

## File Note

**Document Id:** A978677  
**From:** Dean Olsen  
**Date:** 8/02/2017  
**Re:** Relationships between flow and channel braiding in the lower Lindis River

---

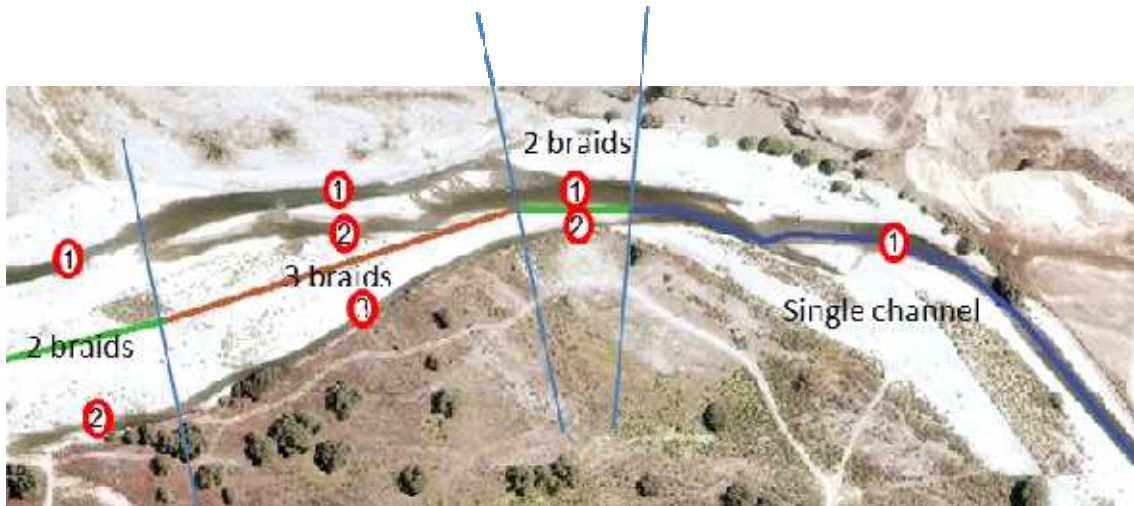
Analysis was undertaken to determine the effect the flow has on braiding patterns in the lower Lindis River (below SH8) to inform the process of setting a minimum flow for the Lindis catchment.

### **Methodology**

This analysis was based on 24 aerial photographs or satellite images of the lower Lindis River as well as 2 measurements taken using a hand-held GPS unit. Images used came from various sources, including ORC, Central Otago District Council, Google Earth, images sourced from Apollo Mapping (including SPOT6, Geoeye-1, QuickBird and WorldView2 satellite imagery) and aerial photographs taken using a drone by Ryder Consulting. Images used were taken when mean daily flows at the Ardgour Road hydrological site were between 158 l/s and 4,536 l/s. Only images that were cloud-free over the whole of the study reach were used. The images used and dates that these were taken are presented in Appendix A. Images were analysed in ArcGIS 10.4.1 (Esri Inc.).

Measurements were made across the reach from the point that the Lindis River enters the Clutha River to the SH8 bridge. For each image, the channel was broken into sections where the channel was dry, there was a single channel, 2 channels, 3 channels etc. (Figure 1). The length of each section was measured along the mid-point of the channels present (Figure 1) to the nearest metre. The length of dry sections was measured along the course of the wetted channel, based on the closest available image in time when the channel was completely wetted.

Ground-based surveys involved marking points at the point at which the number of channels changed using a Garmin GPSmap 60CSx GPS unit. These GPS points were then imported into ArcGIS, and the length of each section determined in the same way as was used to analyse aerial images. The path along which measurements were made was based on the aerial image taken on 24 February 2016 (courtesy of Ryder Consulting).



**Figure 1** An aerial photograph showing a section of the lower Lindis River split into sections with different numbers of braids.

This analysis allowed estimation of the extent of dry channel, the range in the number of braids present and calculation of a weighted average number of braids, a measure of overall braiding across the lower section of the Lindis River. The weighted average was calculated following the formula:

$$\bar{n} = \frac{\sum l_i * n_i}{\sum l_i}$$

Where:

$\bar{n}$  = weighted average number of braids

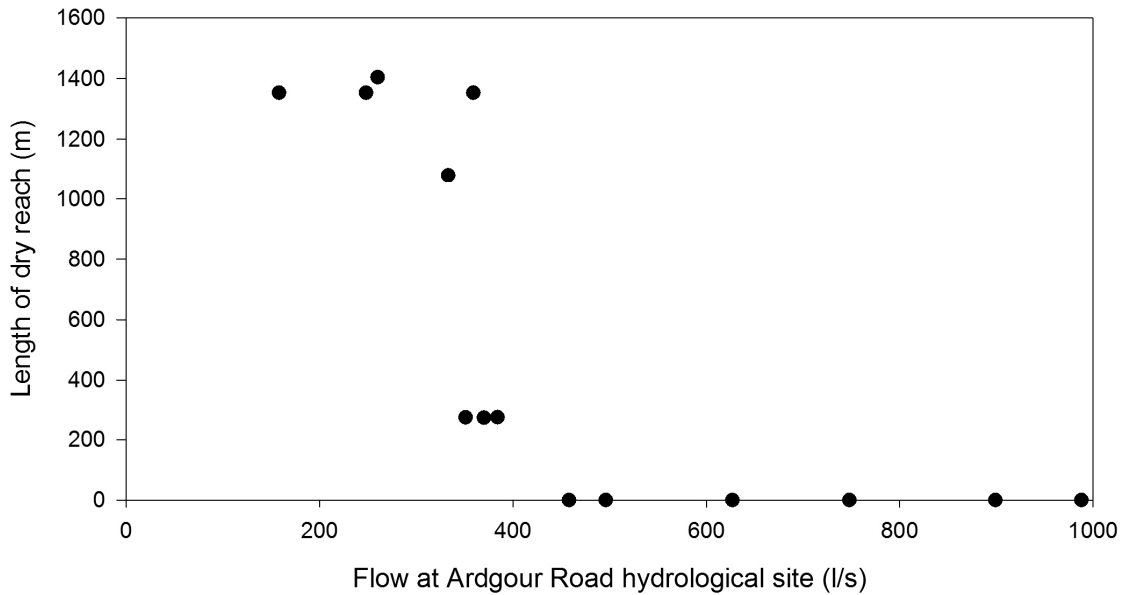
$l_i$  = length of section  $i$

$n_i$  = number of braids in section  $i$

## **Results**

### **Extent of drying reach**

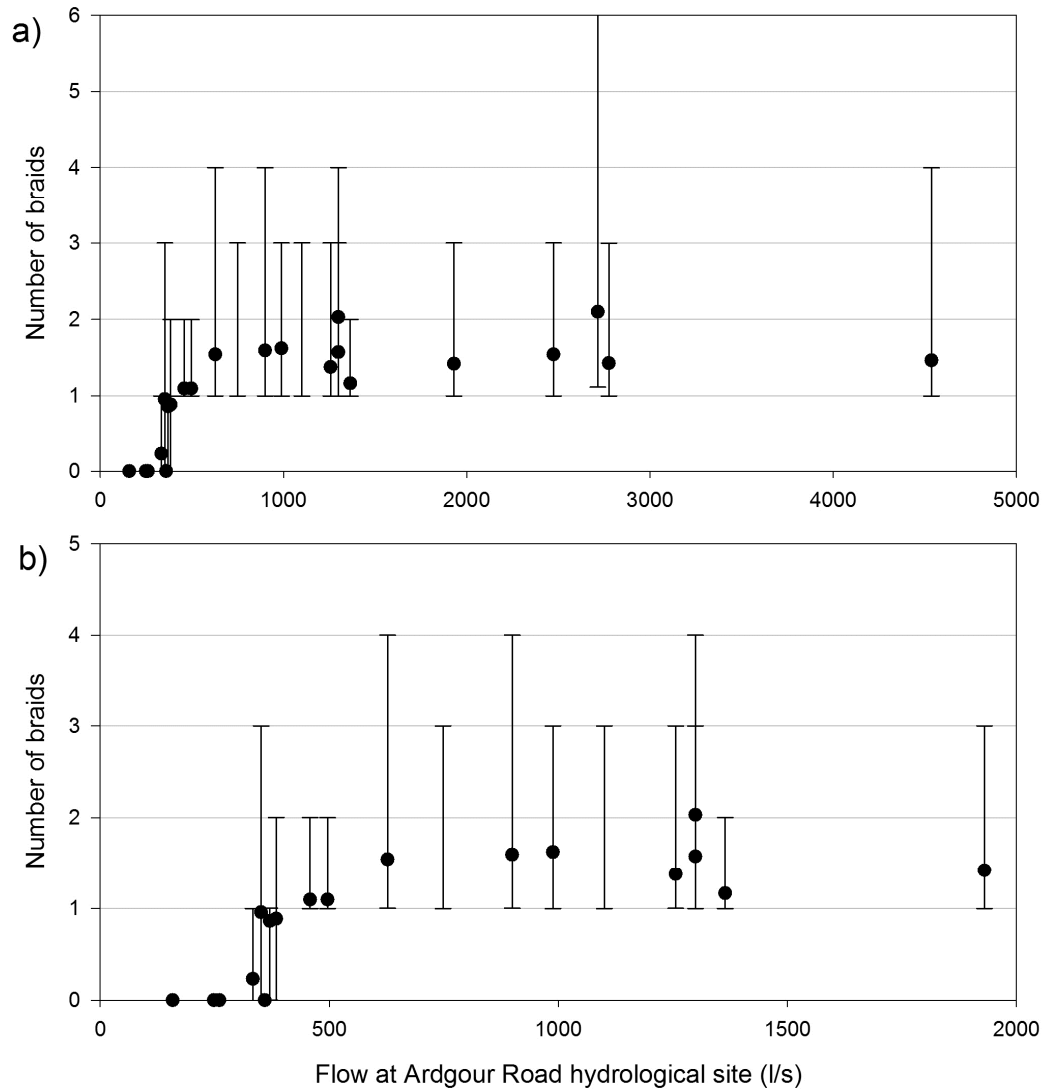
The entire reach from SH8 to the Clutha confluence was dry on four occasions, when flows were between 158 l/s and 359 l/s, while surface flow did not reach the Clutha Confluence on four occasions when flows were between 333 l/s and 384 l/s (Figure 2). Surface flow connection with the Clutha was achieved at all flows in excess of 454 l/s (Figure 2).



**Figure 2 Length of dry river bed in the lower Lindis River at different flows (158-1000 l/s) at the Ardgour Road hydrological site.**

### **Extent of braiding**

The lower Lindis River was largely confined to a single channel at flows less than 500 l/s, with the weighted-average number of channels increasing with flow up to 630 l/s (Figure 3). A 3-parameter sigmoidal curve fitted to the data generated by this analysis reached an asymptote at approximately 1.6 braids, indicating a relatively even balance between single-channel sections and sections with two channels at flows of between 603 l/s and 5,000 l/s.



**Figure 3** Relationship between the number of braids in the lower Lindis River and flow a) full flow range considered (0-5,000 l/s), and b) low flow range (0-2,000 l/s). Data points (black circles) represent the weighted average number of braids and error bars represent the range in the number of braids.

### Discussion

Continuous surface flow was present at all flows in excess of 454 l/s, while, conversely, flow did not reach the Clutha confluence when flows were less than 384 l/s. These results are consistent with previous estimates of flow losses in the lower Lindis River, which have been estimated to be 375 l/s in 2006/07, 450 l/s in 2014/15 and 350 l/s in 2015/16 (Olsen 2016).

The weighted average number of channels increased with flow up to 600 l/s. However, at flows above 600 l/s, the extent of braiding was relatively consistent. Therefore, it is concluded that flows of more than 600 l/s at the Ardgour Road flow recorder will maintain braiding in the lower Lindis River.

It is important to keep in mind that this analysis only considered the physical presence of a flowing, connected braid and does not consider the effect of flow on the amount or quality of habitat present in braids or fish passage through braids.

## Appendix A

**Table 1 Sources of images used in analysis of braiding and extent of drying in the lower Lindis.**  
Flows used were mean daily flows unless otherwise specified.

Date	Flow at Ardgour Road flow recorder (l/s)	Source
18/02/2008	359	SPOT satellite image
15/03/2014	248	Photographs from helicopter from evidence of Aaron Horrell*
23/04/2015	1100	Photographs from helicopter from evidence of Aaron Horrell*
10/12/2015	748	Photographs from helicopter from evidence of Aaron Horrell*
2/11/2013	1364	Pleiades satellite image
26/02/2006	158	ORC aerial imagery
16/02/2007	370	Google Earth
3/12/2011	4536	Google Earth
12/04/2011	2775	Google Earth
5/04/2012	2473	Geoeye-1 satellite image
24/12/2012	1256	Quickbird satellite image
22/01/2013	1930	SPOT6 satellite image
22/11/2013	2715	Worldview-2 satellite image
28/12/2013	1299	SPOT6 satellite image
15/12/2014	1299	Worldview-2 satellite image
1/01/2015	988	SPOT6 satellite image
22/01/2015	253	SPOT6 satellite image
25/12/2015	351	Geoeye-1 satellite image
31/12/2015	333	SPOT6 satellite image
24/02/2017	899†	Ground-based measurement using GPS
25/02/2017	627†	Drone aerial images courtesy of Ryder Consulting
26/02/2017	496†	Drone aerial images courtesy of Ryder Consulting
27/02/2017	458†	Drone aerial images courtesy of Ryder Consulting
21/03/2017	384	Ground-based measurement using GPS

\* The range in the number of braids was estimated from images, but the measurements required to estimate the weighted average number of braids were not possible due to the oblique angle at which images were taken.

† Mean flow over time period when imagery was being taken