# Update of scientific work in the Lindis catchment: 2008-2015

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Cover photo of Lindis catchment supplied by Otago Daily Times

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# 1. Introduction

The Otago Regional Council (ORC) has continued to further investigate the hydrology, ecology and irrigation practices of the Lindis catchment since the publication of the Management flow for aquatic ecosystems in the Lindis River in 2008.

This report summarises the results of the work undertaken since 2008 and discusses the implications for the minimum-flow process in the Lindis catchment.

# 2. Irrigation sources

ORC obtained satellite imagery in 2014, which allowed for detailed mapping of irrigation areas in the Lindis catchment and surrounding areas. Following further consultation with the Lindis catchment group in October 2014 and June 2015, a detailed map of the irrigated area and water sources was created for the Lindis and Tarras areas (Figure 1). This mapping gives an accurate understanding of the extent of use of both Lindis water and alternative sources, and allows consideration of the feasibility and potential extent of alternative source use based on existing technologies and economic conditions.

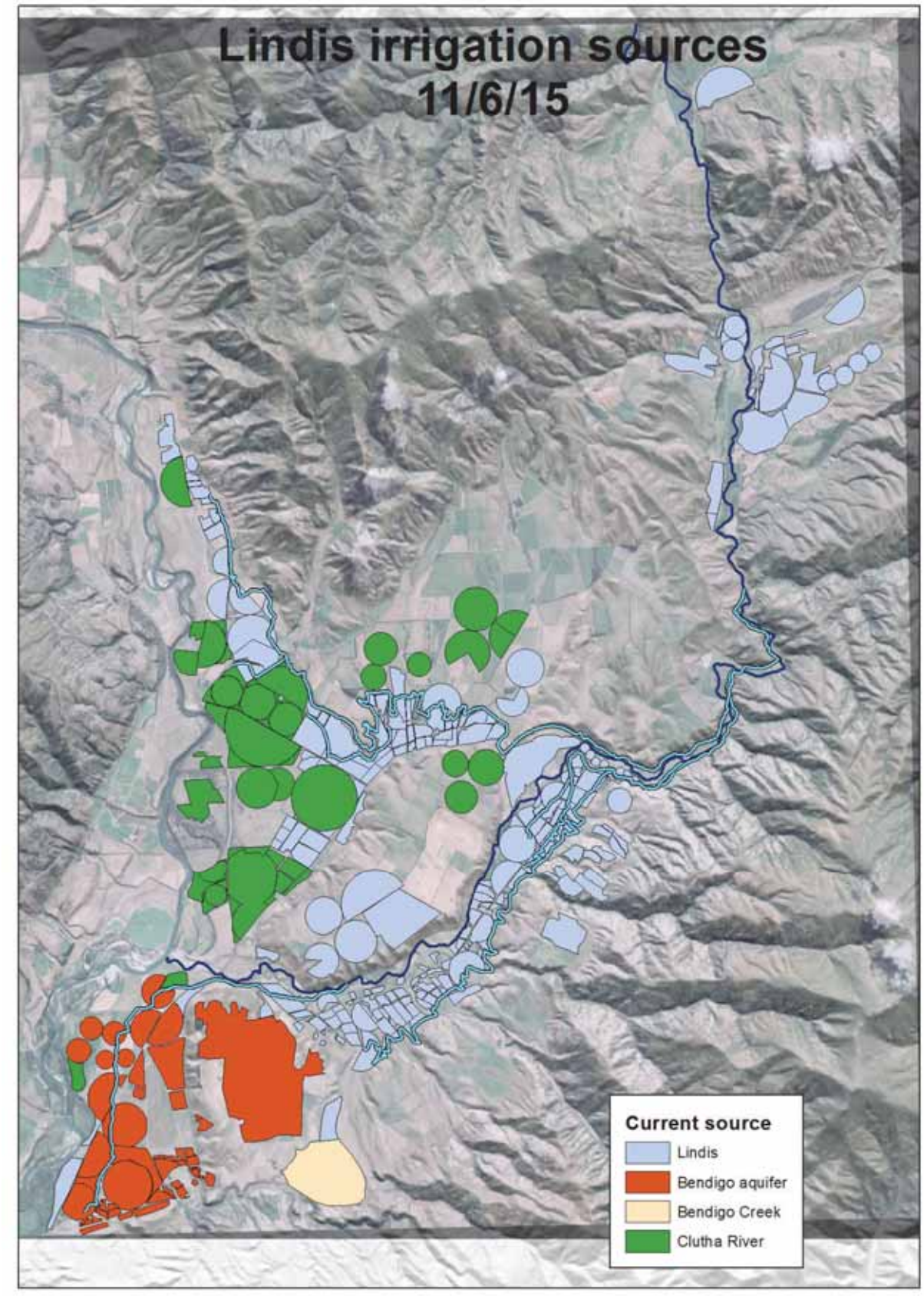


**Figure 1** **Irrigated area and sources for the Lindis and Tarras areas**

# 3. Hydrology

## 3.1. Naturalised flows

Monitoring of flows in tributaries of the Lindis (Figure 2), undertaken from 2012 to 2015, has been used to estimate the naturalised flow of the Lindis River at the Ardgour Road flow recorder. All of the tributary flow recorders used in this study were located either upstream of known water takes, or in the case of Coal Creek and Cluden Stream, in a location that captured all flows before they were taken out of the sub-catchment.

The flow sites used in this study cover around 70% of the Lindis catchment above the Ardgour Road flow recorder (Figure 2). However, much of the area not captured by this study is relatively low yielding and does not contribute significantly to base flows.

The naturalised Ardgour Road flow was calculated by adding 50 l/s to the Lindis Peak flow to account for upstream takes, and then summing together the flows from the six monitored tributaries. Although this is an improvement on historic MALF calculations, it still has several limitations. It does not account for water yields downstream of the tributary flow recorders; nor does it account for several small tributaries that were not monitored as part of this study. While this may lead to a slight underestimation of natural flows, this may be offset to some degree by the loss of some surface flow in the Lindis alluvial aquifer in the reach immediately above the Ardgour Road flow recorder.

The flow records from 2012 to 2014 show that Cluden Stream and Coal Creek contributed a significant amount of water to the middle reaches of the Lindis catchment. This is reflected in the naturalised MALF (October-April) of 1,864 l/s for Ardgour Road, which was estimated in 2014, and which is 16.5% greater than the previous MALF estimate of 1,600 l/s made in 2006. The calculation of a naturalised MALF for Ardgour Road also gives an indication of the amount of water abstracted from the river, with the measured 2012-2014 7-day low flow at Ardgour Road only being 15% of naturalised low flow over this period.

Updated naturalised flow statistics have been calculated for the Lindis at Ardgour Road based on flow records to July 2015 (Table 1). The naturalised MALF for Ardgour Road for the October-April period (1,745 l/s) is lower than that estimated in 2014.

**Table 1** **Updated flow statistics for the Lindis River, including naturalised flows at the Ardgour Road flow recorder based on flows at Lindis Peak. Flow statistics are shown for the full hydrological year (July-June) and two irrigation seasons (October-May and October to April).**

| Site | Calculation period | | 7-day MALF (l/s) | | |
|---|---|---|---|---|---|
| | Start | End | Jul-Jun | Oct-May | Oct-Apr |
| Lindis at Lindis Peak | 24/09/1976 13:45 | 20/07/2015 11:00 | 1626 | 1431 | 1462 |
| Ardgour Actual | 9/11/2005 13:45 | 17/06/2015 11:00 | 252 | 245 | 245 |
| Ardgour Naturalised | 24/09/1976 13:45 | 20/07/2015 11:00 | 1935 | 1709 | 1745 |

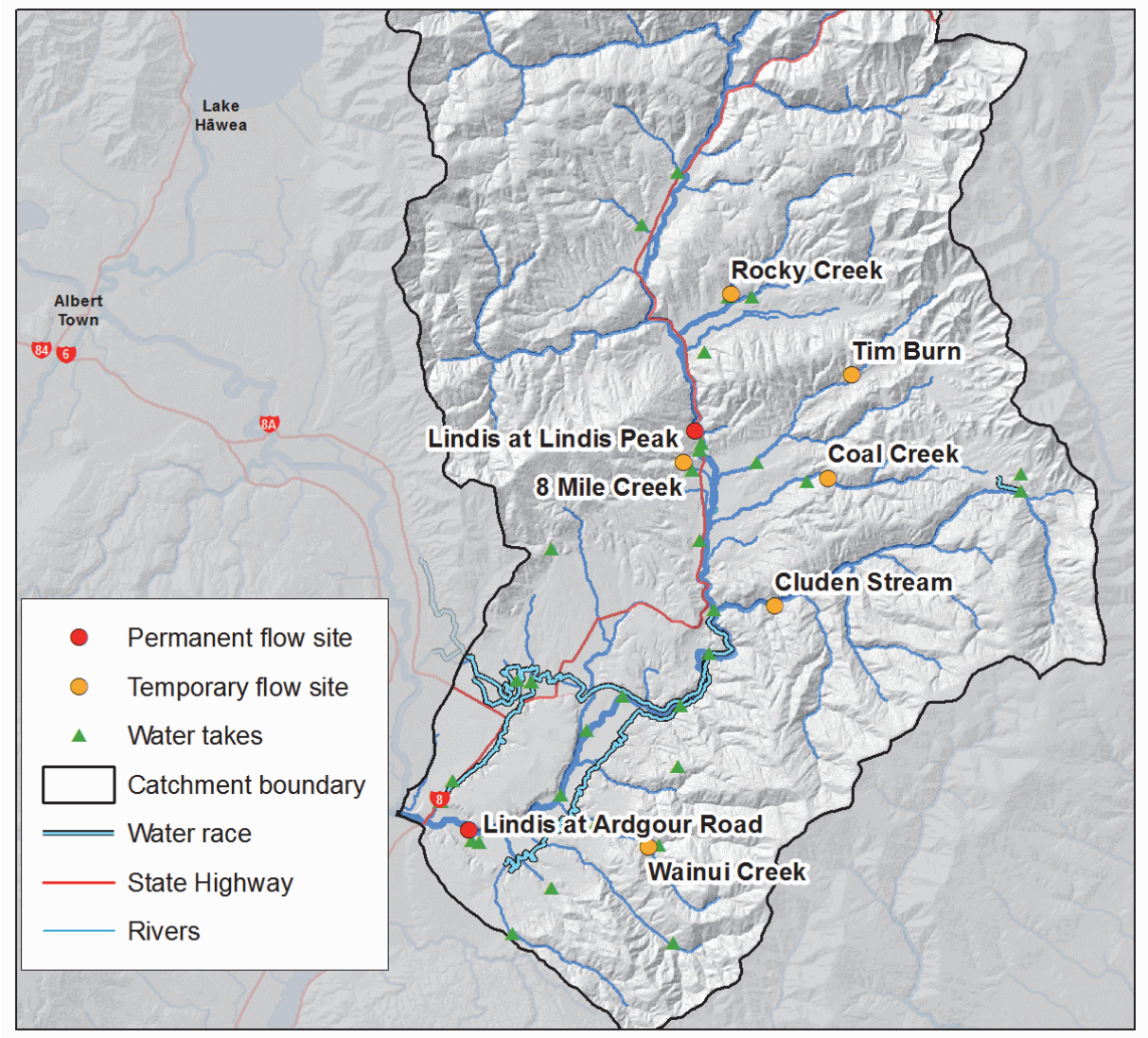


**Figure 2** **Location of flow sites in the Lindis cacthment**

## 3.2. Surety of supply model

ORC has recently produced a model that calculates the effect of any minimum flow and allocation limit on both surety of supply and the hydrology of the Lindis River.

The variables that this model is able to account for include minimum flow (seasonal), total water take and naturalised flows. The output of this model includes rate of take (both days of no take and restriction days), monthly or seasonal volumes, surety of supply (as a percentage) and river flows. The structure of this model is briefly illustrated in Figure 3.

This model will allow ORC and other stakeholders to gain a much more detailed understanding of the effects of minimum flows on a variety of values.

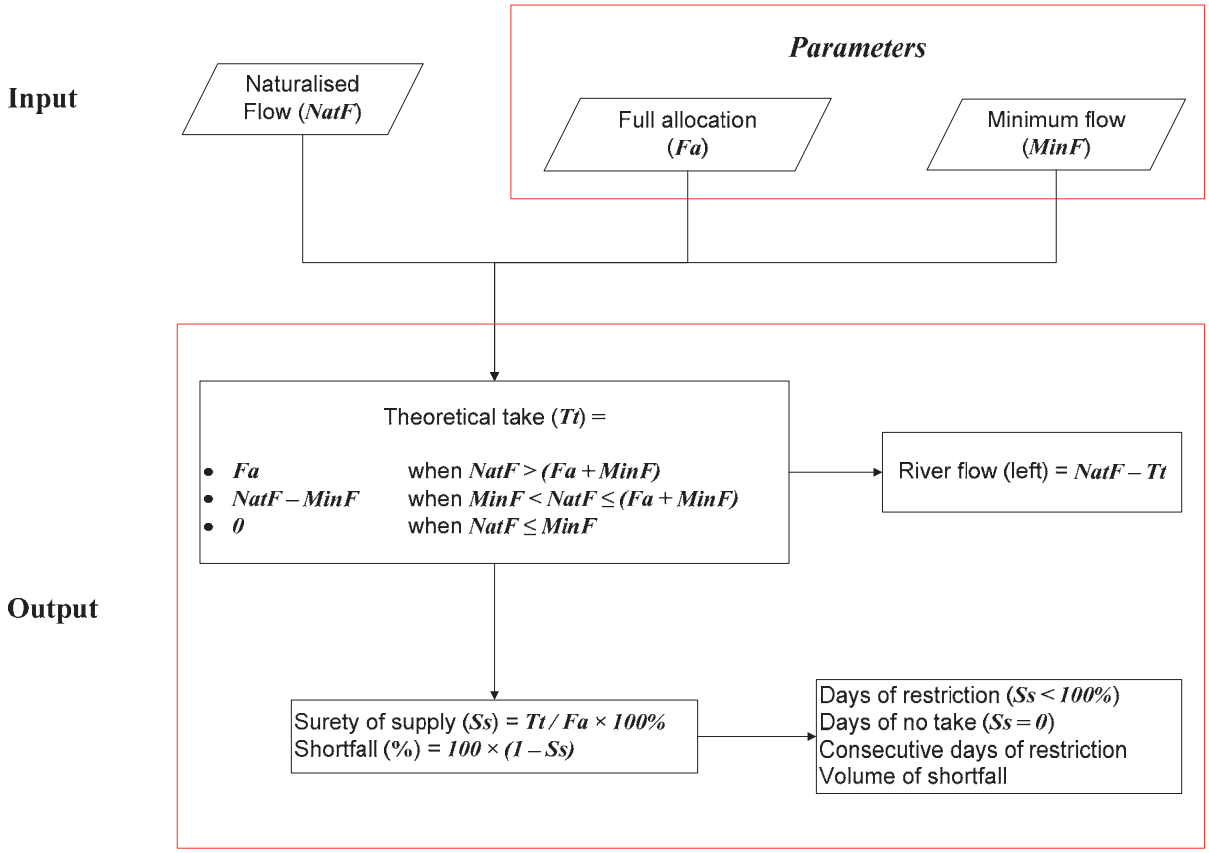


**Figure 3** **A schematic of the surety of supply model applied to the Lindis River**

## 3.3. Surface-flow losses

Following observations of drying in the lower reaches of the Lindis River made by the Clutha Fisheries Trust in March 2014, ORC installed three temporary flow recorders and one temperature recorder in the lower and middle reaches of the Lindis River in October 2014 (Figure 4), in addition to the permanent recorder at Ardgour Road. These monitoring sites were placed to allow for the identification of flow thresholds below which drying was likely to occur by comparing differences in flow between sites during period of a number of days of relatively stable flows. Most of these flow sites performed within expected levels of accuracy (Rutherford's, Ardgour Road and the Lindis Crossing), although confidence in flow estimates for the Clutha confluence site is low (see Appendix 1).

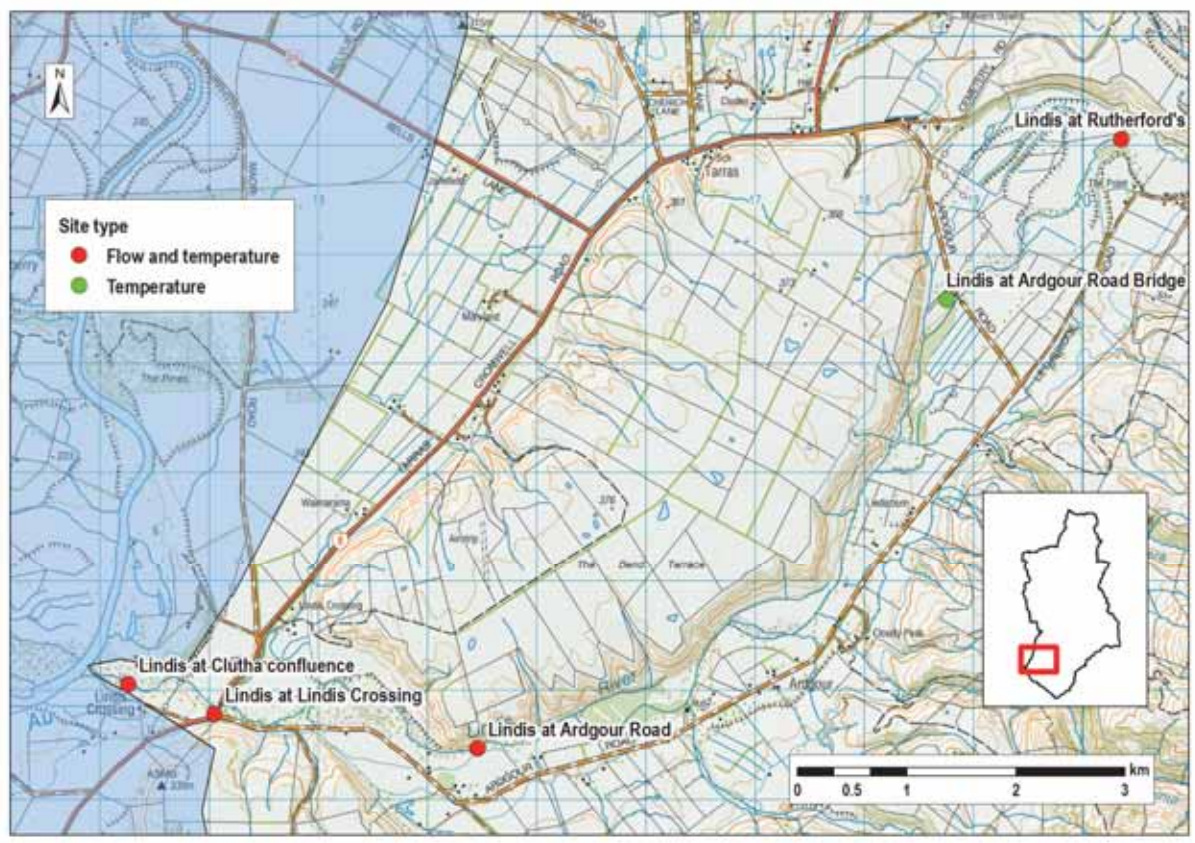


**Figure 4** **Flow and temperature sites in the lower and middle reaches of the Lindis River used in the 2014/15 flow study**

### 3.3.1. Lower reaches

The ORC (2008) study showed that there was a large reach of the lower Lindis downstream of the Ardgour Road flow recorder where surface flows are lost to groundwater. The rate of loss in 2007/08 was estimated to be approximately 440 l/s between the Ardgour Road flow recorder and the Clutha confluence.

In 2013, anecdotal evidence supplied by Otago Fish & Game indicated that losses in this lower reach may have increased. This may have been a result of increased bed permeability following a flood event in September 2012, with bed movement during this event resulting in the removal of fine sediments from within the bed.

To calculate flow losses in the lower Lindis River, a flow differential was calculated between the Ardgour Road flow recorder and the Clutha confluence for the period December 2014 to April 2015 (Figure 5). Because of the low confidence in the flow estimates for the Clutha confluence, these comparisons should be interpreted with caution.

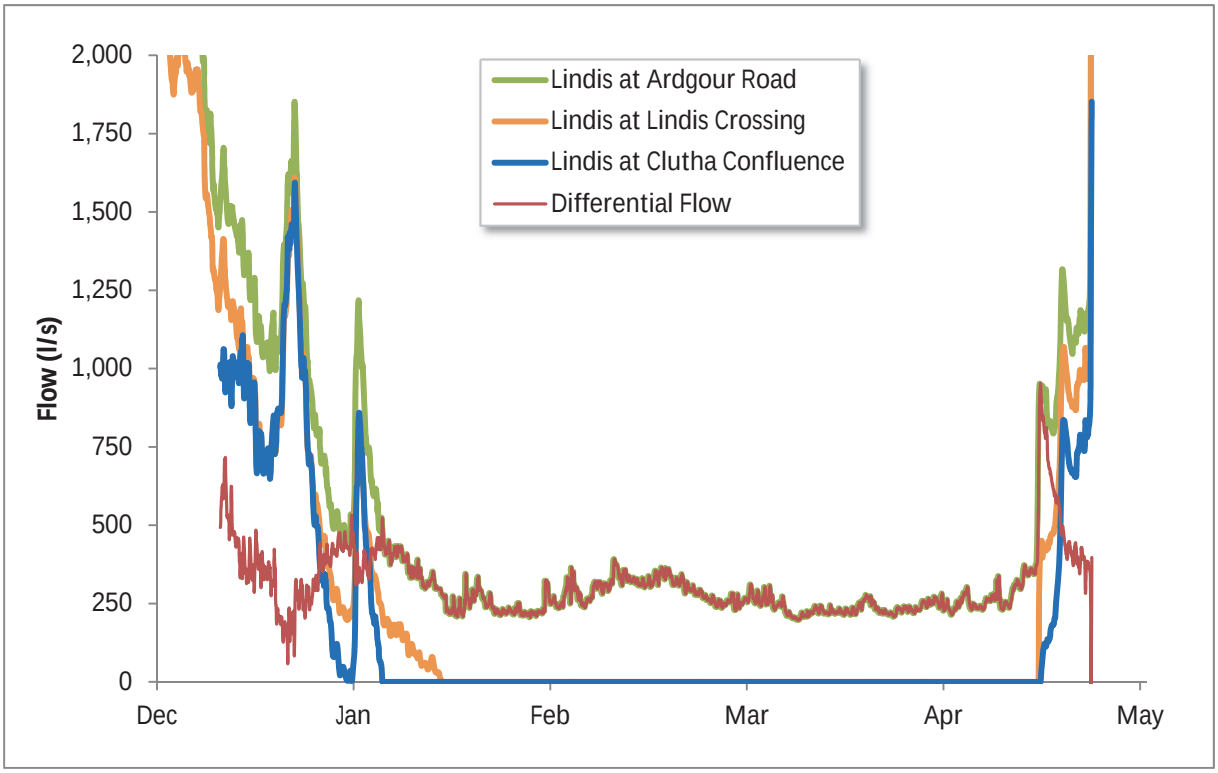


**Figure 5** **Flow differential between the Ardgour Road flow recorder and the Clutha confluence during the 2014/15 irrigation season**

The travel time between the Ardgour Road flow recorder and Clutha confluence over this period was estimated to be three hours. When flow ceased at the Clutha confluence on January 5, the flow differential with the Ardgour flow recorder was 523 l/s. However, estimating flow losses on the falling limb of a flow recession may over-estimate flow losses. (For a discussion, see Section 5.3.4 of ORC 2008.)

An alternative approach to assessing flow losses is to determine the value at which flows at the Clutha confluence are predicted to be zero by a regression of flows at the two flow sites (i.e. the *x*-axis intercept). To determine this, a regression analysis of low flows (>1000 l/s at the Ardgour Road flow recorder) was undertaken at these two sites over the 2014/15 irrigation season (Figure 6). This regression was undertaken on flow data when flows in the river were stable or dropping to avoid periods when inflows were re-wetting previously dry gravels.

The regression equation resulting from this analysis was:

$$Q_{\text{Clutha confluence}} = 0.7507 * Q_{\text{Ardgour Rd}} + 441.73$$

This analysis estimated flow losses between the two sites at about 442 l/s (95% confidence limit: 436-448 l/s) (Figure 6), which aligns with the previous estimate of losses in this reach

(ORC, 2008). This analysis should be interpreted cautiously, given the uncertainty associated with flow estimates for the Clutha confluence.

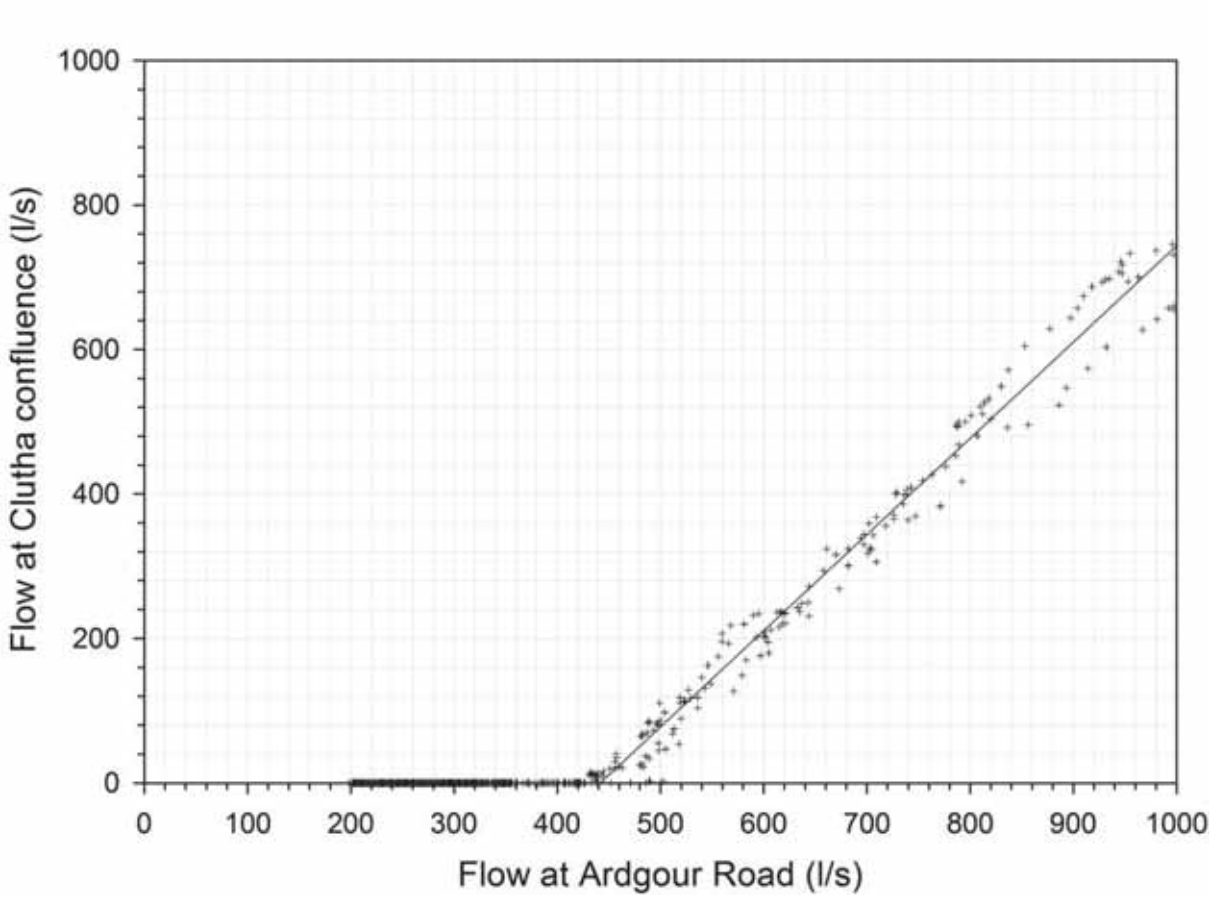


**Figure 6** **Plot of the relationship between low flows at Ardgour Road hydrological site and the Clutha confluence site in the Lindis River. The linear regression applied to flows where 0<Q<1000 l/s.**

### 3.3.2. Middle reaches

The hydrology of the Lindis River above the Ardgour Road Bridge is driven by a combination of groundwater/surface-water interactions, water abstraction and by-wash from irrigation races. Information provided by the Lindis Catchment Group (Figure 7) shows that there is a series of by-wash points that are used to ration water between the four main takes in this reach: the Tarras race, Ardgour race, Rutherford's race and Beggs-Stackpole race.

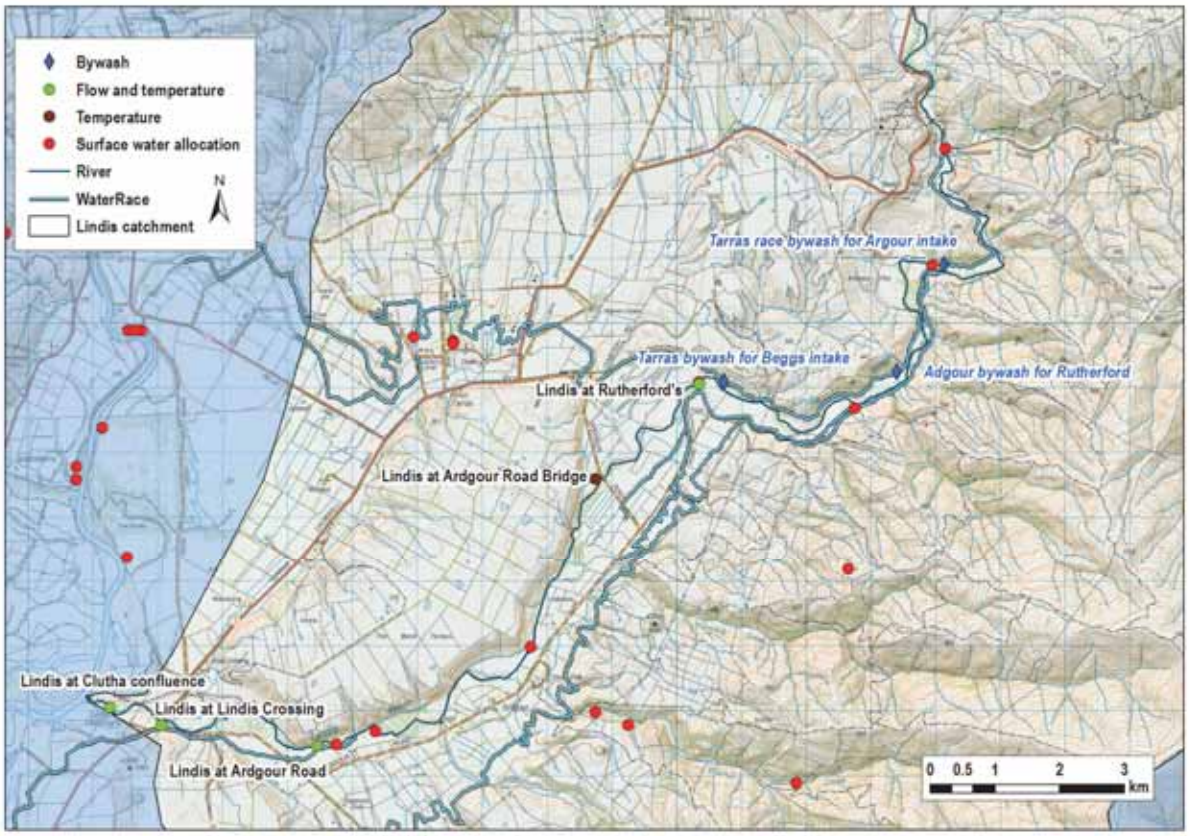


**Figure 7** **Location of by-wash points and water takes relative to monitoring sites in the middle reaches of the Lindis River**

Instead of reducing the rate of take for the top race (Tarras), a portion of the water from the race is by-washed back into the river immediately above the next race down the river, with a similar method being used for all of the subsequent downstream races. In this way, the main water users manage water distribution without the need to take into account the travel time and losses to groundwater if the water were to remain in the river. The negative effect of this method is that water that is not being actively used by each scheme is not returned to the river and the effects of low flows are exacerbated. A detailed report outlining this process has been prepared by the Lindis Catchment Group and is provided in Appendix 2.

The Rutherford's monitoring site was affected by a combination of a water take 100 m upstream of the site, as well as by-wash from the Tarras race, which is illustrated by the sharp changes in flow observed for this site in Figure 8. Unfortunately, the temperature logger at the Ardgour Road Bridge was lost in a flood in late April, and the data from the latter part of the irrigation season were lost.

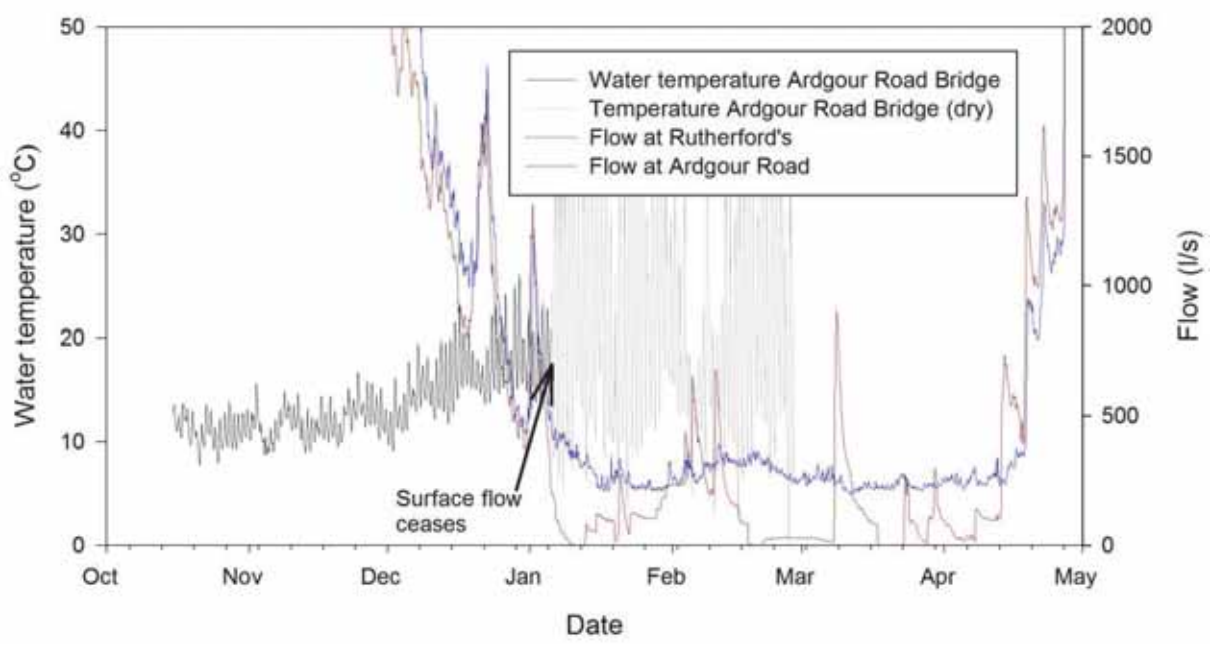


**Figure 8** **Flow and temperature data for the middle reaches of the Lindis River during the 2014/15 irrigation season**

In addition to monitoring water temperature, the data from the logger upstream of the Ardgour Road Bridge can also be used to show when surface flows were lost in this reach. The thermal mass of water reduces diurnal temperature fluctuations (daily peaks and nightly lows), so daily variation is relatively small; however when the surface flows cease the logger is exposed to the air and the diurnal fluctuations are significantly greater (Figure 8).

Figure 8 shows that surface flow ceased at the Ardgour Rd Bridge on 5 January 2015, when flows at Rutherford's were around 500 l/s, indicating significant losses to groundwater as there are no surface water takes between the two sites. The stable base flow of around 250 l/s at the Ardgour Rd flow recorder also indicates that the reach above this site is gaining surface flows from groundwater, as there are no by-wash points between the Rutherford's and Ardgour Rd flow recorders to account for this increase.

It is unclear if the drying patterns observed upstream of the Rutherford's recorder by the Clutha Fisheries Trust in 2014 (Appendix 3) were due to surface water/groundwater interaction of water abstraction/by-wash, however the location of these reaches relative to consented points of take and by-wash points indicates that irrigation infrastructure may play a greater role in these patterns than observed further downstream.

## 3.4. Water temperature

Water temperature is one of the key considerations when assessing the effects of various flows on instream values, as the volume of water in the river has a direct effect on water temperature. Generally, as river flows increase there is less diurnal fluctuation and average and maximum temperatures are lower. However, this pattern may not hold in streams with substantial inputs of groundwater, as groundwater inputs may reduce water temperatures and the amount of diel variation (variation over a 24-h. period) in water temperature.

### 3.4.1. Lindis at the Clutha confluence

Water temperatures in the Lindis at the Clutha confluence reached daily maximums of nearly 30ºC before surface flows ceased in early January (Figure 9).

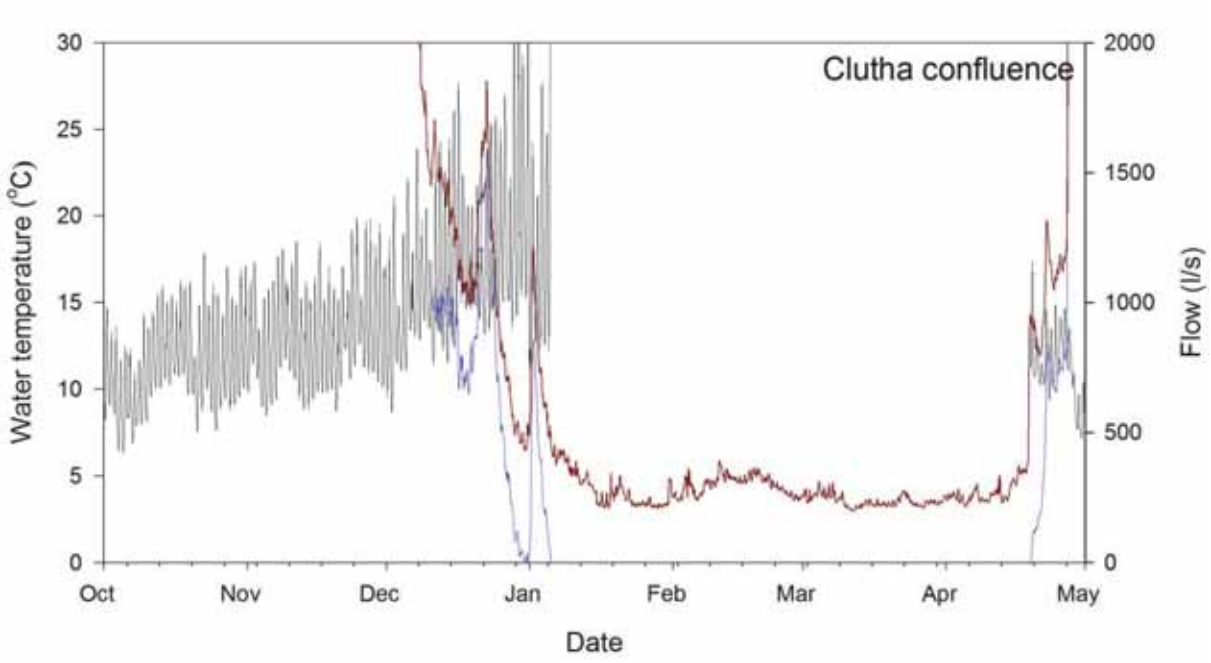


**Figure 9** **Flow (blue line) and temperature (black line) in the Lindis at the Clutha confluence during the 2014/15 irrigation season**

### 3.4.2. Lindis at the Lindis Crossing

Surface flow ceased at the Lindis Crossing nine days after it had ceased at the Clutha confluence, with water temperatures reaching as high as 23ºC (Figure 10). The lower temperatures at this site compared to the Clutha confluence may reflect the increased shading from willows above this point and the continued influence of groundwater inputs to areas upstream of this reach.

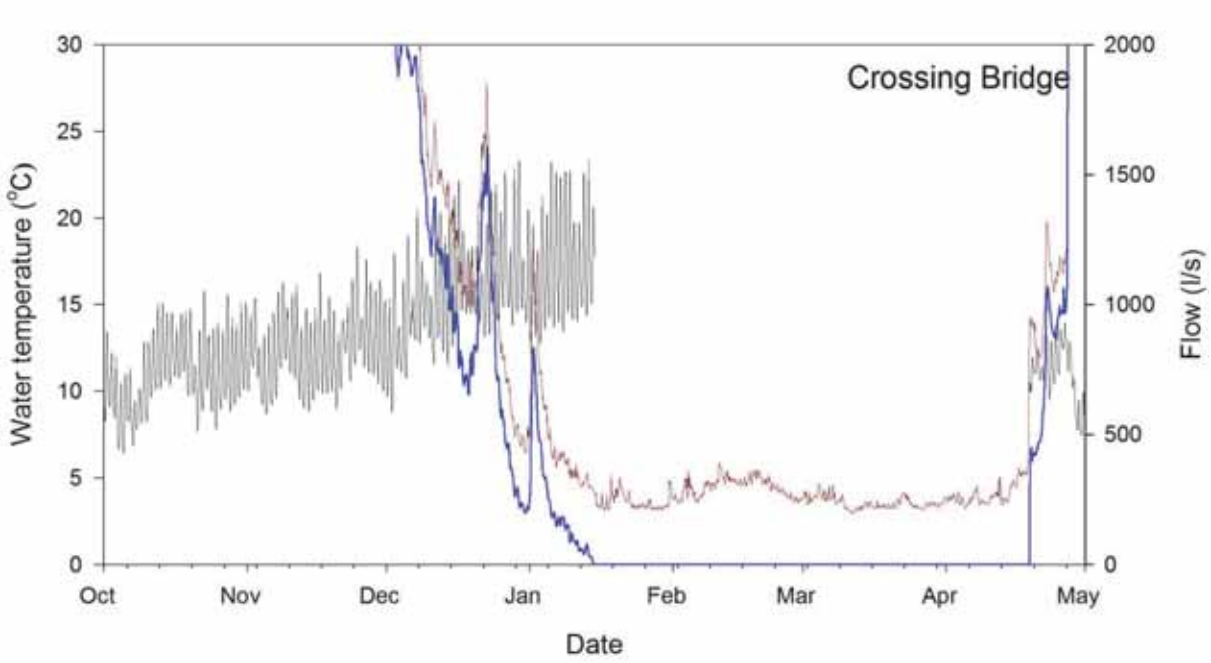


**Figure 10** **Flow (blue line) and temperature (black line) in the Lindis at the Lindis Crossing during the 2014/15 irrigation season**

### 3.4.3. Lindis at Ardgour Road

As discussed in Section 3.3.2, base flows in the reach around the Ardgour Road flow recorder are largely driven by inputs from shallow groundwater. This is further supported by the relatively low temperatures recorded in this reach over the 2014/15 irrigation season (Figure 11).

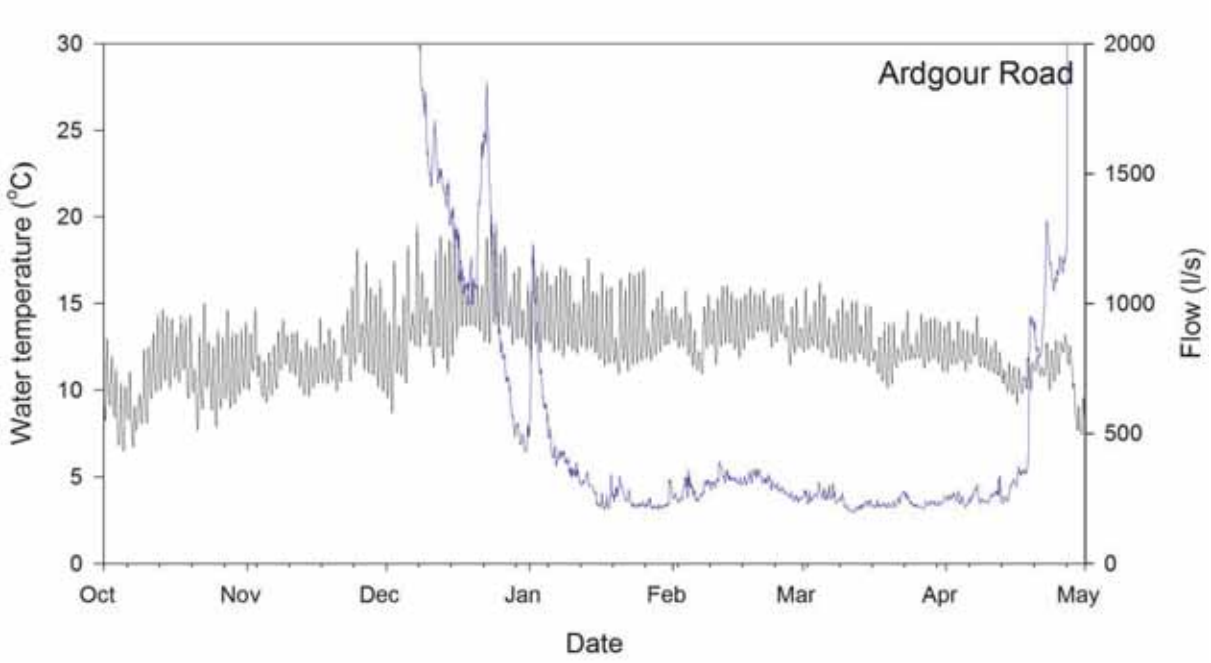


**Figure 11** **Flow (blue line) and temperature (black line) in the Lindis at Ardgour Road during the 2014/15 irrigation season**

Willow-lined banks at the Ardgour Road hydrological site provide good cover and habitat complexity for all fish species, and recent fish surveys undertaken by Otago Fish & Game have shown relatively high numbers of eels in this reach.

### 3.4.4. Lindis at Ardgour Road Bridge and Rutherford's

Water temperatures in the middle reaches of the Lindis were higher than those observed at the Ardgour Road flow recorder (Figure 12). Despite very low flows at Rutherford's, daily maximum temperatures generally stayed below 20ºC, which suggests that the water temperature at this site may be being buffered by inputs from groundwater or the hyporheic zone (the boundary between the river bed and groundwater zone). Before the Ardgour Road Bridge site dewatered in early January, temperatures were as high at 26ºC.

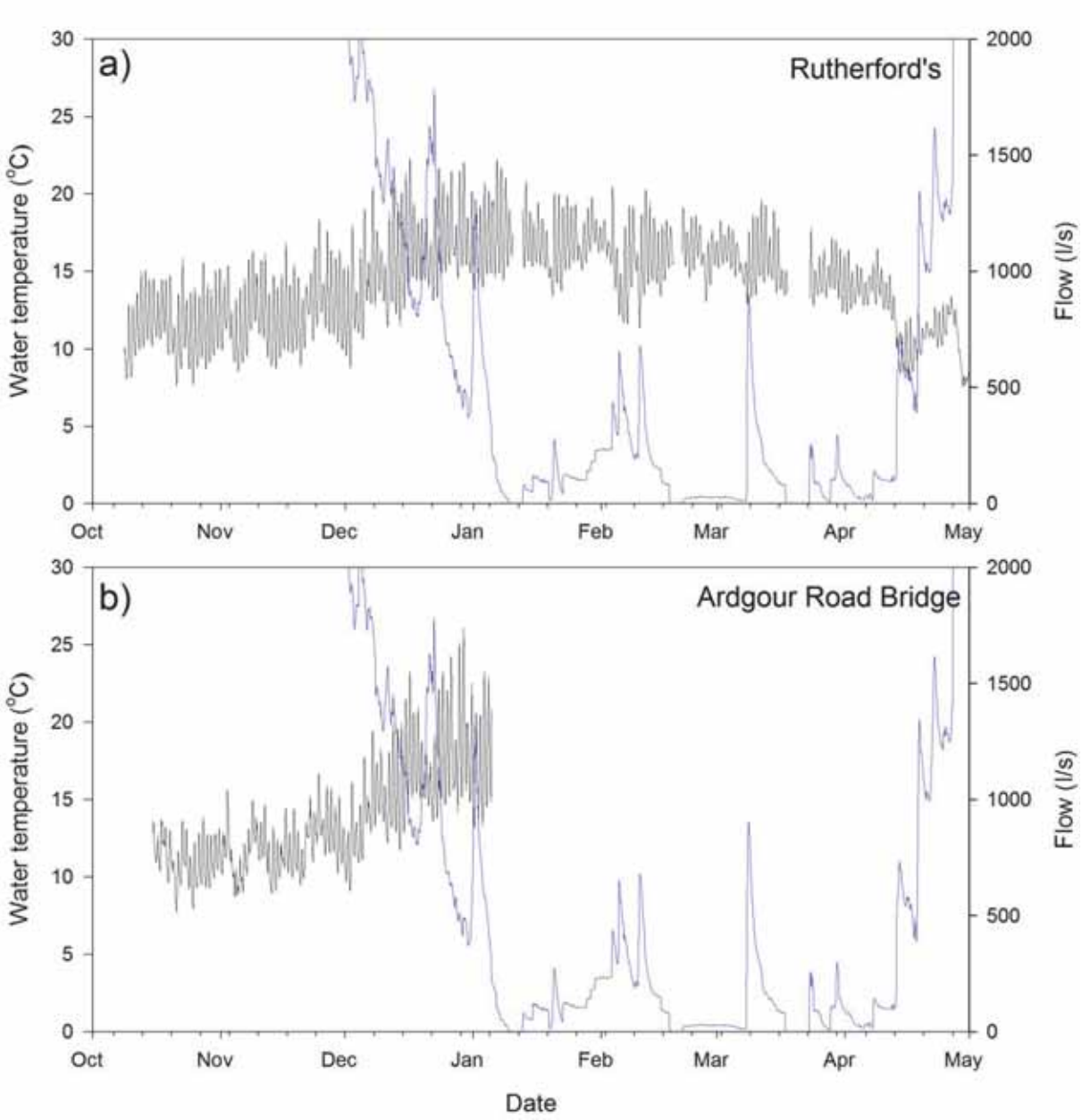


**Figure 12** **Flow (blue line) and temperature (black line) in the Lindis River. a) Ardgour Road Bridge and b) Rutherford's during the 2014/15 irrigation season**

### 3.4.5. Implications of observed water temperatures

Water temperature is a fundamental factor affecting all aspects of stream systems, and it can directly affect fish populations by influencing survival, growth, spawning, egg development and migration. It can also affect fish populations indirectly, through effects on physicochemical conditions and food supplies (Olsen *et al*., 2012).

Brown trout (*Salmo trutta*) and rainbow trout (*Onchyrhynchus mykiss*) are likely to be the fish that are most sensitive to high water temperatures in the Lindis River, and their thermal requirements are relatively well understood. Todd *et al.* (2008) calculated acute and chronic thermal criteria for both of these species, with acute criteria applied as the highest two-hour average water temperature measured within any 24-hour period, while chronic criteria are expressed as the maximum weekly average temperature (Todd *et al.,* 2008).

Most native fish species are more tolerant of high temperatures than trout. Olsen *et al.* (2012) developed interim thermal criteria for native species for which there was sufficient information. No acute criteria are available for the native fish species present in the Lindis River, but chronic thermal criteria were available for longfin eels (34ºC for adults, 28ºC for elvers (juveniles)) and common bully (24ºC in upland sites) (Olsen *et al.,* 2012).

Water temperatures at Rutherford's, and the Ardgour Road hydrological site were suitable for rainbow trout, brown trout, longfin eels or common bullies throughout the period 1 October 2014 and 30 April 2015 (Table 1). Water temperature at the Lindis Crossing Bridge exceeded the chronic thermal criterion for rainbow trout on two days (13-14 January 2015), but were suitable for all other species considered throughout the period considered (Table 1).

Water temperatures at the Ardgour Road Bridge exceeded acute and chronic criteria for rainbow trout on several days in late December-early January and acute criteria for brown trout on two days in late December (Table 1). Flows at the Rutherford's flow recorder dropped from 685 l/s to 411 l/s over this period (Figure 12a).

At the Clutha confluence site, water temperatures exceeded thermal criteria (acute and chronic) for rainbow trout and brown trout in mid-December and late December-early January (Table 1). When these criteria were exceeded in mid-December, flows exceeded 950 l/s at the Clutha confluence flow site and 1,400 l/s at the Ardgour Road hydrological site (Figures 9 and 11). In late December, flows at the Clutha confluence flow site dropped from a mean flow of 1,181 l/s (23 December) to 17.5 l/s (31 December), rising to 637 l/s on 2 January 2015 before dropping until flow ceased on 6 January (Figure 9). Flows at the Ardgour Road hydrological site followed a similar pattern, with flows dropping from 1,408 l/s (23 December) to 476 l/s (31 December), rising to 958 l/s (2 January), before dropping to 410 l/s on 6 January (Figure 9).

These results suggest that the suitability of the reach of the Lindis River from the Lindis Crossing to the Clutha confluence for trout is likely to be limited during warmer months (December-March), due to high water temperatures.

**Table 2** **Summary of the number of days exceeding acute and chronic thermal criteria for the protection of rainbow and brown trout at five sites in the Lindis River between 1 October 2014 – 30 April 2015**

| Site | Total record (d) | Total number of dry days (d) | Number of days exceeding thermal criteria | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Acute (max. 2-h average) | | Chronic (weekly average) | | | | |
| | | | Rainbow trout | Brown trout | Rainbow trout | Brown trout | Longfin eel (adult) | Longfin eel (elver) | Common bully |
| | | | 23.8℃ | 24.6℃ | 18.2℃ | 19.6℃ | 30℃ | 28℃ | 24℃ |
| Rutherford's | 205 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ardgour Road Bridge | 135 | >52 | 3 | 2 | 5 | 0 | 0 | 0 | 0 |
| Ardgour Road hydro | 212 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lindis Crossing | 212 | 93 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Clutha confluence | 212 | 103 | 16 | 13 | 17 | 9 | 0 | 1 | 1 |

# 4. Conclusions

The recent mapping of irrigated areas and water sources for the Lindis catchment has allowed for a much more detailed understanding of the use of alternative sources, and how water resources are currently used in the catchment. There has been a significant increase in the use of Clutha water in the Tarras area, with land irrigated from this source almost completely surrounding (and in many cases overlapping) the historic command area of the Tarras race. A similar pattern can be seen in the Bendigo area, where almost the entire command area of the Beggs-Stackpole race is now serviced with water from the Clutha River or the Bendigo aquifer.

Updated naturalised flow statistics have been calculated for the Lindis at Ardgour Road based on flow records to July 2015, with the 7-d MALF (October-April) estimated at 1,745 l/s. This estimate is lower than that estimated in 2014 (1,864 l/s), but is also substantially higher than the previous MALF estimate of 1,600 l/s made in 2006. The recent naturalised flow calculations more accurately represent the water balance in the Lindis catchment, which, when combined with the surety of supply model, will allow for a much better understanding of the effects of any future minimum flows on surety of supply and hydrology.

The monitoring undertaken over the 2014/15 irrigation season has provided further insight into the hydrology of the middle and lower reaches of the Lindis River; however, a limitation of this data in understanding the effects of any specific minimum flow is that river flows were not able to be held at any specific levels for a prolonged period of time. In addition, the reliability of estimates for flow at the Clutha confluence is low.

The results of temperature monitoring undertaken over the 2014/15 irrigation season suggest that the suitability of the reach of the Lindis River from the Lindis Crossing to the Clutha confluence for trout is likely to be limited during warmer months (December-March) due to higher water temperatures. This suggests that maintenance of flow connectivity sufficient for juvenile trout to move upstream and downstream to refuge habitats such as the perennially flowing reach in the vicinity of the Ardgour Road hydrological site, and the Clutha River is a key consideration when setting an appropriate minimum flow.

# 5. References

Otago Regional Council (2008). Management Flows for Aquatic ecosystems in the Lindis River. Otago Regional Council, Dunedin. July 2008. 50 p. + appendices.

Olsen, D., Tremblay L., Clapcott J., & Holmes R. (2012). Water temperature criteria for native aquatic biota. Auckland Council Technical Report 2012/036.

# Appendix 1: Uncertainty associated with flow measurements at flow-monitoring sites on the Lindis River

### Lindis at Rutherford's

The flow site at Rutherford's conformed to expected flow accuracy of +/-8% for range of flow 0 to 4000 l/s (Figure 13, Table 3).

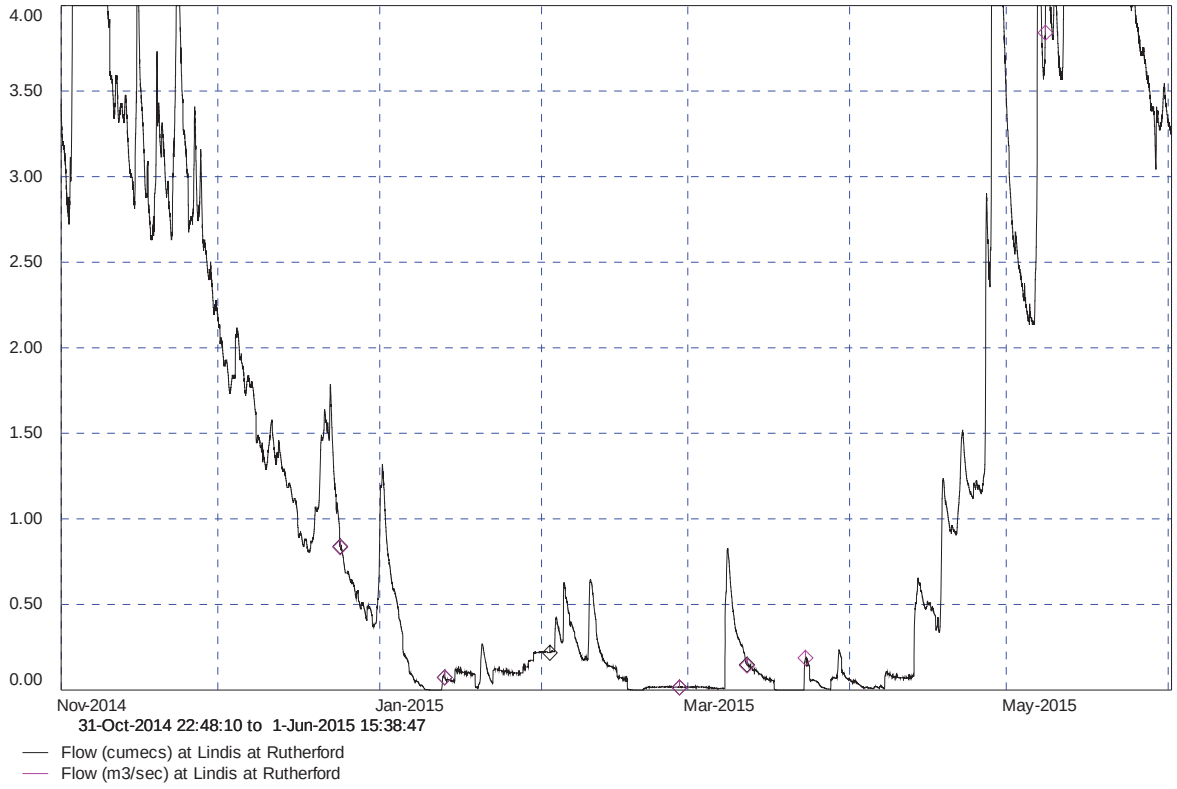


**Figure 13** **Instantaneous flow in the Lindis at Rutherford's with gauged flows overplotted (pink diamonds) for the period 1 November 2014 to 31 May 2015**

**Table 3** **Rating table comparing gauged flow with rated flow for the Lindis at the Rutherford's flow site**

~~~ Hilltop Hydro ~~~ Version 6.47 ~~~ QRate ~~~

Source is U:\Original\Lindis Catchment V2.hts
Gaugings for Lindis at Rutherford from 15-Oct-2014 09:38:00 to 8-May-2015 10:15:00
Deviation from the Ratings: (Qg-Qr)/Qr
Qr computed from the Recorder Stage

| Stage | Gauged flow | Rated flow | Date | Deviation | |
|---|---|---|---|---|---|
| m | m3/sec | m3/sec | | m | % |
| Rating | | | 08-Oct-2014 | | |
| 5.177 | 3.637 | 3.625 | 15-Oct-2014 | 0.000 | 0.3 |
| 5.020 | 0.836 | 0.838 | 24-Dec-2014 | 0.000 | -0.2 |
| 4.906 | 0.075 | 0.078 | 13-Jan-2015 | -0.000 | -3.5 |
| 4.875 | 0.016 | 0.016 | 27-Feb-2015 | 0.000 | -1.2 |
| 4.926 | 0.145 | 0.147 | 12-Mar-2015 | 0.000 | -1.2 |
| 4.936 | 0.190 | 0.193 | 23-Mar-2015 | 0.001 | -1.5 |
| 5.186 | 3.842 | 3.770 | 08-May-2015 | 0.000 | 1.9 |

| Rating | Gaugings | Runs | +ve Dev | -ve Dev |
|---|---|---|---|---|
| 08-Oct-2014 | 7 | 3 | 2 | 5 |
| All Gaugings | 7 | 3 | 2 | 5 |

100% of the gaugings are within 8% of the rating

## Lindis at Ardgour Road

Comparison of gauged versus rated (based on measured water level) flows shows that there is high confidence in flows derived from data at this site (Figure 14). Flows at this site conformed to expected flow accuracy of +/-8% for range of flow 200 to 10,000 l/s, with 86% of the gaugings within 8% of the rating (Table 4).

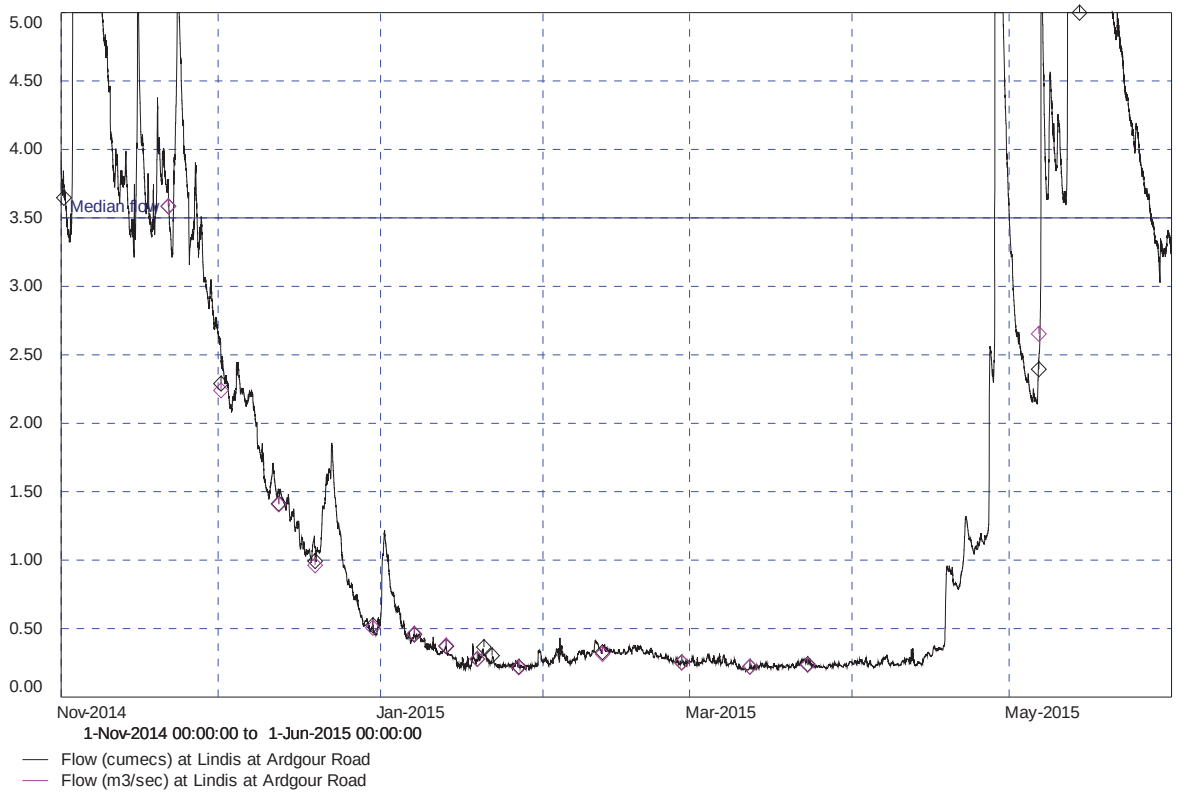


**Figure 14** **Instantaneous flow in the Lindis at Ardgour Road, with gauged flows overplotted (pink diamonds) for the period 1 November 2014 to 31 May 2015**
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**Table 4 Rating table comparing gauged flow with rated flow for the Lindis at Ardgrour Road flow site**

~~~ Hilltop Hydro ~~~ Version 6.47
~~~ QRate ~~~

Source is U:\Original\Lindis Catchment V2.hts
Gaugings for Lindis at Ardgour Road from 22-Sep-2005 09:55:00 to 6-May-2015 14:18:00
Deviation from the Ratings: (Qg-Qr)/Qr

| Stage | Gauged flow | Rated flow | Date | Deviation | |
|---|---|---|---|---|---|
| m | m3/sec | m3/sec | | m | % |
| Rating | | | 01-Nov-2005 | | |
| 1.000 | 4.434 | 0.184 | 22-Sep-2005 | -0.360 | 2310.5 |
| 1.113 | 0.889 | 0.845 | 09-Nov-2005 | -0.010 | 5.2 |
| 1.117 | 0.853 | 0.838 | 09-Nov-2005 | -0.002 | 1.7 |
| 1.118 | 0.883 | 0.833 | 09-Nov-2005 | -0.004 | 5.9 |
| 1.116 | 0.868 | 0.836 | 09-Nov-2005 | -0.004 | 3.8 |
| 1.206 | 1.767 | 1.744 | 14-Nov-2005 | 0.000 | 1.3 |
| 1.206 | 1.767 | 1.773 | 14-Nov-2005 | 0.000 | -0.3 |
| 1.120 | 0.868 | 0.864 | 28-Nov-2005 | -0.000 | 0.5 |
| 1.040 | 0.348 | 0.355 | 01-Dec-2005 | -0.000 | -1.9 |
| 1.027 | 0.301 | 0.265 | 08-Dec-2005 | -0.003 | 13.4 |
| 1.028 | 0.319 | 0.284 | 13-Dec-2005 | -0.006 | 12.2 |
| 1.028 | 0.319 | 0.282 | 13-Dec-2005 | -0.006 | 13.1 |
| 1.000 | 0.195 | 0.183 | 15-Dec-2005 | -0.004 | 6.4 |
| 0.993 | 0.173 | 0.161 | 09-Jan-2006 | -0.003 | 7.1 |
| 1.022 | 0.255 | 0.267 | 19-Jan-2006 | 0.002 | -4.4 |
| 1.022 | 0.255 | 0.264 | 19-Jan-2006 | 0.002 | -3.4 |
| 0.995 | 0.131 | 0.161 | 22-Feb-2006 | 0.016 | -18.4 |
| 1.018 | 0.228 | 0.224 | 22-Mar-2006 | 0.005 | 1.9 |
| 0.983 | 0.138 | 0.139 | 29-Mar-2006 | 0.001 | -0.6 |
| 0.985 | 0.134 | 0.137 | 06-Apr-2006 | 0.005 | -2.1 |
| 1.460 | 7.197 | 6.990 | 27-Apr-2006 | -0.017 | 3.0 |
| 1.493 | 7.985 | 7.429 | 29-Apr-2006 | -0.013 | 7.5 |
| 1.430 | 5.907 | 5.848 | 30-Apr-2006 | 0.004 | 1.0 |
| 1.357 | 4.201 | 4.265 | 02-May-2006 | 0.008 | -1.5 |
| 1.311 | 3.454 | 3.368 | 05-May-2006 | 0.000 | 2.5 |
| 1.265 | 2.553 | 2.659 | 11-May-2006 | 0.006 | -4.0 |
| 1.480 | 7.389 | 7.566 | 31-May-2006 | -0.004 | -2.3 |
| 1.440 | 6.280 | 6.432 | 29-Jun-2006 | -0.001 | -2.4 |
| 1.435 | 5.677 | 6.086 | 27-Jul-2006 | 0.019 | -6.7 |
| 1.485 | 7.606 | 7.425 | 04-Aug-2006 | -0.007 | 2.4 |
| 1.600 | 10.855 | 10.772 | 22-Aug-2006 | -0.002 | 0.8 |
| 1.435 | 6.121 | 6.134 | 03-Oct-2006 | 0.001 | -0.2 |
| 1.515 | 7.353 | 7.988 | 12-Oct-2006 | 0.032 | -7.9 |
| 1.512 | 7.952 | 8.217 | 15-Nov-2006 | 0.007 | -3.2 |
| Rating | | | 29-Nov-2006 | (30-Nov-2006) | |
| 1.488 | 8.586 | 7.518 | 13-Dec-2006 | -0.035 | 14.2 |
| 1.332 | 3.827 | 3.406 | 05-Jan-2007 | 0.000 | 12.4 |
| 1.286 | 3.034 | 2.651 | 12-Jan-2007 | 0.004 | 14.4 |
| 1.140 | 1.388 | 1.321 | 25-Jan-2007 | -0.006 | 5.1 |
| 1.202 | 2.036 | 1.998 | 01-Feb-2007 | -0.004 | 1.9 |
| 1.070 | 0.673 | 0.711 | 08-Feb-2007 | 0.006 | -5.4 |
| 1.010 | 0.361 | 0.335 | 16-Feb-2007 | -0.004 | 7.7 |
| 0.996 | 0.287 | 0.264 | 21-Feb-2007 | -0.004 | 8.6 |
| 0.987 | 0.251 | 0.224 | 28-Feb-2007 | -0.005 | 12.0 |
| 0.976 | 0.191 | 0.199 | 05-Apr-2007 | 0.001 | -4.1 |
| 1.188 | 1.839 | 1.846 | 24-May-2007 | -0.000 | -0.4 |
| Rating | | | 31-May-2007 | (01-Jun-2007) | |
| 1.525 | 10.381 | 9.543 | 02-Jul-2007 | -0.025 | 8.8 |
| 1.289 | 3.457 | 3.625 | 12-Jul-2007 | 0.004 | -4.6 |
| 1.251 | 2.922 | 2.804 | 23-Jul-2007 | -0.007 | 4.2 |
| 1.499 | 8.760 | 8.640 | 16-Aug-2007 | 0.000 | 1.4 |
| 1.345 | 4.702 | 4.745 | 27-Sep-2007 | 0.003 | -0.9 |
| 1.625 | 13.072 | 12.557 | 11-Oct-2007 | -0.002 | 4.1 |
| 1.325 | 4.186 | 4.168 | 07-Nov-2007 | 0.006 | 0.4 |
| 1.342 | 4.468 | 4.690 | 15-Nov-2007 | 0.011 | -4.7 |
| 1.220 | 2.184 | 2.170 | 26-Nov-2007 | 0.008 | 0.7 |
| 1.130 | 1.207 | 1.192 | 29-Nov-2007 | 0.000 | 1.3 |
| 1.062 | 0.671 | 0.599 | 09-Dec-2007 | -0.004 | 12.1 |
| 1.038 | 0.458 | 0.472 | 21-Dec-2007 | 0.006 | -2.9 |
| 1.038 | 0.523 | 0.474 | 21-Dec-2007 | -0.005 | 10.4 |
| 0.975 | 0.194 | 0.168 | 08-Jan-2008 | 0.004 | 15.5 |

**Table 4 (continued) Rating table comparing gauged flow with rated flow for the Lindis at Ardgrour Road flow site**

| Stage | Gauged flow | Rated flow | Date | Deviation | |
|---|---|---|---|---|---|
| m | m3/sec | m3/sec | | m | % |
| 0.975 | 0.213 | 0.196 | 08-Jan-2008 | -0.003 | 8.7 |
| 0.969 | 0.181 | 0.188 | 01-Feb-2008 | 0.002 | -3.7 |
| 1.230 | 2.426 | 2.465 | 12-Jun-2008 | 0.001 | -1.6 |
| 1.395 | 5.931 | 6.264 | 22-Jul-2008 | 0.000 | -5.3 |
| Rating | | | 01-Sep-2008 | (04-Sep-2008) | |
| 1.525 | 9.279 | 9.134 | 11-Sep-2008 | -0.011 | 1.6 |
| 1.570 | 10.105 | 10.594 | 15-Oct-2008 | 0.008 | -4.6 |
| 1.225 | 2.221 | 2.171 | 12-Nov-2008 | -0.006 | 2.3 |
| 1.222 | 2.048 | 2.115 | 26-Nov-2008 | 0.004 | -3.2 |
| 1.720 | 15.572 | 15.730 | 17-Dec-2008 | 0.004 | -1.0 |
| Rating | | | 20-Dec-2008 | (20-Dec-2008) | |
| 1.184 | 2.193 | 2.193 | 21-Jan-2009 | 0.001 | 0.0 |
| 1.085 | 1.138 | 1.085 | 30-Jan-2009 | -0.006 | 4.9 |
| 1.049 | 0.771 | 0.780 | 04-Feb-2009 | 0.002 | -1.2 |
| 1.009 | 0.466 | 0.466 | 01-Apr-2009 | 0.011 | 0.1 |
| 1.390 | 7.018 | 6.033 | 29-Apr-2009 | -0.043 | 16.3 |
| Rating | | | 16-May-2009 | (17-May-2009) | |
| 1.487 | 3.805 | 3.902 | 16-Jul-2009 | 0.002 | -2.5 |
| 1.575 | 6.629 | 6.518 | 04-Aug-2009 | -0.003 | 1.7 |
| Rating | | | 26-Aug-2009 | (26-Aug-2009) | |
| 1.550 | 6.382 | 5.307 | 24-Sep-2009 | 0.001 | 20.2 |
| 1.457 | 3.814 | 3.925 | 07-Oct-2009 | -0.002 | -2.8 |
| 1.477 | 4.368 | 4.456 | 03-Nov-2009 | -0.004 | -2.0 |
| 1.477 | 4.280 | 4.299 | 03-Nov-2009 | -0.000 | -0.4 |
| Rating | | | 12-Nov-2009 | | |
| 4.060 | 2.031 | 1.917 | 13-Nov-2009 | 2.797 | 6.0 |
| 4.004 | 1.383 | 1.253 | 20-Nov-2009 | 2.799 | 10.4 |
| 3.937 | 0.674 | 0.663 | 08-Dec-2009 | 2.802 | 1.7 |
| 3.900 | 0.500 | 0.413 | 23-Dec-2009 | 2.788 | 21.1 |
| 3.885 | 0.331 | 0.325 | 02-Feb-2010 | 2.803 | 1.8 |
| 3.890 | 0.341 | 0.358 | 03-Feb-2010 | 2.805 | -4.7 |
| 3.855 | 0.223 | 0.219 | 23-Feb-2010 | 2.802 | 2.0 |
| 1.322 | 2.762 | 2.820 | 02-May-2010 | 0.003 | -2.1 |
| 1.455 | 5.149 | 5.377 | 08-Jul-2010 | 0.004 | -4.2 |
| Rating | | | 01-Aug-2010 | (02-Aug-2010) | |
| 1.572 | 8.796 | 8.089 | 11-Aug-2010 | 0.007 | 8.7 |
| 1.857 | 18.700 | 19.236 | 18-Aug-2010 | 0.064 | -2.8 |
| 1.580 | 9.460 | 9.241 | 20-Oct-2010 | -0.007 | 2.4 |
| 1.380 | 4.351 | 4.423 | 02-Nov-2010 | -0.002 | -1.6 |
| 1.285 | 2.593 | 2.574 | 11-Nov-2010 | 0.003 | 0.7 |
| 1.231 | 1.933 | 1.872 | 24-Nov-2010 | -0.005 | 3.2 |
| 1.120 | 0.622 | 0.627 | 06-Dec-2010 | -0.000 | -0.8 |
| 1.082 | 0.337 | 0.336 | 14-Dec-2010 | -0.000 | 0.3 |
| Rating | | | 27-Dec-2010 | (28-Dec-2010) | |
| 1.445 | 6.826 | 6.565 | 10-Jan-2011 | -0.009 | 4.0 |
| 1.250 | 2.741 | 2.579 | 21-Jan-2011 | -0.007 | 6.3 |
| 1.140 | 1.185 | 1.190 | 03-Feb-2011 | 0.001 | -0.4 |
| 1.270 | 2.972 | 2.934 | 15-Feb-2011 | -0.002 | 1.3 |
| 1.270 | 2.887 | 2.923 | 15-Feb-2011 | 0.003 | -1.2 |
| 1.231 | 2.273 | 2.386 | 14-Apr-2011 | 0.005 | -4.7 |
| 1.508 | 7.971 | 8.082 | 25-May-2011 | 0.014 | -1.4 |
| 1.341 | 4.053 | 4.164 | 05-Jul-2011 | 0.006 | -2.7 |
| 1.515 | 8.775 | 8.688 | 13-Sep-2011 | -0.006 | 1.0 |
| 1.390 | 4.756 | 4.996 | 13-Oct-2011 | 0.021 | -4.8 |
| Rating | | | 25-Oct-2011 | (26-Oct-2011) | |
| 1.578 | 8.622 | 8.342 | 09-Nov-2011 | 0.000 | 3.4 |
| 1.464 | 5.748 | 5.632 | 01-Dec-2011 | -0.004 | 2.1 |
| 1.235 | 1.772 | 1.722 | 21-Dec-2011 | -0.004 | 2.9 |
| 1.120 | 0.686 | 0.673 | 06-Jan-2012 | -0.004 | 2.0 |
| 1.115 | 0.597 | 0.598 | 02-Feb-2012 | 0.004 | -0.1 |
| 1.245 | 1.759 | 1.729 | 20-Apr-2012 | 0.007 | 1.7 |
| 1.332 | 2.981 | 3.023 | 23-May-2012 | 0.005 | -1.4 |
| 1.590 | 9.190 | 8.941 | 16-Aug-2012 | -0.006 | 2.8 |
| Rating | | | 06-Sep-2012 | (08-Sep-2012) | |
| 1.420 | 5.020 | 5.327 | 15-Nov-2012 | 0.005 | -5.8 |
| 1.313 | 3.158 | 3.217 | 05-Dec-2012 | -0.003 | -1.8 |
| 1.221 | 1.726 | 1.707 | 20-Dec-2012 | 0.000 | 1.1 |
| 1.180 | 1.268 | 1.264 | 29-Jan-2013 | -0.000 | 0.3 |
| 1.080 | 0.466 | 0.479 | 01-Mar-2013 | 0.000 | -2.7 |
| 1.027 | 0.227 | 0.230 | 13-Mar-2013 | -0.000 | -1.4 |

**Table 4 (continued) Rating table comparing gauged flow with rated flow for the Lindis at Ardgrour Road flow site.**

| Stage | Gauged flow | Rated flow | Date | Deviation | |
|---|---|---|---|---|---|
| m | m3/sec | m3/sec | | m | % |
| 1.051 | 0.325 | 0.321 | 05-Apr-2013 | -0.000 | 1.2 |
| Rating | | | 01-Jul-2013 | (06-Jul-2013) | |
| 2.125 | 53.004 | 52.368 | 09-Jul-2013 | -0.008 | 1.2 |
| 1.600 | 12.804 | 13.213 | 26-Jul-2013 | 0.001 | -3.1 |
| 1.480 | 9.034 | 8.957 | 06-Aug-2013 | -0.004 | 0.9 |
| 1.441 | 7.521 | 7.663 | 23-Aug-2013 | 0.004 | -1.9 |
| 1.438 | 7.608 | 7.769 | 26-Sep-2013 | -0.002 | -2.1 |
| 1.363 | 5.343 | 5.483 | 11-Nov-2013 | 0.001 | -2.6 |
| 1.365 | 5.157 | 5.503 | 11-Nov-2013 | 0.010 | -6.3 |
| 1.183 | 1.854 | 1.960 | 04-Dec-2013 | -0.003 | -5.4 |
| 1.322 | 4.359 | 4.393 | 09-Jan-2014 | -0.001 | -0.8 |
| 1.287 | 3.613 | 3.599 | 13-Jan-2014 | -0.001 | 0.4 |
| 1.080 | 0.710 | 0.715 | 31-Jan-2014 | -0.001 | -0.7 |
| 1.085 | 0.711 | 0.714 | 31-Jan-2014 | 0.004 | -0.4 |
| 1.040 | 0.441 | 0.441 | 05-Feb-2014 | -0.001 | 0.1 |
| 1.040 | 0.440 | 0.433 | 05-Feb-2014 | -0.000 | 1.6 |
| 1.027 | 0.368 | 0.372 | 11-Feb-2014 | 0.000 | -1.1 |
| Rating | | | 18-Feb-2014 | (18-Feb-2014) | |
| 1.000 | 0.231 | 0.237 | 06-Mar-2014 | -0.009 | -2.7 |
| 1.031 | 0.323 | 0.329 | 01-Apr-2014 | -0.000 | -1.9 |
| 1.452 | 8.096 | 7.888 | 08-May-2014 | -0.004 | 2.6 |
| Rating | | | 25-Jun-2014 | (25-Jun-2014) | |
| 1.495 | 9.061 | 9.356 | 15-Jul-2014 | 0.007 | -3.1 |
| 1.424 | 7.220 | 7.203 | 04-Sep-2014 | -0.002 | 0.2 |
| 1.376 | 5.977 | 5.956 | 11-Sep-2014 | -0.001 | 0.3 |
| 1.365 | 5.668 | 5.708 | 26-Sep-2014 | 0.002 | -0.7 |
| 1.270 | 3.764 | 3.884 | 15-Oct-2014 | -0.004 | -3.1 |
| 1.268 | 3.614 | 3.744 | 31-Oct-2014 | 0.002 | -3.5 |
| 1.265 | 3.588 | 3.736 | 21-Nov-2014 | -0.000 | -4.0 |
| 1.190 | 2.242 | 2.428 | 01-Dec-2014 | 0.003 | -7.7 |
| 1.125 | 1.410 | 1.508 | 12-Dec-2014 | 0.000 | -6.5 |
| 1.086 | 0.964 | 1.102 | 19-Dec-2014 | 0.003 | -12.5 |
| 1.030 | 0.509 | 0.515 | 30-Dec-2014 | 0.002 | -1.3 |
| 1.021 | 0.465 | 0.447 | 07-Jan-2015 | -0.001 | 4.1 |
| 1.009 | 0.378 | 0.357 | 13-Jan-2015 | -0.001 | 5.8 |
| 0.993 | 0.275 | 0.260 | 19-Jan-2015 | 0.000 | 5.9 |
| 0.982 | 0.214 | 0.221 | 27-Jan-2015 | 0.002 | -3.3 |
| 1.002 | 0.314 | 0.343 | 12-Feb-2015 | 0.002 | -8.4 |
| Rating | | | 13-Feb-2015 | (27-Feb-2015) | |
| 0.998 | 0.255 | 0.249 | 27-Feb-2015 | -0.000 | 2.5 |
| Rating | | | 28-Feb-2015 | (12-Mar-2015) | |
| 1.000 | 0.221 | 0.216 | 12-Mar-2015 | 0.000 | 2.5 |
| 1.005 | 0.234 | 0.239 | 23-Mar-2015 | 0.002 | -2.0 |
| 1.207 | 2.656 | 2.448 | 06-May-2015 | -0.013 | 8.5 |

| Rating | Gaugings | Runs | +ve Dev | -ve Dev |
|---|---|---|---|---|
| 01-Nov-2005 | 34 | 14 | 19 | 15 |
| 29-Nov-2006 | 11 | 4 | 8 | 3 |
| 31-May-2007 | 18 | 10 | 11 | 7 |
| 01-Sep-2008 | 5 | 4 | 2 | 3 |
| 20-Dec-2008 | 5 | 3 | 4 | 1 |
| 16-May-2009 | 2 | 2 | 1 | 1 |
| 26-Aug-2009 | 4 | 2 | 1 | 3 |
| 12-Nov-2009 | 9 | 4 | 6 | 3 |
| 01-Aug-2010 | 8 | 7 | 5 | 3 |
| 27-Dec-2010 | 10 | 6 | 4 | 6 |
| 25-Oct-2011 | 8 | 5 | 6 | 2 |
| 06-Sep-2012 | 7 | 4 | 3 | 4 |
| 01-Jul-2013 | 15 | 8 | 5 | 10 |
| 18-Feb-2014 | 3 | 2 | 1 | 2 |
| 25-Jun-2014 | 16 | 5 | 5 | 11 |
| 13-Feb-2015 | 1 | 1 | 1 | 0 |
| 28-Feb-2015 | 3 | 3 | 2 | 1 |
| All Gaugings | 159 | 79 | 84 | 75 |

86% of the gaugings are within 8% of the rating

## Lindis at the Lindis Crossing Bridge (SH8)

Flows at this site conformed to expected accuracy of +/-8% for range of flow 0 to 4000 l/s (Figure 15, Table 5).

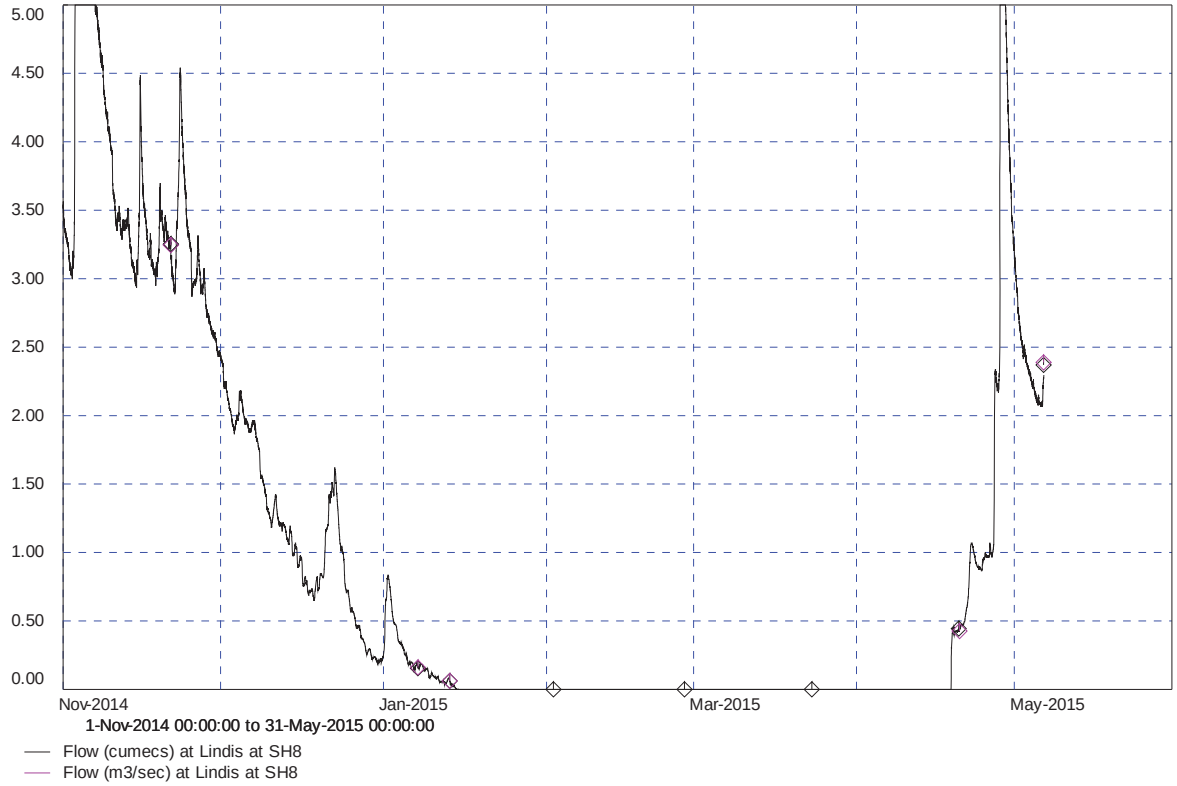


**Figure 15** **Instantaneous flow in the Lindis at the Lindis Crossing, with gauged flows overplotted (pink diamonds) for the period 1 November 2014 to 31 May 2015**

**Table 5 Rating table comparing gauged flow with rated flow for the Lindis at the Lindis Crossing flow site**

~~~ Hilltop Hydro ~~~ Version 6.47

~~~ QRate ~~~

Source is W:\linidis catchment data.hts

Gaugings for Lindis at SH8 from 01-Oct-2014 13:30:00 to 6-May-2015 15:35:00

Deviation from the Ratings: (Qg-Qr)/Qr

Qr computed from the Recorder Stage

| Stage | Gauged flow | Rated flow | Date | Deviation | |
|---|---|---|---|---|---|
| m | m3/sec | m3/sec | | m | % |
| Rating | | 07-Nov-2007 | | | |
| Rating | | 08-Oct-2014 | | | |
| 5.110 | 3.475 | 3.547 | 15-Oct-2014 | -0.001 | -2.0 |
| 5.097 | 3.246 | 3.259 | 21-Nov-2014 | 0.000 | -0.4 |
| 4.823 | 0.160 | 0.163 | 07-Jan-2015 | -0.001 | -2.0 |
| 4.796 | 0.064 | 0.065 | 13-Jan-2015 | -0.000 | -2.2 |
| 4.878 | 0.423 | 0.449 | 20-Apr-2015 | 0.003 | -5.8 |
| 5.040 | 2.388 | 2.369 | 06-May-2015 | -0.001 | 0.8 |

| Rating Gaugings | Runs | Pos Dev | Neg Dev | |
|---|---|---|---|---|
| 07-Nov-2007 | 0 | 0 | 0 | 0 |
| 08-Oct-2014 | 6 | 2 | 1 | 5 |
| All Gaugings | 6 | 2 | 1 | 5 |

100% of the gaugings are within 8% of the rating

## Lindis at the Clutha confluence

Comparison of gauged versus rated (based on measured water level) flows shows that there is low confidence in flows derived from data for this site due to poor performance of water level logger and lack of flow gaugings between 3000 and 110 litres per second (Figure 16, Table 6).

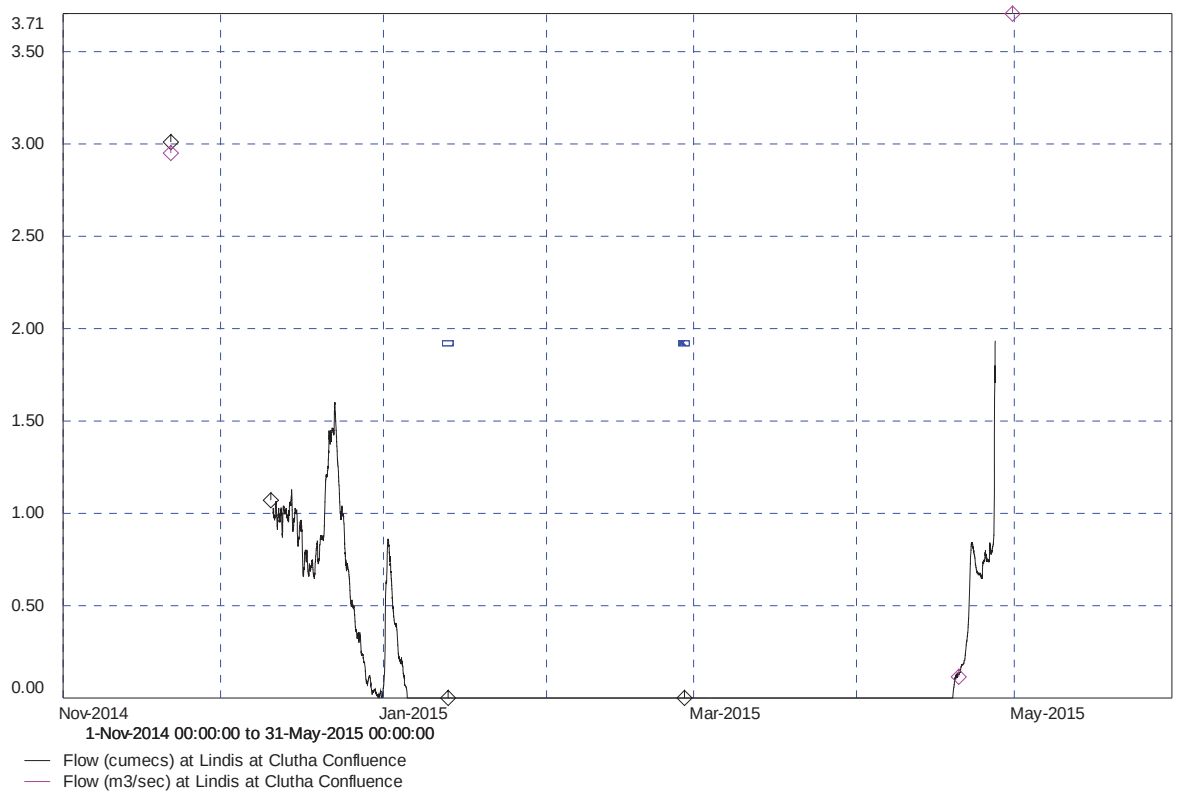


**Figure 16** **Instantaneous flow in the Lindis at the Clutha confluence, with gauged flows overplotted (pink diamonds) for the period 1 November 2014 to 31 May 2015**

**Table 6 Rating table comparing gauged flow with rated flow for the Lindis at the Clutha confluence flow site**

~~~ Hilltop Hydro ~~~ Version 6.47

~~~ QRate ~~~

Source is W:\linidis catchment data.hts

Gaugings for Lindis at Clutha Confluence from 31-Oct-2014 14:16:00 to 30-Apr-2015 16:15:00

Deviation from the Ratings: (Qg-Qr)/Qr

Qr computed from the Recorder Stage

| Stage | Gauged flow | Rated flow | Date | Deviation | |
|---|---|---|---|---|---|
| m | m3/sec | m3/sec | | m | % |
| Rating | 08-Oct-2014 | | | | |
| 5.174 | 3.143 | 3.125 | 31-Oct-2014 | -0.001 | 0.6 |
| 5.167 | 2.949 | 3.011 | 21-Nov-2014 | 0.004 | -2.1 |
| 4.907 | 0.114 | 0.130 | 20-Apr-2015 | -0.000 | -12.0 |
| 5.210 | 3.707 | 3.743 | 30-Apr-2015 | 0.002 | -1.0 |

| Rating | Gaugings | Runs | Pos Dev | Neg Dev |
|---|---|---|---|---|
| 08-Oct-2014 | 4 | 2 | 1 | 3 |
| All Gaugings | 4 | 2 | 1 | 3 |

75% of the gaugings are within 8% of the rating

## Appendix 2: Water management infrastructure and methods in the Lindis River

### Flow sharing in the lower Lindis River.

March 2015

#### Introduction

In the dry Lindis catchment irrigation water availability during summer is crucial. However every summer there is not enough flow for all primary water permits to abstract at their full allocation rate. Over the years the irrigators and the race man have developed and fine tuned a method of ensuring the water is shared fairly between the users.

#### Low flow sharing

Four intakes in the Lindis River work together to share water particularly during low flows. The sharing is done in two ways, firstly some of the flow is left in the river for the other takes and secondly, further flow is returned to the river just above the intake for the next take.
Bywashing or returning water back to the river allows for a finer management of the resource. The race man can see what was initially taken and can then deliver more or less to the next take to achieve the nominated rostering regime whether it be 25%, 50% or 75% cutbacks.

The Lindis Irrigation Company has two intakes which supply two races, the Tarras and Ardgour races. The Tarras race delivers water to properties on the true right of the river around the Tarras flats and beyond. The Ardgour Race runs along the true left of the Lindis and delivers water to shareholders throughout the Ardgour Valley.

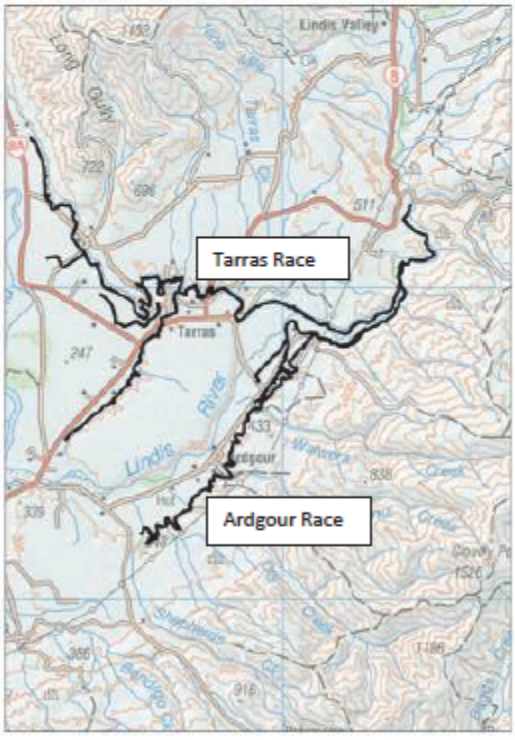


Figure 1: Map showing the Tarras and Ardgour Races in the Lower Lindis Catchment

1

*Prepared by McKeague Consultancy with the assistance of the Lindis Catchment Group*

There are two other takes in the Lower Lindis River that are part of this rostering regime, the Rutherford take and the Beggs take(or Beggs Stackpol take).
The Tarras take is the most upstream take labelled T on the map below. Next intake is the Ardgour take, labelled A. Then the Rutherford take, labelled R and the Beggs take, labelled B.
The Tarras take/race bywashes water back to the river at two locations to supply other takes, at site TA for the Ardgour take and at site TB to supply the Beggs take. The Ardgour take/race bywashes water at site AR to supply the Rutherford take.

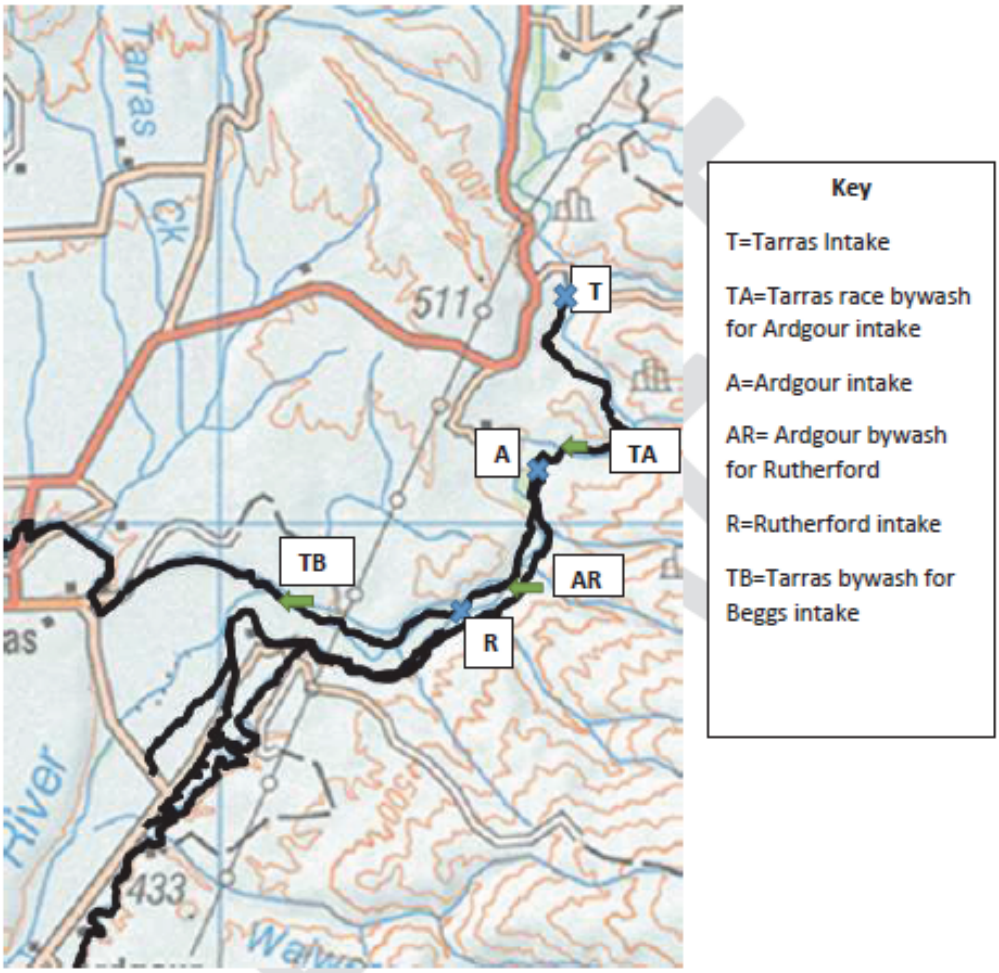


Figure 2: Map showing intake sites and bywash sites in the lower Lindis

As each site is measured at the intake structure and several sites are taking water that has already been measured once, there is a portion of double and in one case triple counting some of the water. During January, February and March to date in 2015 the Raceman recorded the bywash flows. The bywash flow rates were estimated by the Raceman. It was assumed between visits to the bywash sites that the flow rate remained constant. These flow rates were analysed alongside the records of take and it was found that between 5% and 45% of the flow was being double counted. On the 8th February 1457.2L/sec was being recorded but only 1004.2 L/sec was actually taken. 453L/sec was recorded at least twice.

Therefore using the measured flow totals as an estimate of the water abstracted and used in the lower Lindis is inaccurate. See Appendix 1.

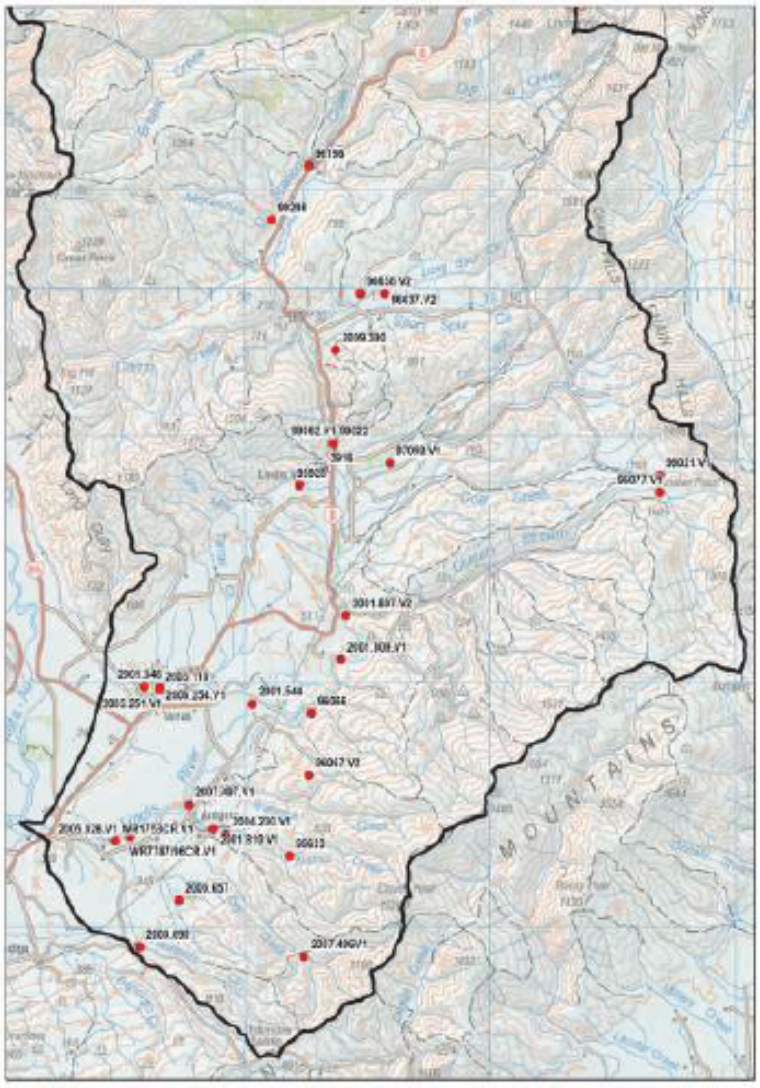


Figure 3: Map of all the water permits in the Lindis catchment

Command area

The water abstracted by the Lindis Irrigation Company is applied to paddocks in the Tarras and Ardgour valley areas. The races are shown on Figure 1. There are also several individually owned Lindis River or Lindis ribbon aquifer takes below the Ardgour bridge that also supply irrigation water to this area.

**Appendix 1: Tarras, Ardgour and Rutherford rates of take**
during January February and March 2015
as measured and removing bywash flows

| | Tarras+Ardgour+Rutherford Takes actually abstracted L/sec | measured abstracted L/sec | % over counted |
|---|---|---|---|
| 12/01/2015 | 1560.4 | 1646.4 | 6 |
| 13/01/2015 | 1567.6 | 1653.6 | 5 |
| 14/01/2015 | 1502.4 | 1588.4 | 6 |
| 15/01/2015 | 1489.7 | 1575.7 | 6 |
| 16/01/2015 | 1451.7 | 1537.7 | 6 |
| 17/01/2015 | 1411.5 | 1510.5 | 7 |
| 18/01/2015 | 1491.6 | 1590.6 | 7 |
| 19/01/2015 | 1551.2 | 1650.2 | 6 |
| 20/01/2015 | 1535.4 | 1634.4 | 6 |
| 21/01/2015 | 1448.0 | 1547.0 | 7 |
| 22/01/2015 | 1475.1 | 1574.1 | 7 |
| 23/01/2015 | 1457.8 | 1556.8 | 7 |
| 24/01/2015 | 1350.6 | 1449.6 | 7 |
| 25/01/2015 | 1210.8 | 1422.8 | 18 |
| 26/01/2015 | 1190.1 | 1430.1 | 20 |
| 27/01/2015 | 1218.3 | 1486.3 | 22 |
| 28/01/2015 | 1155.6 | 1423.6 | 23 |
| 29/01/2015 | 1083.0 | 1436.0 | 33 |
| 30/01/2015 | 989.9 | 1399.9 | 41 |
| 31/01/2015 | 1092.7 | 1545.7 | 41 |
| 1/02/2015 | 1064.9 | 1517.9 | 43 |
| 2/02/2015 | 1116.1 | 1569.1 | 41 |
| 3/02/2015 | 1114.4 | 1567.4 | 41 |
| 4/02/2015 | 1069.8 | 1522.8 | 42 |
| 5/02/2015 | 1127.7 | 1580.7 | 40 |
| 6/02/2015 | 1046.5 | 1499.5 | 43 |
| 7/02/2015 | 1039.4 | 1492.4 | 44 |
| 8/02/2015 | 1004.2 | 1457.2 | 45 |
| 9/02/2015 | 1168.6 | 1464.6 | 25 |
| 10/02/2015 | 1208.2 | 1504.2 | 24 |
| 11/02/2015 | 1182.1 | 1478.1 | 25 |
| 12/02/2015 | 1139.7 | 1478.7 | 30 |
| 13/02/2015 | 1134.1 | 1473.1 | 30 |
| 14/02/2015 | 1137.7 | 1476.7 | 30 |

| | | | |
|---|---|---|---|
| 15/02/2015 | 1244.1 | 1513.1 | 22 |
| 16/02/2015 | 1241.3 | 1510.3 | 22 |
| 17/02/2015 | 1193.6 | 1462.6 | 23 |
| 18/02/2015 | 1172.6 | 1398.6 | 19 |
| 19/02/2015 | 1151.8 | 1377.8 | 20 |
| 20/02/2015 | 1182.1 | 1408.1 | 19 |
| 21/02/2015 | 1142.9 | 1368.9 | 20 |
| 22/02/2015 | 1147.9 | 1373.9 | 20 |
| 23/02/2015 | 1132.8 | 1387.8 | 23 |
| 24/02/2015 | 1129.2 | 1384.2 | 23 |
| 25/02/2015 | 1121.4 | 1376.4 | 23 |
| 26/02/2015 | 1158.0 | 1384.0 | 20 |
| 27/02/2015 | 1118.7 | 1344.7 | 20 |
| 28/02/2015 | 1103.1 | 1329.1 | 20 |
| 1/03/2015 | 1334.6 | 1560.6 | 17 |
| 2/03/2015 | 1278.1 | 1504.1 | 18 |
| 3/03/2015 | 1356.2 | 1554.2 | 15 |
| 4/03/2015 | 1288.7 | 1486.7 | 15 |
| 5/03/2015 | 1179.9 | 1405.9 | 19 |
| 6/03/2015 | 1154.4 | 1409.4 | 22 |
| 7/03/2015 | 1305.6 | 1560.6 | 20 |
| 8/03/2015 | 1308.6 | 1563.6 | 19 |
| 9/03/2015 | 1197.4 | 1452.4 | 21 |
| 10/03/2015 | 1151.6 | 1406.6 | 22 |
| 11/03/2015 | 1191.5 | 1446.5 | 21 |
| 12/03/2015 | 1239.6 | 1494.6 | 21 |
| 13/03/2015 | 1201.4 | 1456.4 | 21 |

# Appendix 3: Clutha Fisheries Trust observations, 15 March 2014