Water Resource Impacts of the Kaikoura Earthquake

Low-flow regimes

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Contents

1 Introduction

A comprehensive community survey and detailed review of all secondary information relating to the potential impacts of the Kaikōura Earthquake on the water resources of the Flaxbourne, Mirza and Waima/Ure catchments were undertaken. From these preliminary investigations, several risks were identified regarding the water resources, and consequently to the community, within these catchments.

The wider Flaxbourne community relies on the Flaxbourne and Waima/Ure Rivers for a diverse range of agricultural practices and land uses; including irrigation, stock water, and domestic potable water supply. Significant anecdotal evidence is available of the dramatic changes to the landscape and waterways that occurred following the earthquake; including potential changes to the flow regimes of the rivers, and the connection between surface water and groundwater.

1.1 Aim and Objectives

Water resources are most stressed during summer and periods of prolonged low-flow. It is known that reaches of the Waima/Ure and Flaxbourne Rivers go dry for extended periods, although this has not occurred since the Kaikōura Earthquake.

To better understand how the Kaikōura Earthquake may have influenced water resources in the Flaxbourne, Mirza and Waima/Ure catchments, a low-flow monitoring programme was implemented. Increasing the spatial and temporal coverage of summer flow gauging within the Flaxbourne, Mirza and Waima/Ure River catchments will help to:

- Characterise the low-flow regimes of these rivers, and the nature of low-flow recession;
- Identify both gaining and losing reaches of these rivers between the foothills and the coast;
- Identify the location of potential groundwater recharge zones; and
- Identify how the flow dynamics of the rivers have changed since the Kaikōura Earthquake.

2 Methodology

A low-flow monitoring programme was developed and a series of low-flow gaugings were undertaken along the main stems of each of the three river systems. Gaugings commenced at the boundary of the hill country, where river flow is confined within a bedrock channel, and extend downstream to the limit of tidal influence of each river.

Gauging locations were broadly upstream and downstream of major tributaries, and where other known features may influence the flow regime. The gauging locations also recognised the availability of existing data held by Marlborough District Council (MDC). All gaugings were undertaken in a manner consistent with NEMS (2013) *Open Channel Flow Measurement*.

It is important to note that flow gauging of these gravel-bed rivers is difficult, especially where there is a varying thickness of gravel overlying bedrock. Variability in gauged flows over short reaches of such rivers (i.e. 50m) can be as high as 20% (per. comms Val Wadsworth MDC, 27 May 2019).

2.1 Gauging locations

Flow gaugings have been conducted previously by MDC at various locations on the Flaxbourne and Waima/Ure Rivers (Table 2.1); however, few gaugings have been conducted since the Kaikōura Earthquake. To increase the spatial coverage of the gaugings, five additional sites were 'nested' between the Ure Road Bridge and the coast in the lower Waima/Ure catchment (Figure 2.1 & Table 2.2).

Table 2.1: Flow gauging locations used previously by MDC.

Site	First gauging	Last gauging	Total number of gaugings
Waima/Ure at State Highway One	9/03/1994	20/04/2018	19
Waima/Ure DS Blue Mountain Stream	30/01/2008	26/06/2009	13
Waima/Ure River at Blue Mountain	22/12/2007	30/01/2018	20
Waima/Ure River at The Narrows	9/03/2006	18/08/2010	51
Waima/Ure at Ure Road Bridge	16/09/2008	30/01/2018	14
Flaxbourne River at Corrie Downs	13/06/2001	8/04/2019	215
Flaxbourne River at Glenake	24/08/2000	21/11/2001	13
Flaxbourne River at State Highway One	20/01/1954	6/08/2003	22
Flaxbourne River at Ward Beach Road Ford	27/05/1982	6/08/2003	19

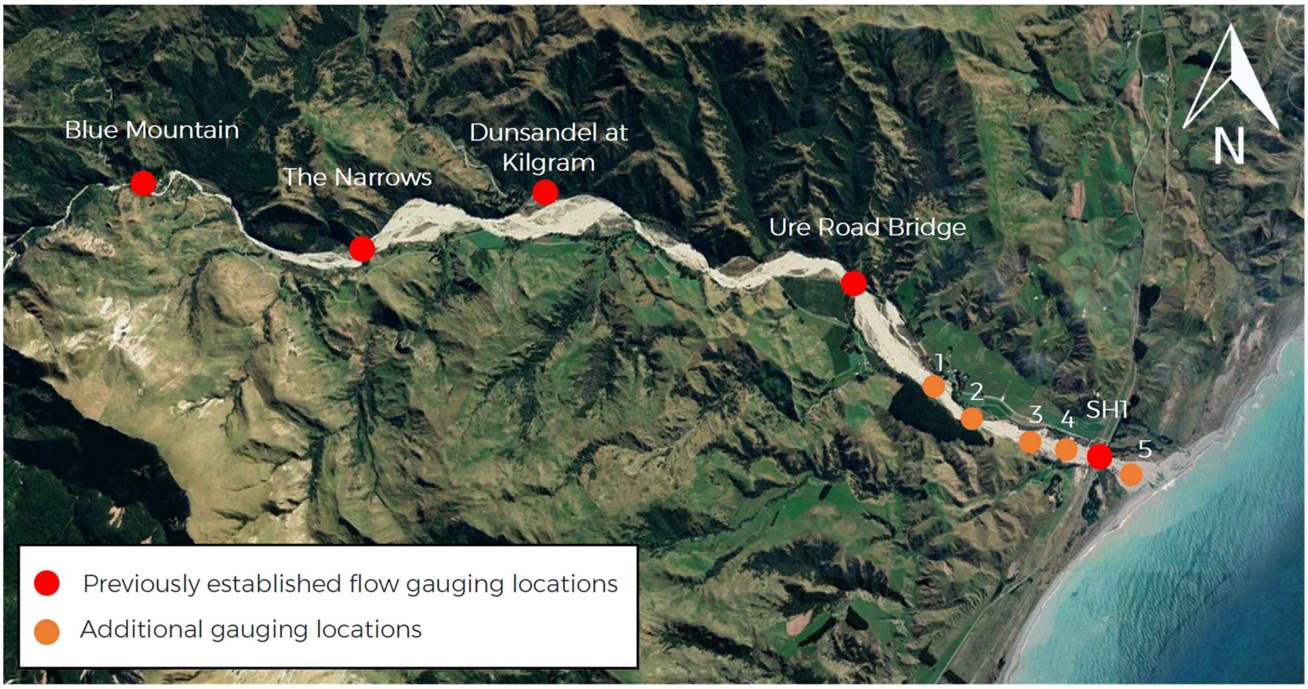

Figure 2.1: Overview of the Waima River and low-flow gauging locations.

Table 2.2: Flow gauging locations used in this study.

Waima/Ure		Waima/Ure - lower reaches		Flaxbourne	
Site	ID	Site	ID	Site	ID
Blue Mountain	1100431	Ure Road Rd Br	1100439	Dog Hill	1100264
The Narrows	61201		1	Glenake	
Dunsandel at Kilgram	1100507		2	Corrie Downs	60901
Ure Road Rd Br	1100439		3	SH1	1100068
SH1	1100090		4	Quarry	1100510

	SH1	1100090	Coast	1100511
		5	Tachells above Needles conf.	1100066
			Needles at SH1	1100225
			Needles at Ward Beach rd.	1100514
			Woodside at SH1	1100509
			Flag at SH1	1100506

A number of sites were also selected for gauging down the main stem of the Flaxbourne River and its major tributaries (Figure 2.2).

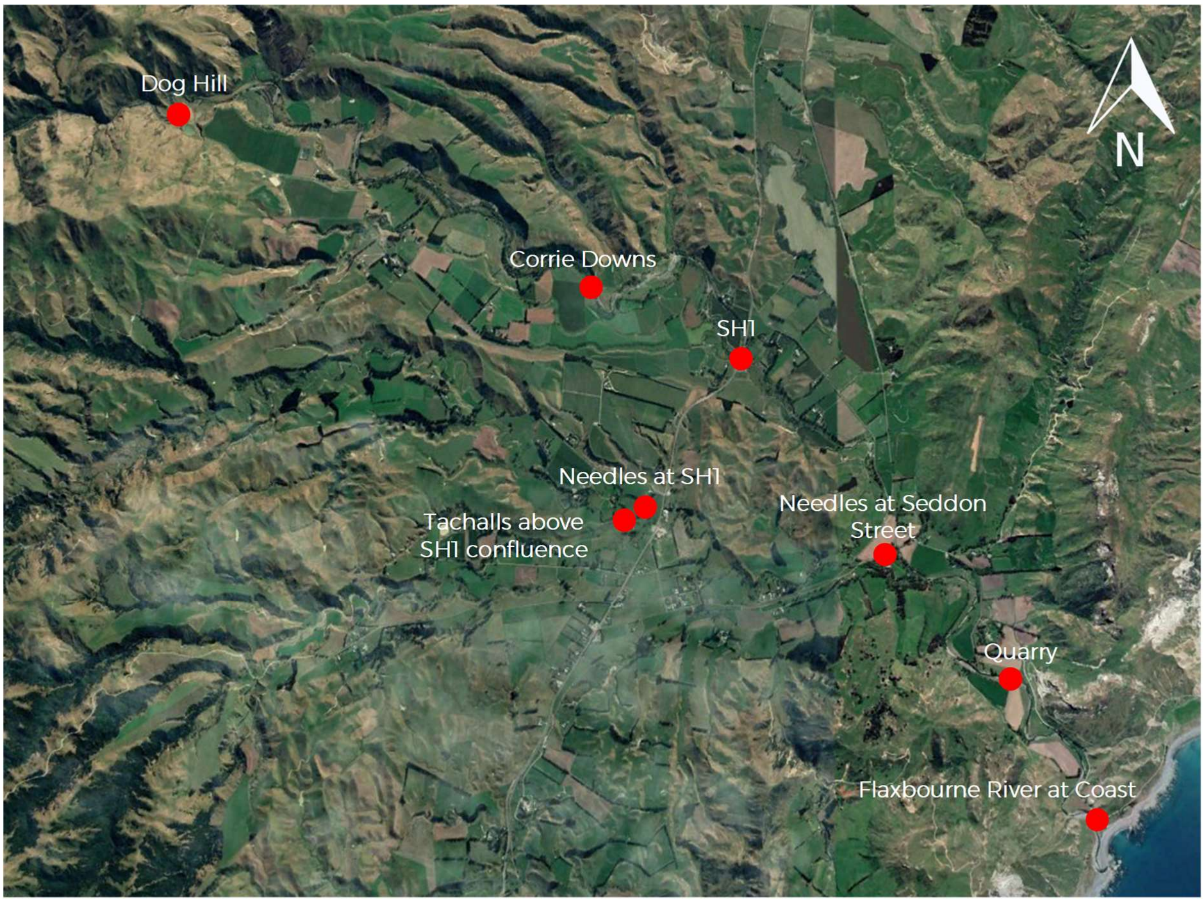

Figure 2.2: Overview of the Flaxbourne River and low-flow gauging locations.

Because of higher flows than normal in these catchments over the 2018-2019 summer, gauging did not start until early February 2019. The period of low-flows was then curtailed earlier than usual because of an uncharacteristically wet April. Gaugings were therefore conducted over three sampling runs; on the 4-6 February 2019, 18-21 February 2019 and 20-22 March 2019.

3 Results

3.1 Waima River

Gauging conducted in the Waima/Ure catchment was split across two days during each gauging run. Previously established gauging locations were gauged on the 4 and 19 February and 20 March 2019. The additional sites 'nested' around these were gauged the following day; except on the 20 March 2019 when all sites were gauged on the same day. The results are presented in Table 3.1 & Table 3.2.

Flows recorded in the Waima/Ure River at the Ure Road Bridge and at SH1 varied by between 0.03 m^3/s and $0.06 m^3/s$ between gauging runs. This variation is approximately 20% of the gauged flow and likely this reflects uncertainty in the gauging results rather than a natural reduction in flow between visits (i.e. one day).

Gauging results in the lower reaches of the Waima/Ure are presented in Figure 3.1 & Figure 3.2. Surface water flow is 'lost' between Blue Mountain and the Ure Road Bridge, but then 'gained' between the Ure Road Bridge and the coast.

A comparison of gaugings results from sites with sufficient data pre and post-earthquake was conducted to correlate the flows between sites (Figure 3.3, Figure 3.4 & Figure 3.5). In general, there is a reduction in flow in the Waima/Ure River downstream of Blue Mountain i.e. flows are higher at Blue Mountain than at The Narrows, the Ure Road Bridge, the SH1 Bridge and upstream of the coast.

Comparison of the flows at Blue Mountain and the SH1 Bridge shows a significant loss of surface flow over this reach. However, there appears to have been a shift in this relationship since the earthquake (Figure 3.3). A greater proportion of the flow at Blue Mountain is now 'lost' upstream of the SH1 Bridge. This shift does not appear to exist, at least to the same level, between the Blue Mountain and the Ure Road Bridge (Figure 3.4). The apparent change in the proportion of surface flow 'lost' to the underlying gravel would therefore appear to be largely the result of changes to the connectivity between surface water and groundwater between the Ure Road Bridge and SH1.

This change in river behaviour is consistent with the differential uplift that resulted from the Kaikōura Earthquake. Uplift at the coast reduced the channel gradient and provided a greater volume of porous gravel above sea level. This has facilitated both greater storage and greater underflow i.e. flow through the gravel.

The longer-term effects of this are currently difficult to predict, certainly the timeframe of any future changes. However, over time, it is likely that the Waima/Ure River will downcut through the uplifted gravel to attain a grade and long-profile similar to that before the Kaikōura Earthquake. Once this has occurred, it is likely that the surface water and groundwater dynamics, and their interaction, will return to something similar to that before the earthquake. The speed of downcutting will be controlled by the frequency, magnitude and duration of flood events. Since floods are essentially random in time, any future changes in the lower Waima/Ure catchment are difficult to predict at this time.

Table 3.1: Low-flow gauging results Waima/Ure catchment.

Site	ID	Catchment Area (km^2)	Flow (m^3/s)		
			04-Feb-2019	19-Feb-2019	20-Mar-2019
Blue Mountain	1100431	100.3	0.73	0.51	0.60
The Narrows	61201	107.5	0.64	0.44	0.52
Dunsandel at Kilgram	1100507	19.7	0	0	0
Ure Road Bridge	1100439	144.6	0.24	0.01	0.12
SH1	1100090	156.7	0.30	0.11	*

*dewatering at bridge pier

Table 3.2: Low-flow gauging results Waima/Ure River - lower reaches.

Site	ID	Flow (m^3/s)		
		05-Feb-2019	20-Feb-2019	20-Mar-2019
Ure Road Bridge	1100439	0.21	0	0.12
	1	0.22	0.05	0.13
	2	0.29	0.09	0.22
	3	0.31	0.08	0.21
	4	0.28	0.10	0.25
SH1	1100090	0.24	0.10	*
	5	0.41	0.22	0.32

* *Dewatering at bridge pier*

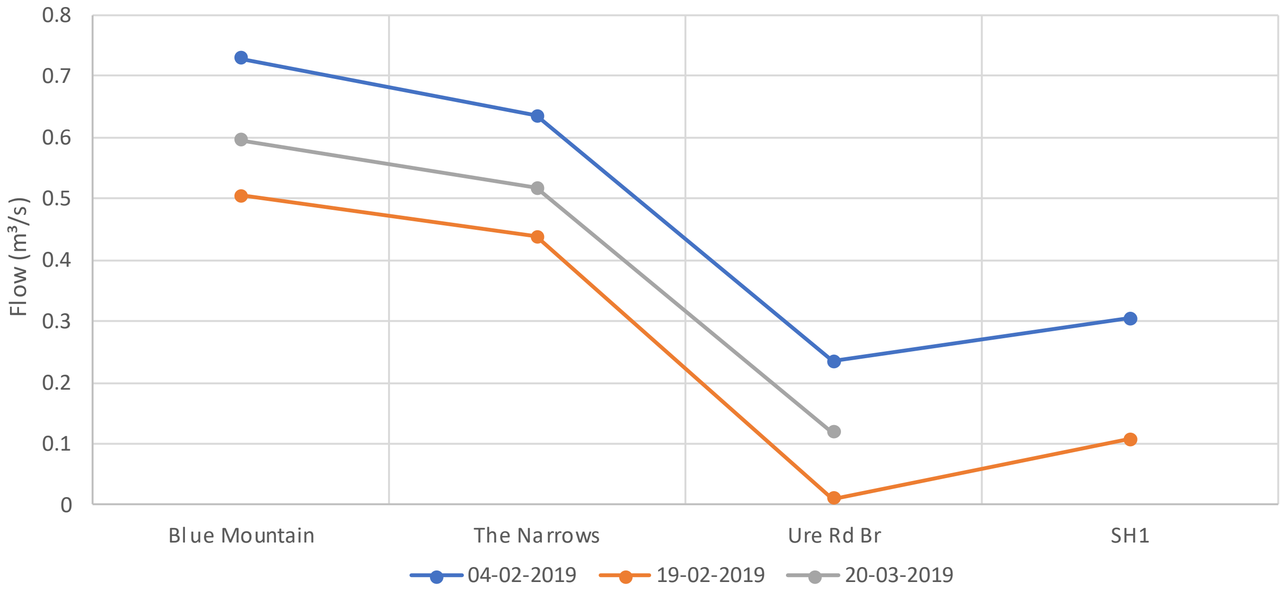

Figure 3.1: Gauging results for established gauging locations on the Waima/Ure River.

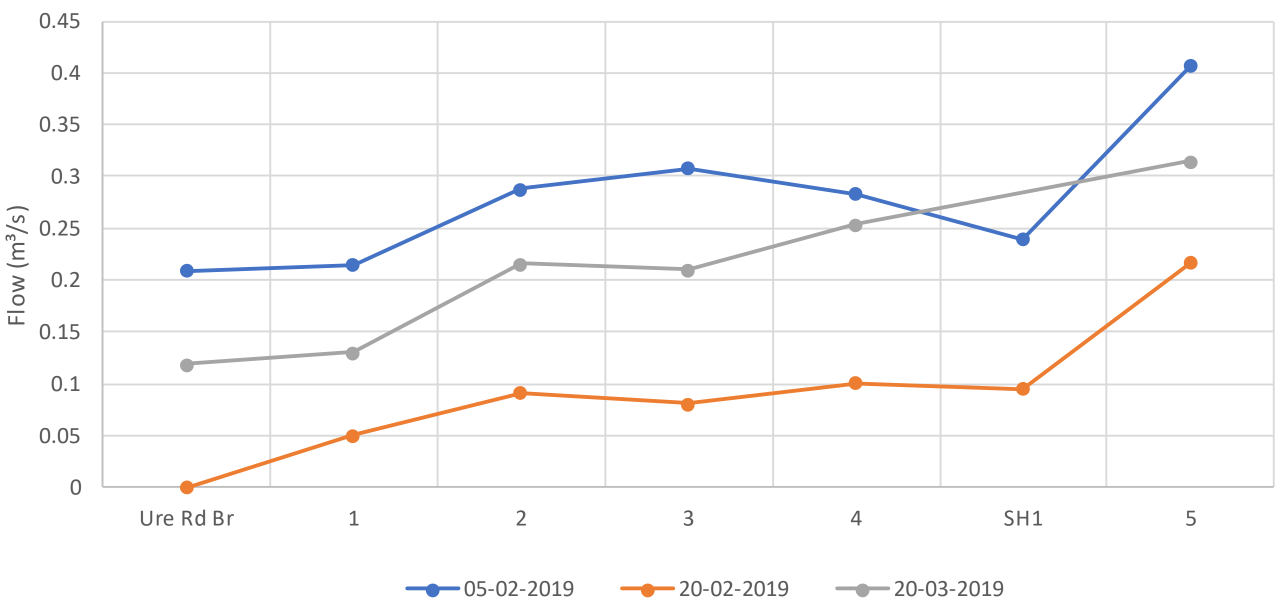

Figure 3.2: Gauging results for additional low-flow gaugings over the lower reaches of the Waima/Ure River.

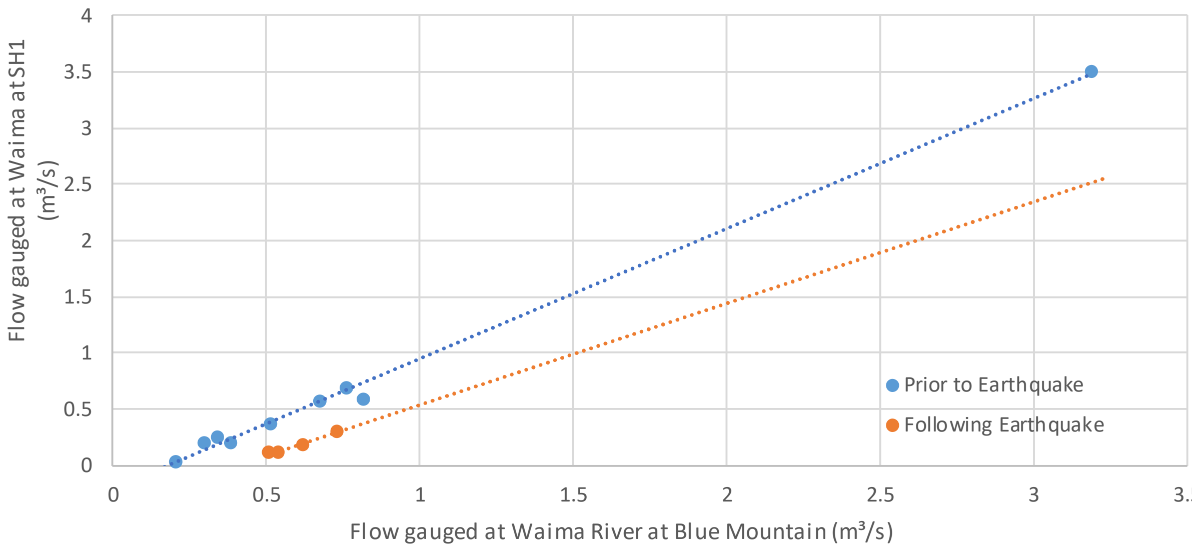

Figure 3.3: *Correlation of flows recorded in the Waima/Ure River at Blue Mountain and SH1.*

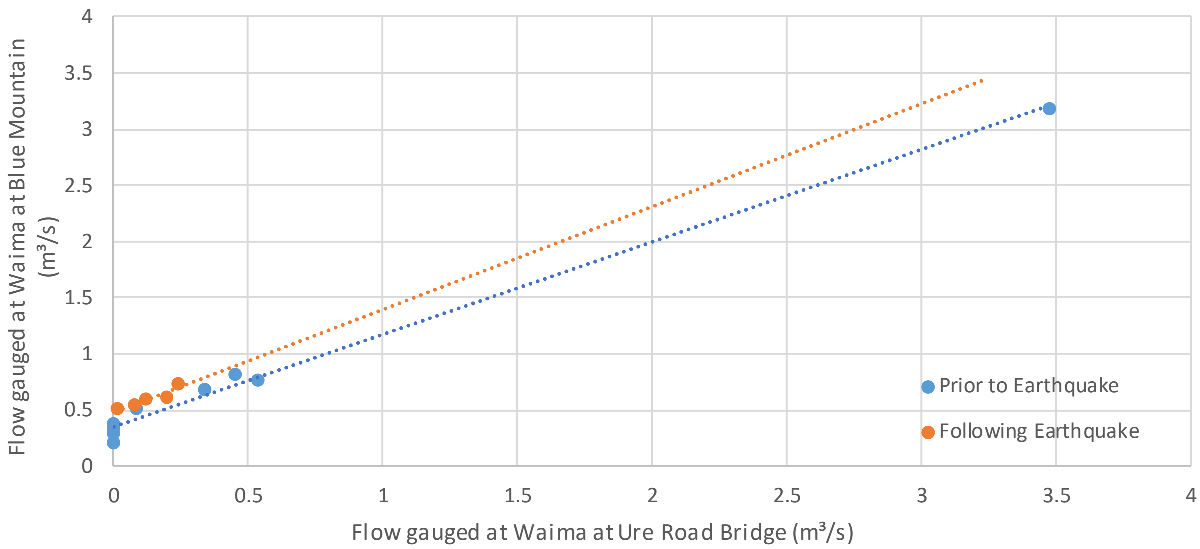

Figure 3.4: *Correlation of flows recorded in the Waima/Ure River at Blue Mountain and the Ure Road Bridge.*

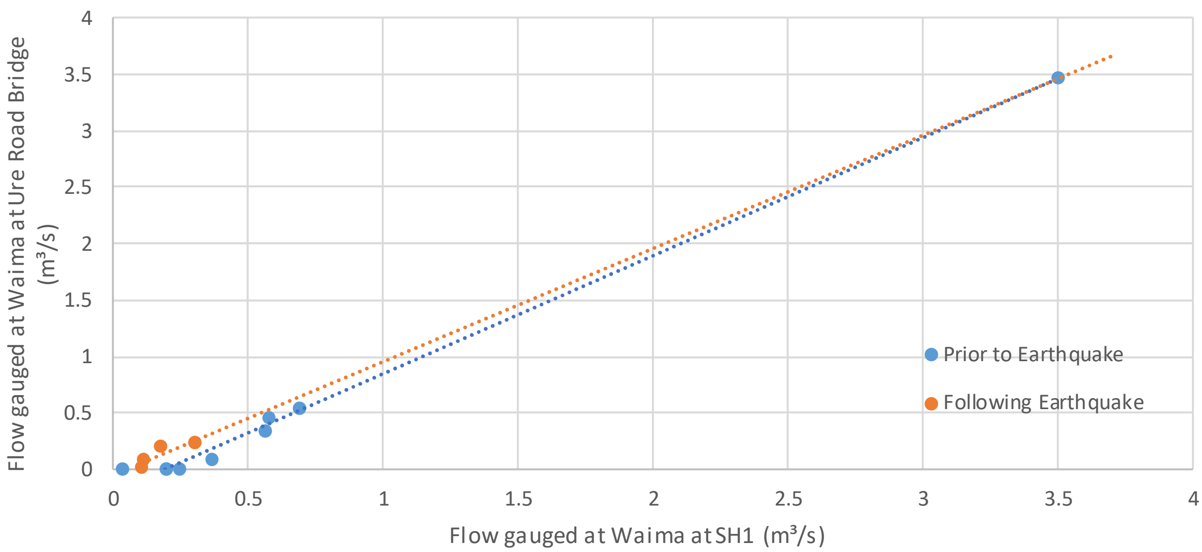

Figure 3.5: *Correlation of flows recorded in the Waima/Ure River at SH1 and Ure Road Bridge.*

3.2 Flaxbourne catchment

The low-flow gauging results for the Flaxbourne catchment are presented in Table 3.3. The results show a reduction in surface flow downstream of Dog Hill to SH1 of between 14% and 31%. Measured flows increase from SH1 to the coast; however, this is attributed to inflows from Needles Creek which flows into the Flaxbourne River upstream of the quarry.

Flows recorded in Needles Creek reduce through the reach between SH1 and Seddon Street, indicating a 'loss' of water to the underlying gravel.

Removing the recorded flows at Needles Creek from flows recorded in the Flaxbourne River downstream of the confluence still does not account for a gain in flow over the lower reach of the Flaxbourne. It is therefore likely that water is 'gained' from the underlying gravel over this reach of river.

Table 3.3: Low-flow gauging results in the Flaxbourne catchment.

Site	ID	Flow (m^3/s)					
		06-Feb	18-Feb	20-Feb	21-Feb	21-Mar	22-Mar
Dog Hill	1100264	0.209			0.026	0.057	
Glenake		0.215					
Corrie Downs	60901	0.288			0.029	0.063up/0.047down (see cmts)	
SH1	1100068	0.308			0.018	0.049	
Quarry	1100510	0.283			0.016	0.074	
Coast	1100511	0.24			0.035	0.071	
Tachells above Needles conf.	1100066	0.005		0.0012			0.002
Needles at SH1	1100225	0.012		0.0056			0.019
Needles at Seddon Street	1100514	0.008		0.004			0.017
Woodside at SH1	1100509		0.355				0.278
Flag at SH1	1100506		0.007				0.015

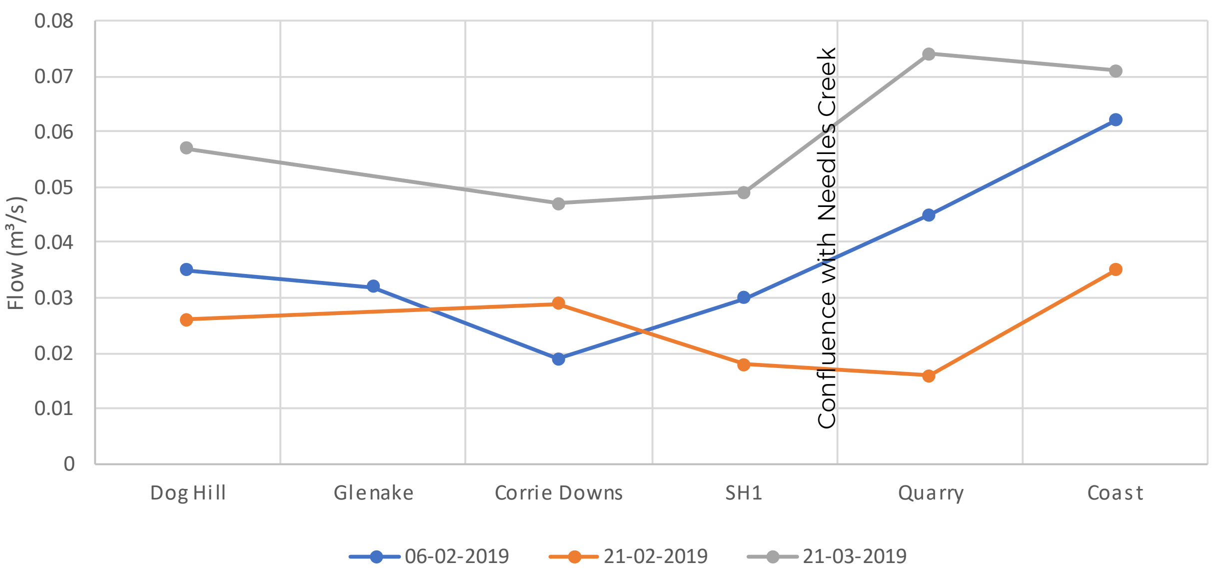

Figure 3.6: Low-flow gauging results in the Flaxbourne River.

4 Conclusions

Results from the summer low-flow gauging programme show:

- All three gauging runs show consistency in the results between sites;
- That the low-flow gaugings confirmed some of the assumptions made following earlier investigations undertaken by MDC;
- Some of the gauging sites selected for this initial survey did not add significantly to our understanding of the low-flow regimes of these rivers. These sites could be removed from future gauging runs allowing greater efficiency while maintaining effectiveness;
- There is more surface flow in the Waima/Ure River at Blue Mountain than at all downstream locations:
- Flow measured at the Ure Road Bridge is the lowest along the Waima/Ure River, however, an increase in flow is observed from the Ure Road Bridge to the coast. This increase in flow is apparently linear with distance over this reach;
- There has been a change in the relationship between flows recorded at Blue Mountain and at SH1, but not between Blue Mountain and the Ure Road Bridge, since the earthquake;
- Changes to the interaction between surface water and groundwater are likely confined to the lower reaches of the Waima/Ure River because of coastal uplift associated with the earthquake;
- A reduction in surface flow in the Flaxbourne River from Dog Hill to SH1 of between 14% and 31%;
- Surface flow increases in the Flaxbourne River downstream of SH1. This is attributed partially to inflow from Needles Creek which flows into the Flaxbourne River upstream of the quarry;
- Subtracting the flow in Needles Creek from that in the Flaxbourne River does not account for a gain in flow over this reach;
- Insufficient gaugings are available pre and post-earthquake to identify any change in the low-flow regime of the Flaxbourne catchment; and
- It is recommended that this study be repeated over the 2019-2020 summer period to provide more statistical certainty regarding the above conclusions.

5 Water Resource Implications

These findings and conclusions have a number of implications for water resources in the Flaxbourne and Waima/Ure catchments, and water resource management. These include:

- There is no robust relationship between flows at any of the sites within the Waima/Ure catchment and the flow recorder in the Flaxbourne at Corrie Downs. Management of the surface water resource in the Waima/Ure catchment would likely require the installation of a permanent flow recorder, most likely at Blue Mountain where the highest flows are recorded;

- The apparent shift in the previously developed relationship between flows at Blue Mountain and at SH1 has significant water resource implications. There appears to be significantly less surface flow at SH1 relative to Blue Mountain since the Kaikōura Earthquake; and
- The reduction in surface flow in the lower Waima/Ure catchment has implications for the management and maintenance of surface flows, and the connectivity between surface water and groundwater. This has implications for both surface water and groundwater abstraction.

6 Recommendations

Based on the preliminary findings from the low-flow gaugings undertaken over the past summer, it is recommended that:

- At least two more gauging runs be carried out over the next summer to confirm these preliminary results;
- The various gauging sites be reviewed with the aim of targeting key localities, and those with significant water resource implications;
- Given the significance of water resource use in the Waima/Ure catchment, changes in the flow regime between Blue Mountain and SH1 deserve further investigation;
- Regular high-resolution LiDAR surveys between SH1 and the coast be considered to monitor bed level changes; and
- Review the implications of the changes in bed level for both the shallow unconfined aquifer and surface water – groundwater interactions in the lower Waima/Ure catchment.