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Turbidity monitoring of the Flaxbourne River

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Contents

1 Introduction

WSP is working with the Flaxbourne Settlers' Association and the Marlborough Research Centre to identify the changes, and quantify the potential impacts, of the Kaikōura Earthquake on the water resources of the Flaxbourne, Mirza and Waima/Ure catchments.

In 2019, a turbidity sensor was installed in the Flaxbourne River to measure the suspended sediment concentration in the water; and how this varies over time and with flow. Suspended solids (which includes sand, silt, clay and organic particles) are a main cause of turbidity. This report summarises the data collected so far and discusses the relationships between turbidity, flow, and suspended solids. The report:

- Compares turbidity and flow data and assesses any trends evident in the data;
- Estimates the total suspended solids from the turbidity data, based on available information; and.
- Suggests the next steps and recommendations for a way forward.

2 Methodology

Marlborough District Council (MDC) installed a turbidity sensor[1] in the Flaxbourne River at Corrie Downs in December 2019 (Figure 2-1 & Figure 2-2).

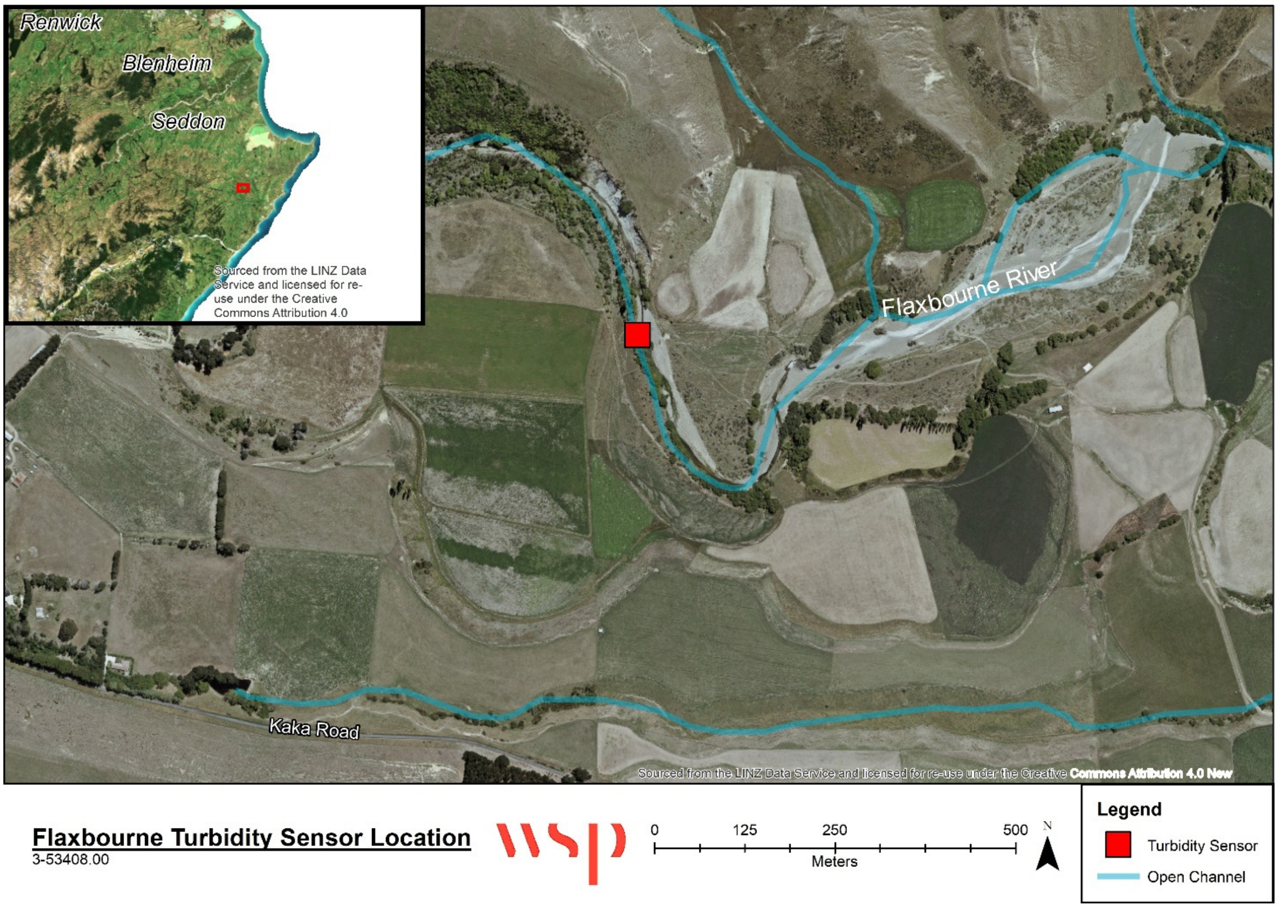

Figure 2-1: Location of the turbidity sensor on the Flaxbourne River at Corrie Downs.

[1] Turbidity sensor is a YSI EXO3 Nephelometric near-IR turbidimeter, non-ratiometer sensor with a removeable probe.

Figure 2-2: Turbidity sensor (left) and hydrometric station (right) at Corrie Downs. The recorder housing and PumpPro are situated on the left bank and the Exo3 is installed at the external staff gauge on the right bank.

The sensor has measured and recorded turbidity, as Formazin Nephelometric Units (FNU), at 15-minute intervals over the past year. There are several 'spikes' in the turbidity record that are not associated with an increase in streamflow. These are likely caused by large suspended particles crossing the probe optics as a reading was taken. Some spikes have been removed from the record; where there was a spike and no associated increase in streamflow and where the spike occurred as a single value and not part of a trend of increasing turbidity. Some spikes remain in the record. Until the data has been quality assured by MDC, it was considered prudent not to edit the record too heavily.

Water level and flow have been recorded since 2003, providing 17.5 years of data. Flow is derived from the water level record via a stage-discharge relationship. There are several significant gaps in the record, however, none of these are during the period over which turbidity data have been recorded (Table 2-1).

Table 2-1: Data used in this analysis.

Record	Start	End	Length of Record	# Gaps	Average gap length	Maximum gap length
Turbidity (FNU)	Dec-2019	Dec-2020	354 days	0	n/a	n/a
Flow (cumecs)	Jun-2003	Dec-2020	17.5 years	32	6 days	97 days
Water level (mm)	Jun-2003	Dec-2020	17.5 years	32	6 days	97 days

It is assumed that the data provided by Marlborough District Council is of good quality, and no further assessment of its reliability or accuracy has been undertaken.

3 Results

3.1 Turbidity and flow

Turbidity has been measured at Corrie Downs since December 2019. Turbidity has varied considerably across the year, indicated by a high standard deviation relative to the mean. Turbidity has not dropped below 1FNU; with a mean of 7.7FNU and a median of 2.7FNU (Table 3-1). The mean being about three times the median is a function of the short periods of relatively high turbidity that bias the mean.

Flow is the primary control of turbidity in any catchment. A comparison of streamflow and turbidity is presented in (Figure 3-1). In general, increases in turbidity coincide with increases in flow, although there are several, apparently random, spikes in turbidity that do not appear to be related to changes in flow. The increase in turbidity, however, is not necessarily related directly to the size of the flow event, i.e. there is not a consistent turbidity response pattern from one event to the next.

At low flows, there is considerable variability in turbidity. Over late summer of 2020, while there were no significant rainfall events, there were several 'pulses' of increased suspended sediment; on 29 March 2020, turbidity reached 240 FNU with only a very small increase in flow (Figure 3-2).

Because of the high degree of variability, daily maximum values were used to identify the relationship between streamflow and turbidity. Ignoring low flows (i.e. flow less than the mean), there is a weak but significant positive correlation between streamflow and turbidity (R-squared: 0.113, p-val: 0.004). There is little difference in the strength of this relationship when only flows greater than the 75% percentile are considered (R-squared: 0.129, p-val: 0.001).

Table 3-1: Summary statistics of 15-minute turbidity (FNU) data.

Mean	Median	Standard Deviation	Minimum	Maximum	25% Percentile	75% Percentile
7.7	2.7	31.8	1.1	1935	2.1	5.1

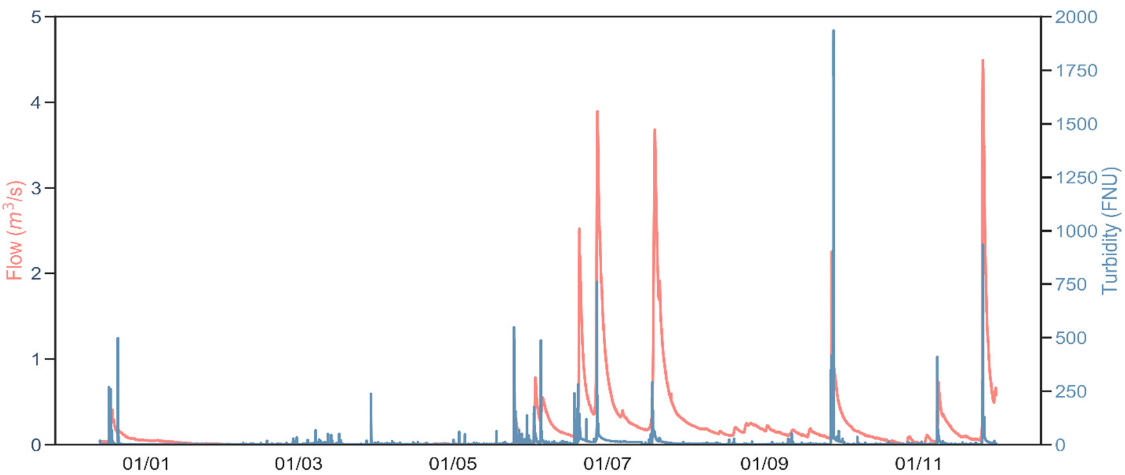

Figure 3-1: Streamflow and turbidity time series.

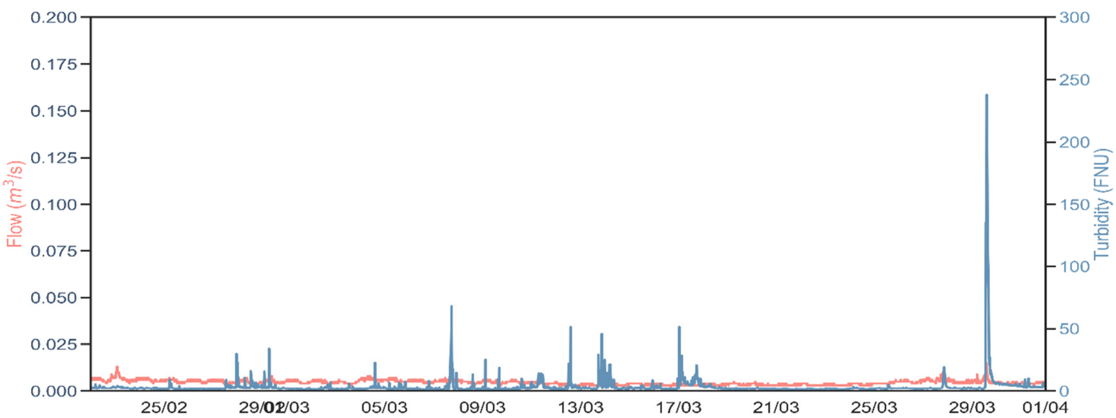

Figure 3-2: Streamflow and turbidity over the low flow period in March 2020.

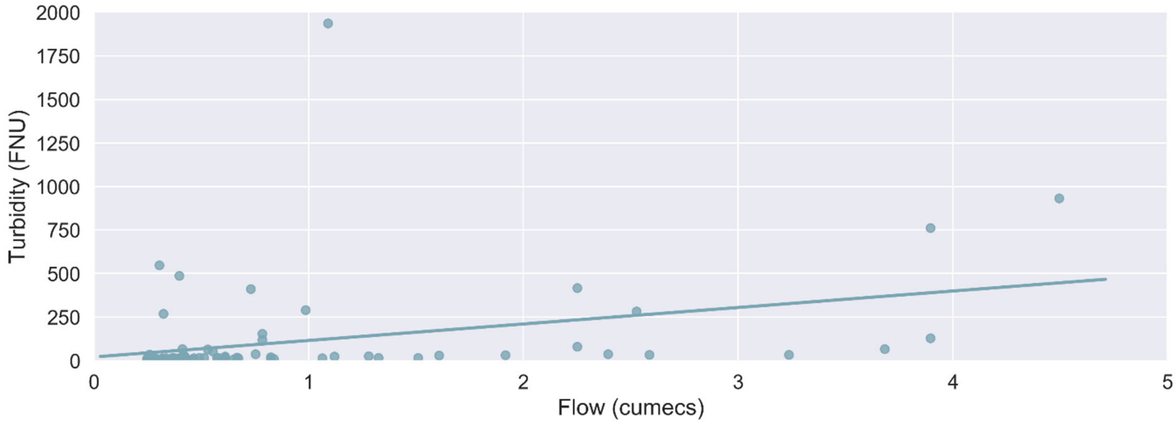

Figure 3-3: *Scatterplot of daily maximum streamflow and daily maximum turbidity when the river is above mean flow (r^2: 0.113; p-val: 0.004).*

3.2 Relationship between turbidity and total suspended solids.

Turbidity is used as an indirect measure of total suspended solids (TSS), which is difficult to measure directly continuously. There have been several catchment studies in New Zealand which have derived an empirical relationship between turbidity and TSS, but these rely on direct measurements of TSS to generate a site-specific rating curve. Deriving such a relationship is currently not possible for the Flaxbourne catchment.

Hicks *et al.* (2016) developed a power-law relationship between the two parameters, from data from 77 catchments around New Zealand; 64 of these catchments were considered lagely 'natural'.

The relationship for these natural catchments had an r^2=0.90; and is considered suitable to provide an initial estimate of TSS in the Flaxbourne catchment. The relationship is:

$$TSS\ (gm^{-3}) = 1.65x^{0.99}$$

Using this relationship, total suspended solids has varied from 1.7g/m^3 up to 2961g/m^3 (2.96kg/m^3); with an average of 12g/m^3 (Table 3-2). Based on a mean flow of 0.824m^3/s, this equates to an annual sediment load of approximately 312 tonnes/year. This is significantly less than the 5,756 tonnes/year estimated for the Flaxbourne River on the NZ RiverMaps database (NIWA, 2017). This difference could be caused by the relatively short record of turbidity available currently, and the period of relative quiescence regarding flows over the past year i.e. there were no large or prolonged floods.

It is important to note that because this relationship is based on data from all around New Zealand; there may be considerable uncertainty in the model output with respect to the Flaxbourne catchment. Further, turbidity depends on catchment specific variables such as particle size, shape and chemical composition and not just the concentration of suspended sediment. These controls are not explicit in the turbidity data or in the above relationship

More accurate estimates of suspended solids in the Flaxbourne River will require empirical, measurements of suspended sediment to calibrate the relationship between turbidity and suspended solids.

Table 3-2: *Summary statistics of total suspended solids (g/m^3).*

Mean	Median	Standard Deviation	Minimum	Maximum	25% Percentile	75% Percentile
12	4.4	45.7	1.7	2961	3.4	8.1

4 Conclusions

This high-level desktop study supports the following conclusions:

- A turbidity sensor was installed on the Flaxbourne River at Corrie Downs in December 2019 and has been recording turbidity at 15-minute intervals.
- The data indicate considerable variability in turbidity, ranging from 1.1FNU up to 1935FNU over the past year. Typically, turbidity spikes during high flows, although there are some spikes in the turbidity data that do not correspond to large flows.
- A relationship derived from 64 catchments around New Zealand has been used to convert turbidity to total suspended solids (TSS). An average TSS of 12g/m^3 has been estimated, which equates to a TSS load for the Flaxbourne catchment of 312 tonnes/year.
- This estimate appears extremely low given the nature of the Flaxbourne catchment, obvious potential sources of sediment, and the effects of the Kaikōura earthquake. The low estimate of sediment yield may be caused by the relatively short record of turbidity available currently, and the period of relative quiescence regarding flows over the past year i.e. there were no large or prolonged floods.
- There is considerable uncertainty in the estimation of suspended solids as catchment specific variables such as particle size, shape and chemical composition may not be well-represented.
- More accurate estimates of suspended solids in the Flaxbourne River require the sampling and direct measurement of suspended sediment over a range of flow conditions. This will allow the development of a catchment specific sediment rating curve to convert turbidity to TSS.

5 References

Hicks, D.M., Greenwood, M., Clapcott, J., Davies-Colley, R., Dymond, J., Hughes, A., Shankar, U. and Walter, K., 2016. Sediment attributes stage 1. NIWA Client Report CHC2016-058 prepared for the Ministry for the Environment. Christchurch: NIWA.

NIWA (2018). *New Zealand River Flood Statistics.* Retrieved from https://niwa.maps.arcgis.com/apps/webappviewer/index.html?id=933e8f24fe9140f99dfb57173087f27d on 21/12/2020.

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