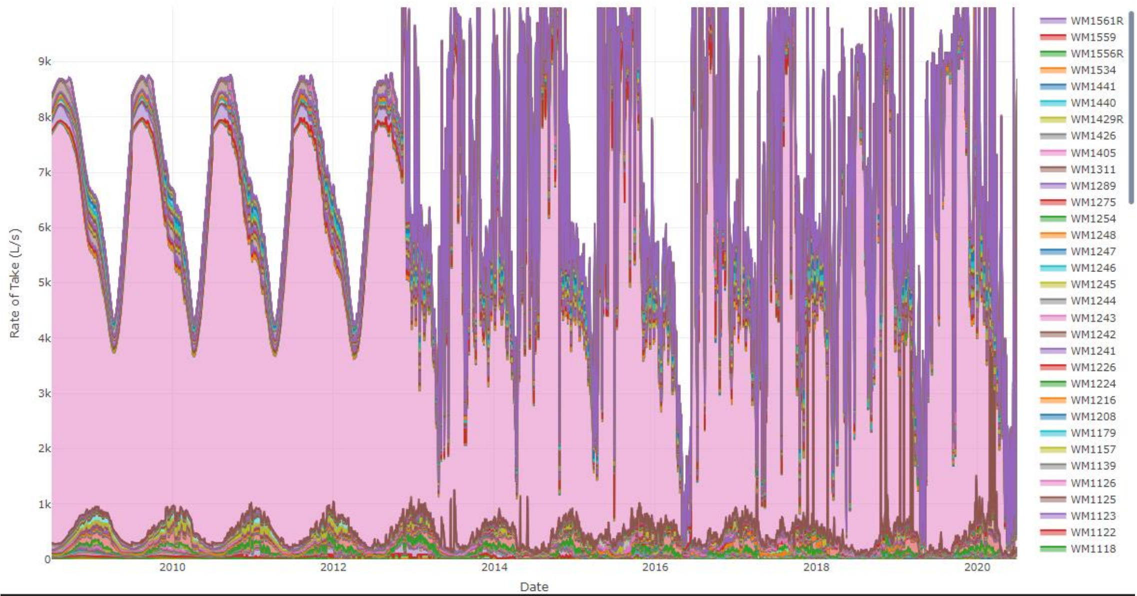

Figure 8: Metered water take above Waipiata. Note that post 2015 the water-take data shows many spikes. The spline approach used to model the data removes these and thus the prior to 2014 period, which is primarily modelled, does not have spikes.

Above Outram below Waipiata takes

Of the water meter data selected, the majority of meters supply records from 2015-2020. Prior to 2015, a large portion of meter data is filled using the gap fill splines. Takes above Outram and below Waipiata often take approximately 1000 L/s during their summer peaks with higher pulses.

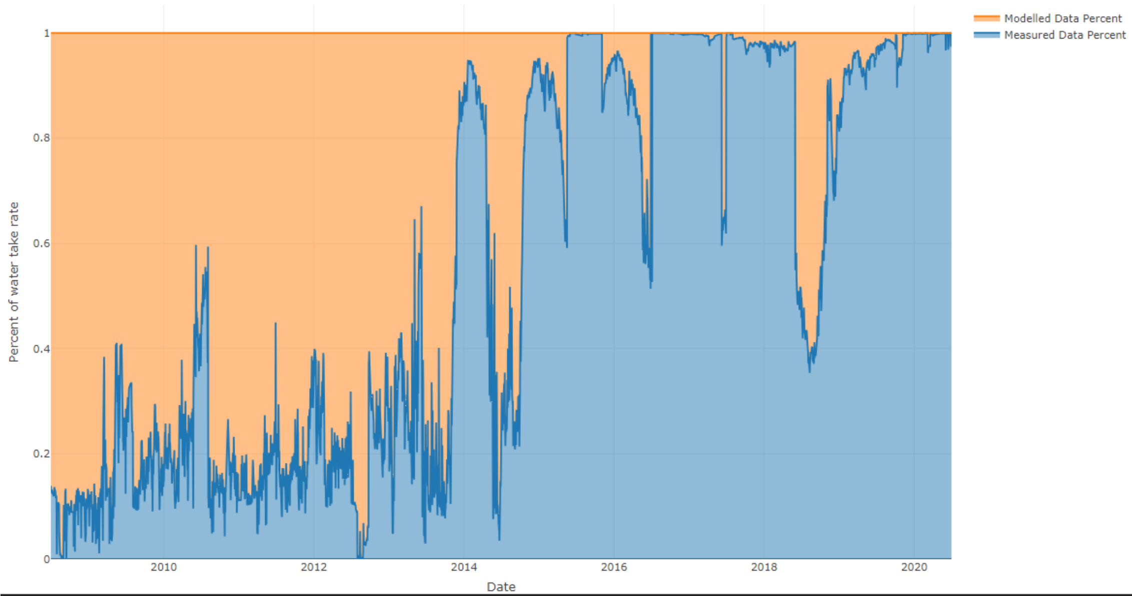

Figure 9: Modelled vs. metered data for the water-takes above Outram and below Waipiata. Post 2015, the majority of meters selected are reporting values.

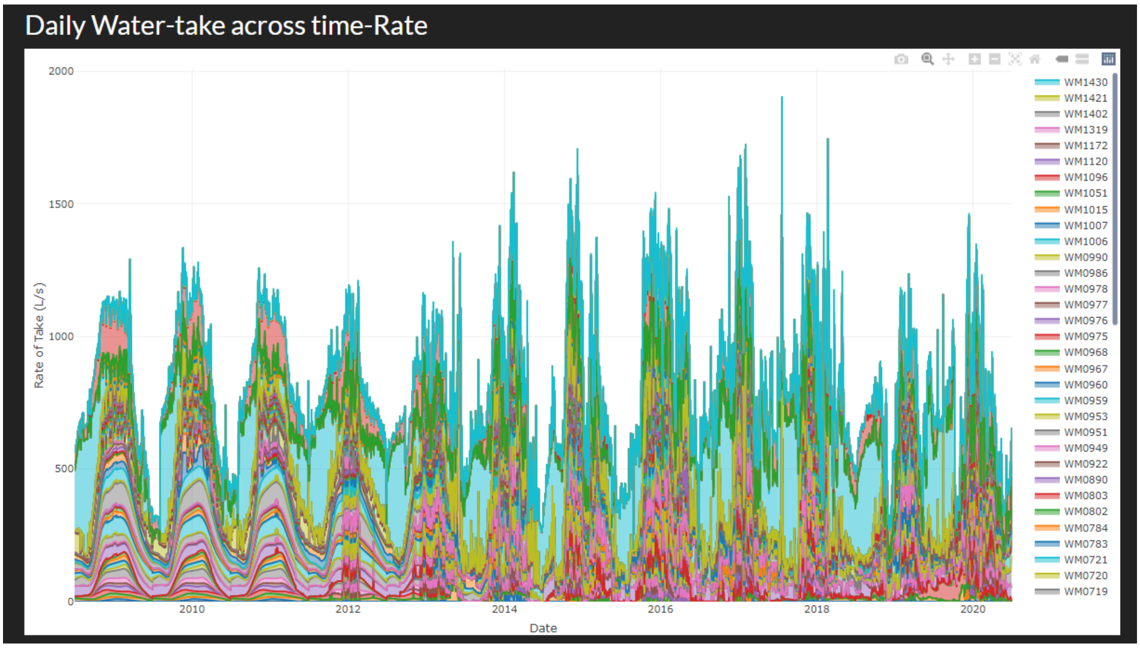

Figure 10: Metered water take above Outram and below Waipiata. Note that post 2015 the water-take data shows many spikes. The spline approach used to model missing data removes these and thus the prior to 2014 period, which is primarily modelled, does not have spikes.

Table 1: Metered summer mean water abstraction when Canadian Flat is below median flow (1.76)

Site	Min	25th percentile	Median	Average	75th percentile	Max
U/s Waipiata	2.54	4.53	5.52	5.36	5.90	9.54
U/s Outram	3.23	5.41	6.48	6.33	7.08	10.07

Metered Abstraction Water balance- Canadian flat median flow

Water balances calculated when the Taieri at Canadian Flat is at or below median flow indicate the balances are consistently negative. Therefore, at least some run-of-river water is being abstracted.

Table 2: Mean water balance percentiles for the area upstream of Waipiata and upstream of Outram when Canadian flat is at or below median flow. Negative values indicating water taken that is not stored whereas positive values indicate stored water has not been taken (i.e. supplementing mainstem flows)

Water balance Percentile	Upstream Waipiata	Upstream Outram
5	-4.51	-5.48
25	-3.17	-4.20
50	-2.50	-3.50
75	-1.88	-2.79
95	-1.15	-1.99
100	-0.777	-1.61
Average	-2.68	-3.61

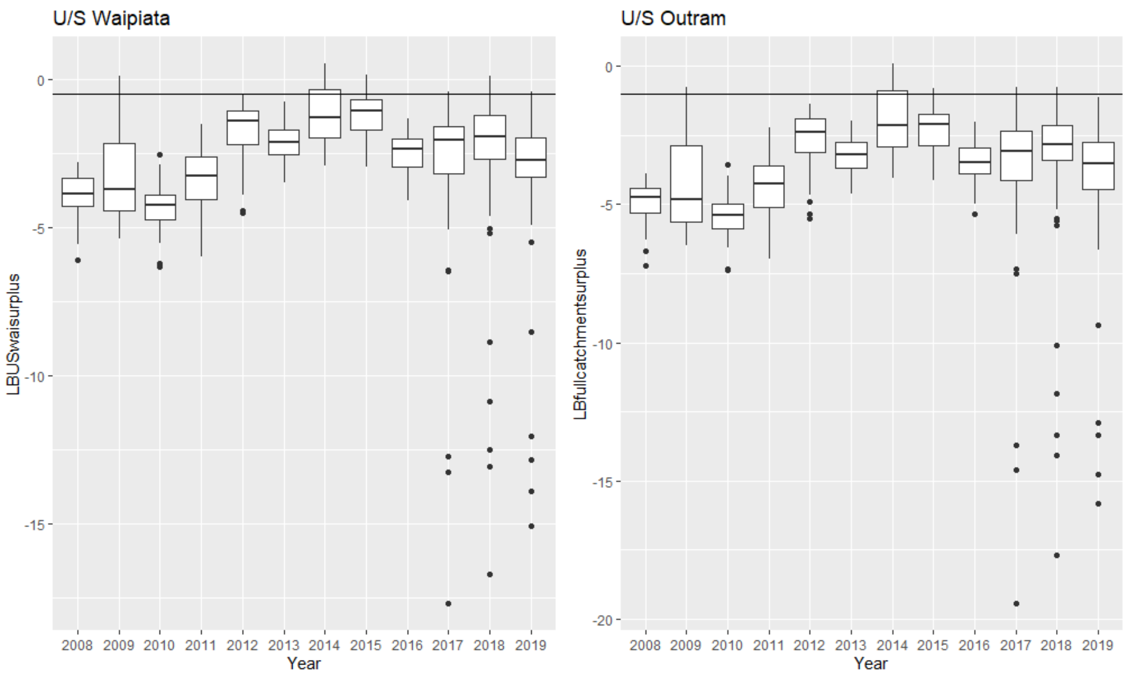

Figure 11: Boxplots of summer water balance when Canadian flat is below median flow where positive numbers indicate a surplus of water from Logan Burn and negative numbers indicate abstraction beyond that released by Logan Burn.

Canadian Flat low flow

Water balance numbers when the Taieri at Canadian Flat is experiencing low flow conditions indicate numbers which begin to approach zero suggesting less flow alteration during these periods. Alteration in these periods more closely align but exceed the values suggested by ORCs default allocation guidelines (Hayes et al. 2021).

Table 3: Water balance percentiles for the area upstream of Waipiata and upstream of Outram when Canadian flat is experience low flows. Negative values indicating water taken that is not stored whereas positive values indicate stored water has not been taken (i.e. supplementing mainstem flows)

Water balance Percentile	Upstream Waipiata	Upstream Outram

5	-2.27	-3.25
25	-1.80	-2.70
50	-1.38	-2.28
75	-1.08	-2.03
95	-0.740	-1.57
100	-0.559	-1.38
Average	-1.54	-2.45

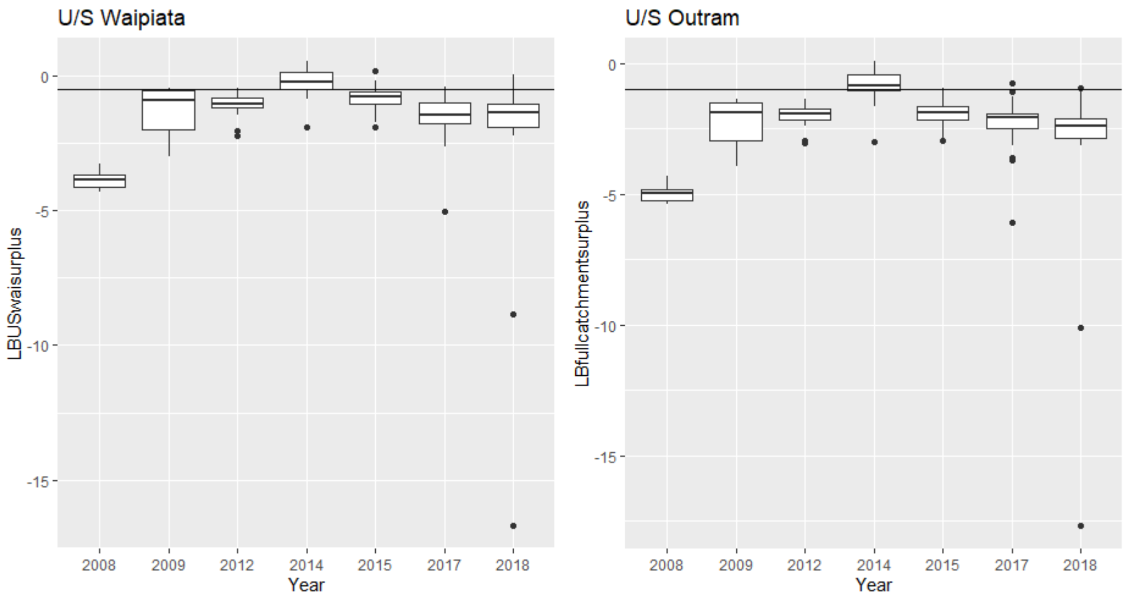

Figure 12: Boxplots of annual water balance when Canadian flat is experiencing low flows (lower quartile) where positive numbers indicate a surplus of water from Logan Burn and negative numbers indicate abstraction beyond that released by Logan Burn.

Irrigated demand

Irrigated demand for the Taieri catchment is approximately 3 m^3/s above Waipiata and 4 m^3/s for the whole catchment. These values are substantially less than the estimated abstraction determined by meter accumulation.

Table 4: Estimated water demand based on irrigated area

Site	Demand	Demand minus border dyke+flood
U/s Waipiata	2.73	2.3
Taieri Catchment	4.18	3.74

Bracketing

Based on the estimated water demand, four scenarios were developed. The first scenario aligns with the irrigated demand figures with 3 m^3/s of demand above Waipiata and 4m^3/s for the whole catchment. The second scenario is 4 m^3/s above Waipiata and 5m^3/s for the whole catchment. Scenario three more closely resembles the abstraction data with 5 m^3/s abstracted above Waipiata and 6 m^3/s for the whole catchment. The fourth scenario provides and upper bound of 6 m^3/s above Waipiata and 7 m^3/s for the catchment as a whole.

Scenarios

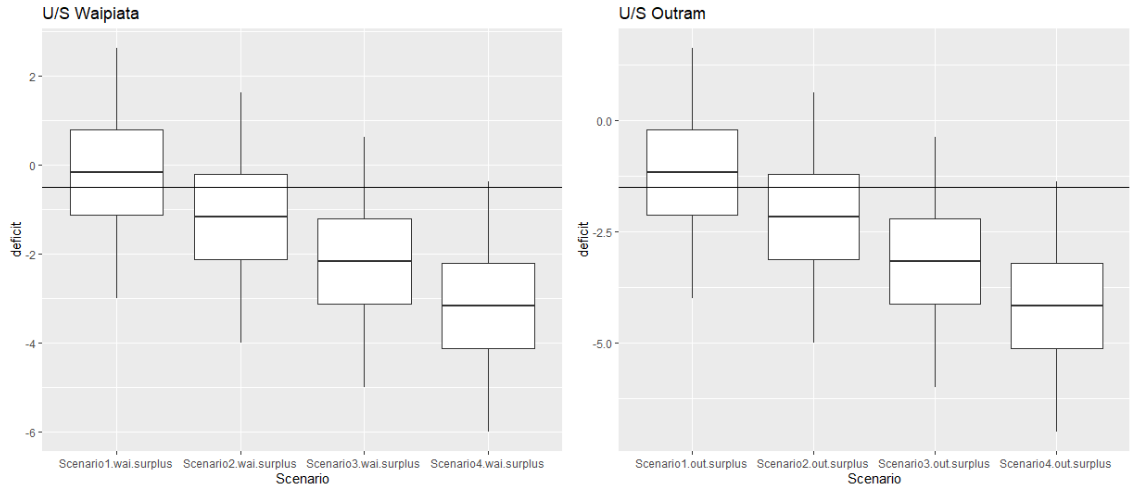

Figure 13: Box plot of water surplus above Waipiata (scenario 1= 3m^3/s, 4m^3/s, 5m^3/s, and 6m^3/s) and above Outram (scenario 1= 4m^3/s, 5m^3/s, 6m^3/s and 7m^3/s) when Canadian Flat is below median flow.

When Canadian flat is below median flow, the scenario analysis indicates water balances approaching neutral through to highly negative values. The first scenario has a median value of approximately zero above Waipiata indicating the river is supplemented approximately 50 percent of the time and run of river water is abstracted 50% of the time. Scenario two, three and four show predominately negative balances. When considering the catchment as a whole, all scenarios are predominantly negative.

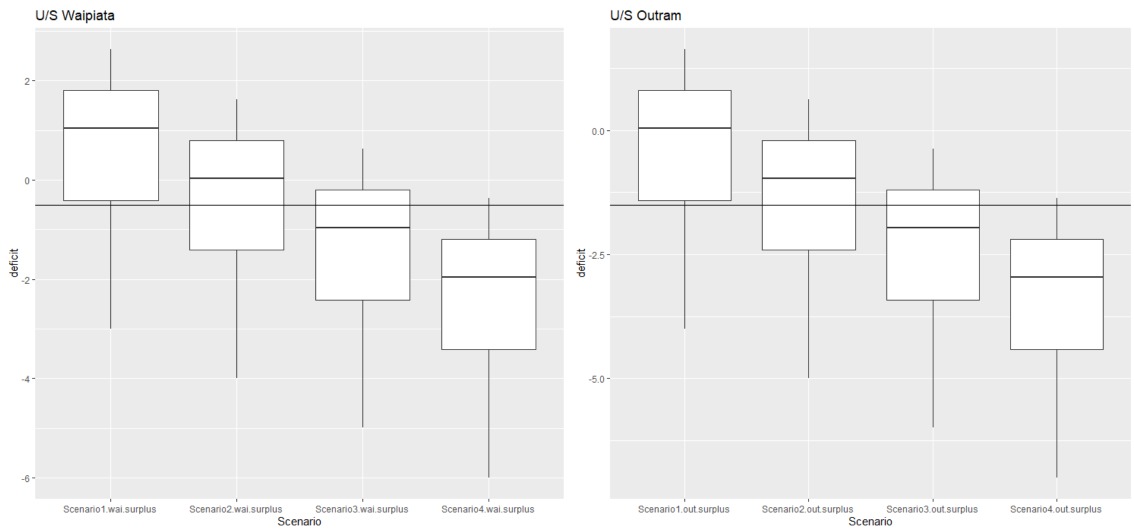

Figure 14: Box plot of water surplus above Waipiata (scenario 1= 3 m3/s, 4 m3/s, 5 m3/s, and 6 m^3/s) and above Outram (scenario 1= 4 m3/s, 5 m3/s, 6 m3/s and 7 m3/s) when Canadian Flat is below the 7-dMALF.

When Canadian Flat is at low flow, scenarios one and two indicate predominantly positive or neutral balances above Waipiata and balances which adhere to default guidelines over 50% of the time (Hayes et al. 2021) . Scenarios three and four indicate predominantly negative values and higher level of run of river abstraction.

Discussion

Metered Scenario

Based on all metered data, the Logan Burn-abstraction balance is generally negative indicating “run of river” water is being abstracted in addition to stored water release from the Loganburn Reservoir. The run of river water being abstracted would be considered “true” primary allocation whereas the “stored water” could be removed from this allocation block.

The analysis is significantly complicated by the metering arrangement around the Paerau power station (WM0970). It is difficult to determine whether, and when, the metered data is totally or partially consumptive. This particular meter comprises most of the measured abstraction. If a substantial portion is discharged into the river, then the water is double accounted.

Further, it is difficult to quantify what portion of metered data within the catchment is re-take etc. As a result, it is likely that the allocation “pressure” is lower than that indicated by the balances based on accumulated meters presented here.

As a result of likely discharges and double accounting in this catchment, it is not possible to develop a timeseries depiction of allocation pressure. In a simpler catchment, the surplus or deficit could be added or subtracted to a flow record. In this catchment this is not possible.

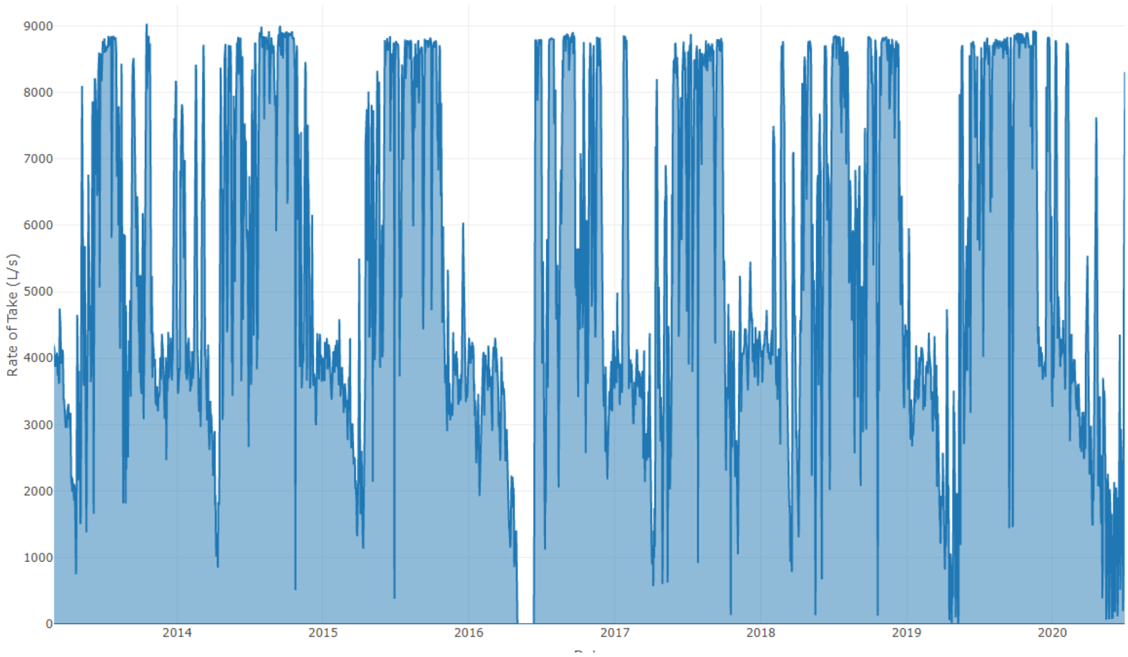

Figure 15: Water take record for WM0970

Irrigated demand and bracketing scenarios

The low-end scenario was determined based on demand for mapped irrigated area. The U/s of Waipiata demand is estimated as 3 m^3/s and the Outram demand is estimated as 4 m^3/s. Under this scenario, default allocation guidelines are exceeded less than 50% of the time with the median value having an approximately neutral balance meaning run of river water is neither supplemented nor abstracted at the Waipiata flow site. This would imply the true “primary allocation” block is small. Under the second lowest demand scenario (U/s Waipiata demand =4 m^3/s, U/s Outram demand= 5 m^3/s) the river is supplemented approximately 25%

of the time and beyond the Hayes threshold over 50% of the time implying a larger functional primary allocation block.

The two higher demands have water balances which suggest rare flow supplementing and predominantly negative balances suggesting large realised primary allocation blocks.

It is difficult to determine which scenario best represents reality due to uncertainty associated with the mapped irrigated area. Generally, reasonable irrigation demand exceeds the actual amount of water used to irrigate. In this analysis, the "reasonable demand estimation" is approximately half of the accumulated metered water take. It is difficult to determine whether this is due to an underestimate of irrigated area, substantial double accounting in the meter dataset or elements of both.

Ecological implications

As the default guidelines apply to the primary allocation block, the alteration level is best referenced at times of low flow. Higher levels of alteration than 20% of MALF are likely be environmentally acceptable at higher flow levels.

The low flow specific analyses, based on the accumulated meter data, indicate values which are regularly beyond these guidelines. As such, environmental effects such as reduced instream habitat cannot be ruled out.

The results of low flow specific scenario assessments vary. Scenario one is generally within the guidelines and surplus is provided (i.e. augmented flows). Scenario two is often within the guidelines and supplements flows in the river at times. Scenarios three and four regularly exceed the default allocation guidelines and run a deficit from natural flows.

Without the ability to assess a naturalised hydrograph, it is difficult to assess the full ecological impact of any of the scenarios. While supplementary flows from the Logan burn Reservoir could be considered an ecological benefit, they may also result in less hydrological variation than would naturally occur (i.e. flat lining). Scenarios three and four consistently run a deficit and therefore are likely to result in a reduction in in-stream habitat during low flow periods but may retain more flow variability.

Conclusion

Given the uncertainty, it is impossible to assess the ecological effects of alternative flow regimes. Mapped irrigated demand suggests potential ecological benefits though also the potential for flat lining; aggregated metered abstraction suggests a significant deficit and therefore potential for habitat reductions. Increases in minimum flow without appropriate allocation reduction and dam management could lead to extended flatlining as well as shifts in demand toward median, or higher, flows. This may have negative impacts on the Taieri Scroll Plain wetland. Lowering of minimum flows could lead to reduced instream habitat for many species.

To improve modelling results, ORC must rectify the disconnect between demand and measured abstraction to allow for re-apportioning what is currently considered primary allocation into appropriate blocks for stored and run of river abstraction. It would then be possible to the effects of the current and alternative flow regimes.

Works Cited

Booker DJ, Woods RA. 2014. Comparing and combining physically-based and empirically-based approaches for estimating the hydrology of ungauged catchments. J Hydrol. 508:227–239. https://doi.org/10.1016/j.jhydrol.2013.11.007

Dark A, Kashima A. 2021. Otago irrigated area spatial dataset: 2021 update.

Hayes J, Booker D, Singh S, Franklin P. 2021. Default Minimum Flow and Allocation Limits for Otago. Letter to Jason Augspurger, Otago Regional Council.

Kashima A. 2022. Update of reasonable water requirements for pastoral land uses.

Richter BD, Davis MM, Apse C, Konrad C. 2012. A PRESUMPTIVE STANDARD FOR ENVIRONMENTAL FLOW PROTECTION. River Res Appl. 28(8):1312–1321. https://doi.org/10.1002/rra.1511