



LAUDER CREEK HYDROLOGY

Report Prepared for:

Otago Regional Council

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February 2021



Table of Contents

1. General	2
2. The Lauder Creek Catchment	3
3. Flow Measuring Sites	5
4 Flow Gauging Analysis	6
4.1 General	6
4.2 Analysis of Flow Gauging Program Data	6
4.3 Analysis of Targeted Gauging Runs (November and December 2020).....	7
5. Results, Conclusion and Recommendation	11
5.1 Results.....	11
5.2 Conclusion	11
5.3 Recommendation.....	11

1. General

Lauder Creek is a tributary of the Manuherikia River and it joins that river just south of the small Lauder settlement. It has a total catchment area of 164.5 km² to its confluence with the Manuherikia River and has its headwaters in the Dunstan Mountains.

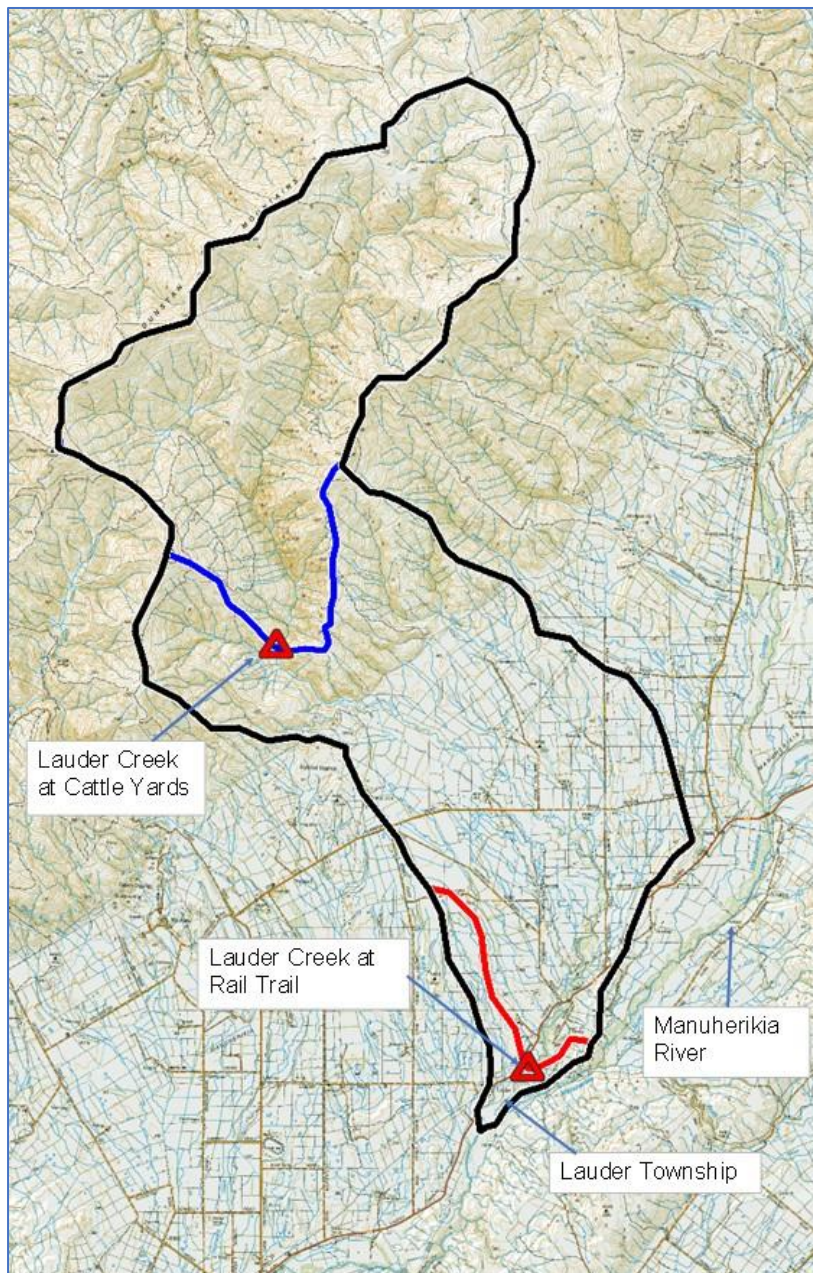
As is typical of rivers and streams flowing from mountain ranges in Central Otago, after the watercourse leaves the mountainous area, they tend to lose water to shallow groundwater and Lauder Creek is no exception. They usually regain some or all of this water as they approach the main stream/river they are a tributary of. Losses begin soon after Lauder Creek leaves the mountainous area and the purpose of this report is to determine if, under natural conditions, Lauder Creek will dry up naturally due to natural losses in the flood plain area.

Currently Lauder Creek dries up every year during the irrigation season over an approximate length of at least 2km length in the middle of the reach between where Lauder Creek moves out onto the floodplain and the Glassford Road Bridge.

2. The Lauder Creek Catchment

The Lauder Creek catchment is a long narrow catchment as shown in Figure 1.

Figure 1. Lauder Creek Catchment



This figure also shows the location of the two water level recorders in this catchment, one at the bottom end of the headwaters of the catchment (Lauder Creek at Cattle Yards) and the other well down the catchment near the confluence with the Manuherikia River (Lauder Creek at Rail Trail). The catchment area to the Cattle Yards site is 73.92km² while that to the Rail Yards site is 112.78km². Catchment elevation ranges from about 330m at its confluence with the Manuherikia River to 1680m in its headwaters.

The river has a mean flow of 1194 l/s at the Cattle Yards recorder site which is situated about 2km upstream of where Lauder Creek emerges onto the flatter flood-plain section of the Manuherikia River Valley. At the downstream site Lauder Creek at Rail Trail which is

situated just upstream of the confluence with the Manuherikia River, it has a mean flow of 1228 l/s.

Lauder Creek is located in the heart of Central Otago and is subject to typical Central Otago weather conditions with generally hot, dry summers, and cold, frosty, dry winters.

Mean annual rainfalls range from about 430mm at Lauder settlement to a about 800mm in the headwaters of Lauder Creek so conditions are not so dry in the highest parts of the catchment.

Lauder Creek has a distinct higher headwaters area in the Dunstan Mountains and a much flatter lower catchment. This lower section passes through lowland farming areas which are heavily irrigated in summer to ensure good crop and pasture growth.

Lauder Creek contributes significant amounts of its flow to irrigation in the irrigation season. Abstraction records show this contribution can be as much as 767 l/s at times (6 January 2019). Also as mentioned earlier, there is a natural loss to shallow groundwater as the Creek traverses the flatter section of its catchment before its confluence with the Manuherikia River.

3. Flow Measuring Sites

There are two continuous water level recorder sites in Lauder Creek, one at the Cattle Yards and the other at Rail Trail as earlier identified. The Lauder Creek at Cattle Yards site records natural flows while the Rail Trail site is significantly affected by abstractions.

Both sites have two periods of measurement including between 2008 and 2010, and from 2016 and they both continue today. The hydrological statistics for Lauder Creek at Cattle Yards are included in Table 1.

Table 1. Lauder Creek at Cattle Yards Statistics (l/s)

Mean	Median	7DMALF*	Min Flow	Max Flow
1194	874	320**	211	36840

*7DMALF is the 7-day mean annual low flow

**The 7DMALF in Table 1 is the official 7DMALF adopted by the Otago Regional Council.

From the latest available data for this site, the calculated 7DMALF is 329 l/s. The lowest 7-day low flow measured at the Cattle Yards site is 237 l/s from 15-22 March 2010.

Flow statistics for the Lauder Creek at Rail Trail site are not relevant to this analysis because it is well downstream of the reach that goes dry annually. The measured data at the Rail Trail site are significantly affected by irrigation abstraction over the irrigation season. The measured mean flow for this site is 1278 l/s, only 84 l/s greater than that for the Cattle Yards site even though the catchment area to the Rail Trail site increases by 50% over that at Cattle Yards. It is likely this lack of increase in mean flow, in spite of the catchment area increase, is due to irrigation abstraction, natural losses to groundwater and the very low rainfall in the lower catchment once Lauder Creek leaves its headwaters mountainous area.

Table 2 is the flow duration table for Lauder Creek at Cattle Yards, and it shows that flows less than 237 l/s has occurred for less than 1% of the time. Flows less than the adopted 7DMALF occurred for at least 5% of the time.

Table 2. Flow Duration Table for Lauder Creek at Cattle Yards

Percent	0	1	2	3	4	5	6	7	8	9
0	36440	6205	4289	3658	3257	2989	2753	2580	2445	2311
10	2195	2084	1987	1905	1832	1770	1714	1659	1612	1572
20	1534	1497	1465	1433	1399	1370	1342	1316	1293	1272
30	1253	1232	1210	1188	1169	1150	1130	1109	1090	1069
40	1049	1028	1009	991	974	959	944	930	914	899
50	884	871	858	845	833	821	808	794	781	767
60	752	737	721	705	688	673	658	642	629	616
70	603	590	576	559	542	527	511	496	484	472
80	461	451	440	431	421	412	403	395	386	377
90	368	359	349	339	324	310	292	275	255	244
100	211									

The Otago Regional Council (ORC) has also undertaken extensive gauging exercises in the reach from the Cattle Yards water level recorder to the Manuherikia confluence. Many of these gaugings were collected to assist in the investigation into whether or not if there was no irrigation, Lauder Creek would go dry naturally. This will be addressed in the next section of this report.

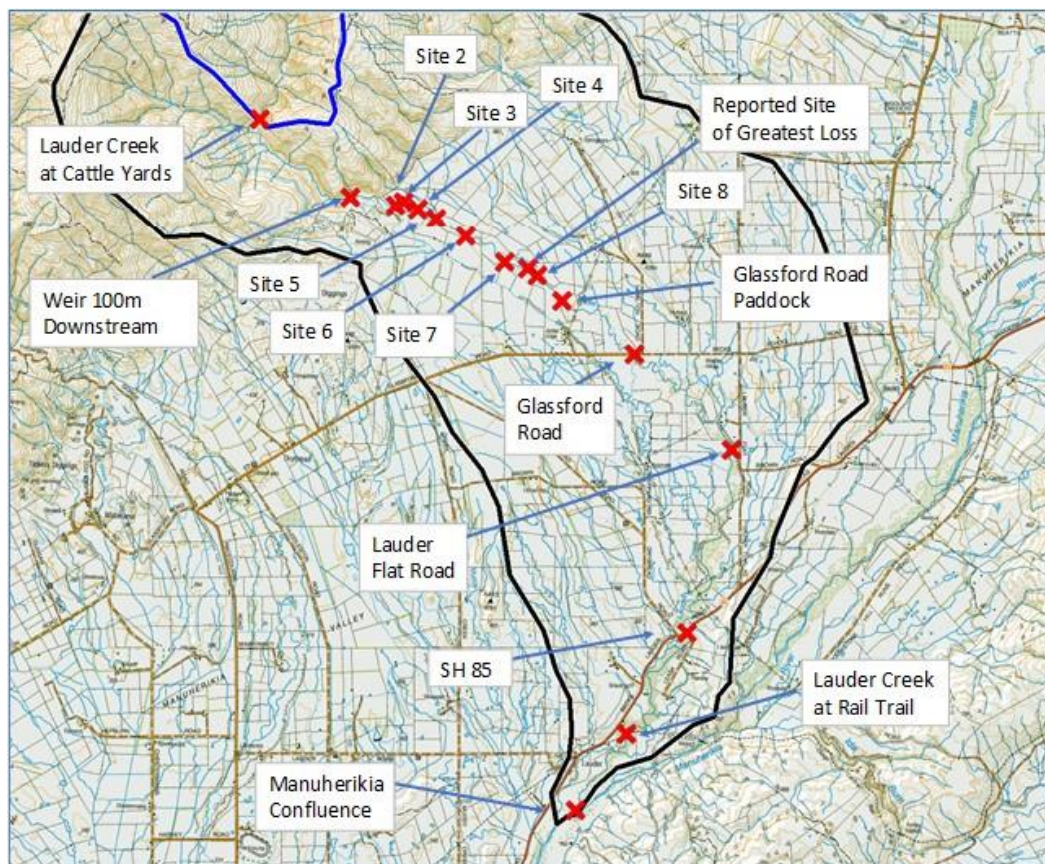
4 Flow Gauging Analysis

4.1 General

The ORC flow gauging program began in late 2017 and the number of sites gauged reached 6 by August 2018 including the Weir 100m Downstream (Weir), Glassford Road Paddock, Glassford Road Bridge, Lauder Flat Road, SH 85 and Manuherikia Confluence. Lauder Creek at Cattle Yards and Rail Trail were automatically included as they are continuous water level measurement sites (see Figure 2). The sites downstream of the Glassford Road Paddock site will not be analysed as they are not relevant to this particular investigation and are downstream of the main losing reach.

Another specifically targeted series of gaugings was undertaken in November and December 2020. The purpose of these gaugings were to try to identify the reach/site of greatest loss in the reach between the Weir and Glassford Road Paddock sites (see Figure 2 Sites 2-8 and reported site of greatest loss).

Figure 2. Instantaneous Gauging Sites Locations



4.2 Analysis of Flow Gauging Program Data

The exclusion of the sites downstream of the Glassford Road Paddock site leaves the 2 gauging sites of Weir and Glassford Road Paddock plus Lauder Creek at Cattle Yards available for analysis. Unfortunately, the area of greatest loss to groundwater is between the Weir and the Glassford Road Paddock sites but these sites do provide some useful information about losses to groundwater.

To assess the loss to groundwater in this Weir to Glassford Road Paddock reach, the natural flow at the Weir site needed to be derived. The Lauder Creek at Cattle Yards site is a natural flow site and is unaffected by abstractions.

Gaugings at the Weir site were corrected for abstractions from four water meters upstream and this showed a distinct increase in flow to more than that at the Cattle Yards site. These corrected flows were then correlated with the corresponding flow at the Cattle Yards site. This produced the relationship:

$$\text{Weir flow} = 1.162 * (\text{Cattle Yards Flow}) + 6 \text{ with an } R^2 \text{ value of } 0.989$$

This relationship shows that natural flows at the Weir site are about 16% greater than those at the Cattle Yards site. If the adopted 7DMALF for the Cattle Yards sites of 320 l/s is applied to the above formula, then the 7DMALF at the Weir sites is 371 l/s. The lowest flow measured at this site was 211 l/s on 30 January 2018. This flow would translate to a natural flow of 247 l/s at the Weir site.

In the reach from the Weir to the Glassford Road Paddock site (about 4.82km long), the site of greatest loss occurs at about 3.74km downstream from the Weir site. After that, Lauder Creek begins to gain flow again. Using naturalised data at both sites, a relationship can be derived between them which is:

$$\text{Glassford Road Paddock} = 0.939 * \text{Weir site} - 74 \text{ with an } R^2 \text{ value of } 0.97.$$

This result shows that between the Weir and Glassford Road Paddock sites, there is a consistent loss to shallow groundwater with the volume lost varying with the flow in Lauder Creek.

Analysing the data as irrigation season (September to April) and non-irrigation season (May to August), losses to groundwater appear higher in the irrigation season than in winter.

4.3 Analysis of Targeted Gauging Runs (November and December 2020).

Table 2 lists the gauging results from the targeted gauging series.

Table 2. Data from Targeted Gauging Runs (l/s)

Gauging Site	Gauging Runs		
	5 November 2020	18 November 2020	16 December 2020
Cattle Yards		802	451
Site 1 Weir	420	358	26
Site 2	437		
Site 3	314		
Site 4	352	344	12
Site 5	313		0
Site 6	223		0
Site 7	156		0
Site 8		200	0
Site 9 Glassford Road Paddock		279	9
Site 10 Glassford Road Bridge		336	82

*No flow data entry in this table indicates the site was not measured.

Except for Lauder Creek at Cattle yards, the flows included in Table 2 are not natural flows. The flows from the Weir to Glassford Road sites are all affected by abstraction throughout the year.

There are four water meters upstream of the Weir site and there are two more in the reach between the Weir and Site 4. There is also a discharge/bywash between sites 2 and 4.

After Site 4, there are no abstractions to the Glassford Road Paddock site and losses and gains in this 3.5 km reach site will be natural.

With the available data, it is not possible to assess the natural losses or gains between the Weir and Site 4 because of the two abstractions and (...the Morons/Brown take can discharge back to the creek. (Site 4 is downstream of this discharge point)” (Pete Ravenscroft email dated 17 November 2020). There are 2 small tributaries in this 1.3 km reach which may contribute to flows and for about 0.5 km of this reach below the Weir site, the creek borders the base of the hilly section of the catchment and losses along this reach may be minimal.

Table 3 shows the analysis of the 5 November gauging run data in Table 2.

Table 3. 5 November Gauging Analysis

Sites	Distance (km)	Loss (l/s)	Loss Rate (l/s/km)
Weir to Site 2	0.79		
Site 2 to Site 3	0.19		
Site 3 to Site 4	0.32		
Site 4 to Site 5	0.41	39	95
Site 5 to Site 6	0.76	90	118
Site 6 to Site 7	0.95	67	71

From Table 3, the rate of loss to shallow groundwater in the reach from Site 4 to Site 7 is variable and ranges from 71 l/s to 118 l/s/km. More gaugings over the same sites when Lauder Creek has flow throughout its length are needed to confirm these losses.

The estimated site of greatest loss has been provided by Matt Hickey of Water Resource Management in map form in an email to David Stewart (Raineffects Ltd) on 25 November 2020 in map form. The map provided by Mr Hickey is included here as Figure 3. He identifies the losing reach as a red line on this map and the gaining reach as a blue line. Where the two lines meet is his estimate of the point of greatest loss.

Figure 3. Estimated Site of Greatest Loss in Lauder Creek



The total natural loss in the 2.12 km reach between Sites 4 and 7 is 196 l/s. Assuming the loss rate in the 0.51 km reach between Site 7 and the reported point of greatest loss is the same as that between Sites 6 and 7 gives a loss of 48 l/s giving an overall loss between Site 4 and the point of greatest loss of 244 l/s.

An estimate of potential loss in the 1.3 km reach between the Weir site and Site 4 can be made. Assumptions for this estimate include:

- the losses in the 0.5km reach downstream of the Weir site are offset by inflow from the tributary;
- losses will be minimal as Lauder Creek traverses the base of the hills;
- losses will increase as the Creek moves out onto its floodplain;
- and the loss rate calculated for between sites 4 and 5 would apply to this first reach.

This would provide a loss over the 0.8 km reach from where the creek leaves the base of the hills to Site 4 of 76 l/s. When this is added to the calculation of loss between Site 4 and the point of greatest loss the total loss is 320 l/s.

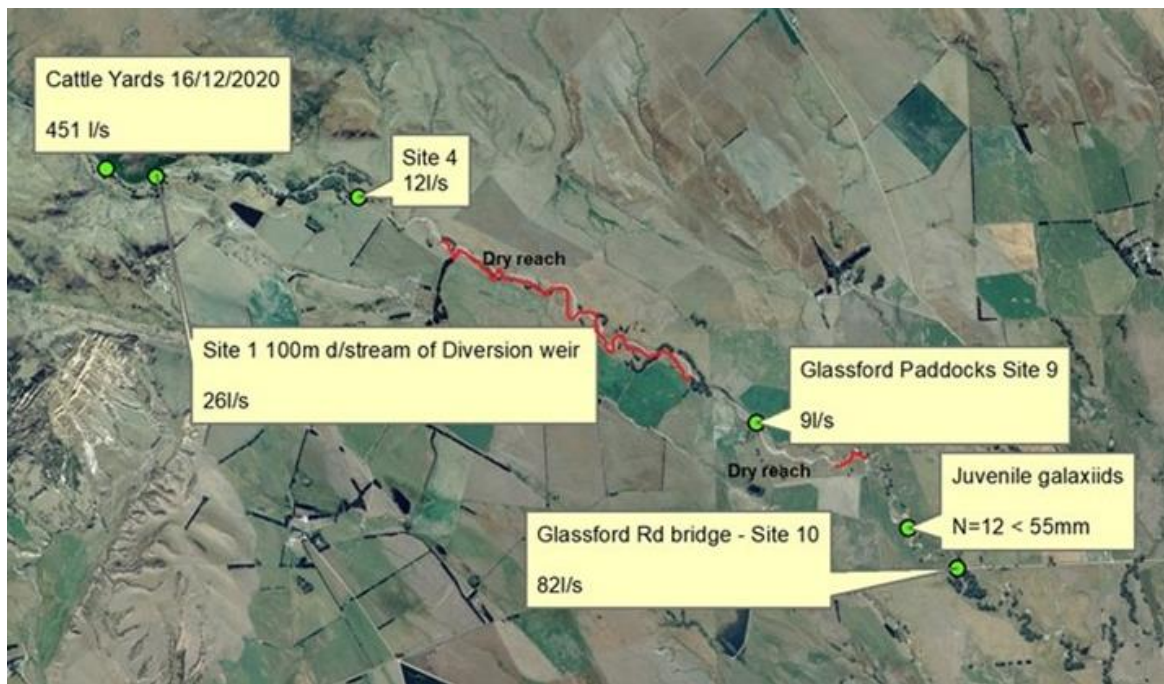
The 3.38 km reach between the point of greatest loss to Glassford Road Bridge is a gaining reach as shown by the data in Table 4.

Table 4. Gaining Reach Gaugings

Date	Site 8	Glassford Paddock	Glassford Bridge	Date	Site 8	Glassford Paddock	Glassford Bridge
14-Mar-18		884	1000	20-Nov-19		1187	1191
18-Apr-18		1155	1335	19-Dec-19		1453	1551
15-May-18		1338	1472	22-Jan-20		58	140
28-Jun-18		790	967	12-Feb-20		170	285
25-Jul-18		1302	1490	11-Mar-20		23	118
29-Aug-18		671	743	06-May-20		208	297
27-Sep-18		1045	1216	10-Jun-20		207	302
31-Oct-18		2832	3117	08-Jul-20		1753	1838
19-Dec-18		1312	1407	05-Aug-20		1184	1329
30-Jan-19		123	182	09-Sep-20		827	923
02-May-19		945	988	07-Oct-20		1384	1519
05-Jun-19		1458	1564	18-Nov-20	200	279	336
10-Jul-19		536	634	16-Dec-20	0	9	82
07-Aug-19		1092	1160	10-Feb-21		510	582
10-Sep-19		657	776	10-Mar-21		15	92
08-Oct-19		1222	1309				

Only 2 gaugings at Site 8 have been undertaken during the gauging period. The 18 November 2020 gauging recorded 200 l/s and on 16 December 2020, the creek was dry at Site 8. Figure 4 shows the dry reach on 16 December 2020.

Figure 4. Dry Section of Lauder Creek on 16 December 2020



5. Results, Conclusion and Recommendation

5.1 Results

- A correlation between the Weir and Cattle Yards sites using naturalised data for the Weir predicted that natural flows at the Weir were at least 16% higher than those at Cattle Yards. There is an increase in catchment area of about 9.23km² to the Weir site.
- This makes the Weir 100m Downstream site the site with greatest natural flow. By adding 16% of the flow at Cattle Yards site, the adopted 7DMALF for the Cattle Yards site of 320 l/s translates to 371 l/s at the Weir site and the lowest recorded natural flow at the Cattle Yards site of 211 l/s translates to 247 l/s at the Weir site.
- There is significant loss of flow to shallow groundwater between the Weir and Glassford Road Paddock sites. This loss can be predicted using the good correlation between the two sites.
- There is significant loss of flow to shallow groundwater in the reach between Sites 4 and 7 and the loss rate is variable.
- More data is needed to properly assess the losses between the Weir and Site 4 and between Site 7 and the estimated point of greatest loss but estimates can be made of these losses based on existing loss rates between Sites 4 and 7.
- Using several assumptions, the estimated total natural loss to shallow groundwater between the Weir and the estimated point of greatest loss is 320 l/s on 5 November 2020.
- The estimated natural loss of 320 l/s in the reach from the Weir site to the point of greatest loss is the same as the ORC adopted 7DMALF of Lauder Creek at Cattle Yards. The 7DMALF will vary down the reach between Cattle Yards and Rail Trail with the highest 7DMALF likely to be that estimated as 371 l/s at the Weir site.
- Data show that from the point of greatest loss to Glassford Road Bridge is a gaining reach and the gain between the Glassford Road Paddock and Bridge sites is quite variable.

5.2 Conclusion

The calculated natural loss of 320 l/s in the reach from the Weir to the estimated point of greatest loss is 320 l/s. The lowest calculated flow at the Weir site is 247 l/s. Therefore, Lauder Creek will go dry naturally in the above reach even when no abstraction is occurring in the very driest of times. Naturally, it is likely to go dry about once every two years on average.

5.3 Recommendation

If the ORC needs greater refinement and certainty in these results, then a series of gaugings at the Weir site, Sites 2-7, the estimated point of greatest loss, Site 6 and Glassford Road Paddock is needed when Lauder Creek has continuous flow throughout the reach from the Weir to Glassford Road Paddock sites and an estimate or measurement of return flow/bywash downstream of Site 2.