greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Te Awarua-o-Porirua Harbour catchment sediment monitoring programme

Results of continuous turbidity and sediment monitoring, 2016/17 & 2017/18

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Contents

1. Introduction

Continuous turbidity monitoring stations were installed in the lower reaches of the three main tributaries of Te Awarua-o-Porirua Harbour (Porirua Harbour) by Greater Wellington Regional Council between August 2012 and June 2013. This followed initial catchment sediment modelling using CLUES (Catchment Landuse for Environmental Sustainability) that identified the Horokiri, Pauatahanui and Porirua stream sub-catchments as delivering the most sediment to the harbour (Green et al. 2014). Excess sediment entering Porirua Harbour is one of the key pressures on estuarine health. The sediment monitoring programme quantifies the annual sediment inputs to Porirua Harbour from these three sub-catchments.

1.1 Monitoring objectives

The objectives of GWRC's Porirua Harbour catchment sediment monitoring programme are to:

1. Collect continuous turbidity data from the three sub-catchments;

2. Collect stream water samples across a range of turbidity measurements to convert the continuous turbidity record into a suspended sediment concentration (SSC) record; and

3. Use the suspended sediment concentration record to derive annual sediment yields for each of the three sub-catchments being monitored.

1.2 Report purpose

This report summarises the monitoring results obtained between July 2016 and June 2018[1]. Sediment loads and yields are also presented for the full monitoring period (2012–2018).

[1] No report was prepared for the 2016/17; thus, this report presents both the 2016/17 and 2017/18 monitoring data.

2. Monitoring sites and methods

The Porirua catchment sediment monitoring programme consist of three monitoring sites (Figure 2.1):

- Horokiri Stream at Snodgrass,
- Pauatahanui Stream at Gorge, and
- Porirua Stream at Town Centre.

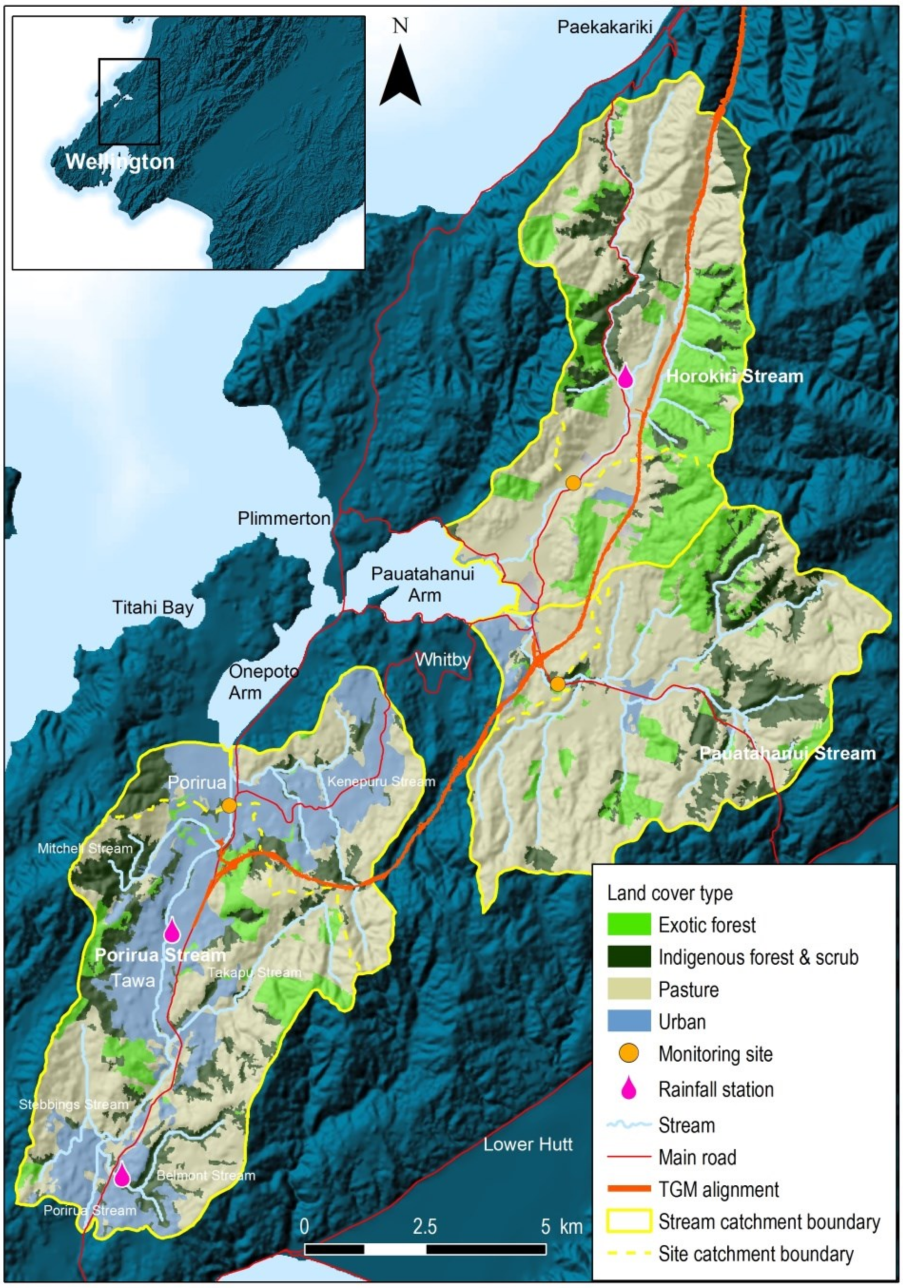

Figure 2.1: Location of the three continuous turbidity monitoring sites in the Porirua Harbour catchment and the major land cover types within each catchment. The position of the Transmission Gully Motorway (TGM) route is also shown. Areas downstream of the dashed site catchment line are not captured by the monitoring site

2.1 Site set up and data collection

At each sediment monitoring site continuous turbidity, stage and flow time-series data are measured. Data are telemetered, via HydroTel, and checked daily for faults, equipment malfunctions and wet weather events.

Autosamplers installed at each site can take up to 24 discrete water samples. Sampling is triggered by turbidity at all sites, with the samplers programmed to collect samples at set intervals. Sampling ceases when the turbidity has dropped below a set trigger or the sampler has samples in all its bottles. All samples taken by the automatic samplers are dispatched to Hill Laboratories, typically within 48 hours, for determination of turbidity and SSC (see Appendix 1 for a summary of laboratory methods). The laboratory turbidity data are used to validate whether the field sensor is operating correctly.

Discrete SSC results are used to convert the turbidity sensor data into a suspended sediment concentration record. Site setup and maintenance, including sensor choice, as well as methodology used to derive SSC from continuous turbidity are further detailed in Appendix 2.

For the 2016/17 to 2017/18 monitoring period, only those samples required to fill gaps in the existing, long term, SSC/turbidity relationship were sent to the laboratory for SSC and turbidity analyses. Overall, there is a good SSC/turbidity relationship for each of the three monitoring sites, but some gaps do exist at higher turbidity concentrations.

2.2 Sediment loads and yields

In this report the continuous SSC record is used to calculate both annual and event-specific sediment loads and yields for each site. However, the calculated loads and yields should be considered provisional for the following reasons:

- The continuous turbidity data records, from which the continuous SSC record is derived, can contain gaps, all of which require patching. Some of the gaps can be large (133 days[2]). Gaps generally coincide with storm or flood events (when the majority of sediment is transported), which means the some of the sediment loads/yields presented in this report have a high degree of uncertainty depending on how much of the load is derived from patched (synthetic [QC300]) data.

- There will be a slight variation in the loads and yields presented in this report compared to those in previous reports due to the SSC results collected between June 2016 and July 2018 being used to update the SSC/turbidity rating curve.

- It is necessary to collect many years of data before we can fully characterise the annual and event-based sediment yields for each catchment.

- Sediment gaugings and particle grain size analyses need to be carried out at each site to determine whether the turbidity sensor's data are representative

[2] No turbidity data was collected from Pauatahanui Stream at Gorge from 15 November 2016 to 28 March 2017 as a result of high flows, which flooded the station box housing the turbidity/logger instrumentation.

of suspended sediment concentrations over the entire stream width and what influence sediment grain size has on suspended sediment concentrations.

Event-specific sediment yields were calculated for events with a ≥ 1-year return period[3]. The start of each event was defined as the point when flow began to rise, while the end was determined manually by visually delineating when flow and turbidity had dropped to a stable level (turbidity <10 FNU). While it is essential to determine the start point, the point that an event is determined to have ended is unlikely to influence the sediment load significantly (Andrew Hughes, pers. comm.). Sometimes events were combined when several peaks occurred (due to ongoing rainfall) before flows returned to a stable level (ie, some events are of longer duration than others).

[3] Return period flows were calculated by fitting a frequency distribution through flood event records.

3. Results & Discussion

This section presents a summary of the SSC data collected at each of the three monitoring sites between July 2016 and June 2018. In addition, event-based sediment loads and annual sediment yields are presented for all three stream catchments for the full monitoring period (2012–2018).

3.1 Porirua Stream

3.1.1 SSC Results

Twenty-eight water samples were sent to the laboratory for SSC and turbidity analyses from two different events during the monitoring period. These two events were selected for laboratory analysis based on existing gaps in the SSC/turbidity relationship. A summary of the sample results from the two events is given in Table 3.1. No samples below a turbidity of 77 FNU[4] were sent for analysis with 24 of the 28 samples ≥ 1,500 FNU.

Table 3.1: Range (minimum and maximum) of field turbidity and suspended sediment concentrations (SSC) in water samples collected at Porirua Stream, along with maximum flow when sampled and total rainfall recorded at Seton Nossiter Park prior to sample collection. Each date is a separate 'event' (ie, samples collected in sequence)

Date	Total rainfall (mm) prior to first sample		*n*	Field turbidity (FNU)	SSC (g/m^3)	Maximum flow (m^3/s)
	0–6hr	6–24hr				
15/11/2016	47.2	21.4	24	1,098 - 1,531	1,620 - 2,500	54.2
14-15/08/2017	8.6	23.8	4	77.1 - 1,220	69 - 2,600	18.3

Results for all the samples collected during the monitoring period are presented in Figure 3.1, and have been used to update the SSC/turbidity relationship.

With the addition of the 2016/17 and 2017/18 data, the SSC/turbidity relationship has improved from a R^2=0.95 to R^2=0.96, indicating a strong relationship between the two variables (Figure 3.1).

[4] Formazin Nephelometric Units

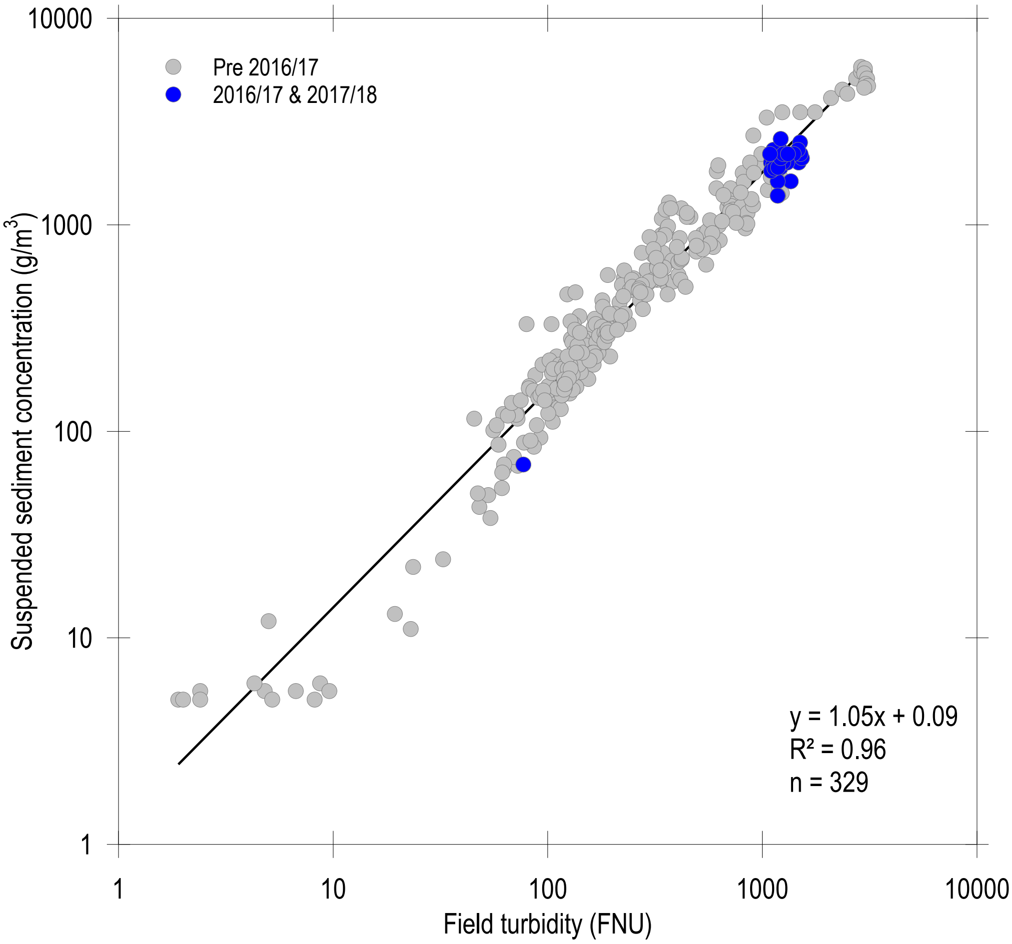

Figure 3.1: Relationship at Porirua Stream site between suspended sediment concentration (SSC) and field turbidity. Note the log scale. Points in blue are for the 2016/17-2017/18 monitoring period, while the points in grey are for all data collected before 2016/17 monitoring period

3.1.2 Sediment yield calculations

Figure 3.2 displays the cumulative sediment loading, continuous stream flow and total daily rainfall at the Porirua Stream monitoring site for both 2016/17 and 2017/18.

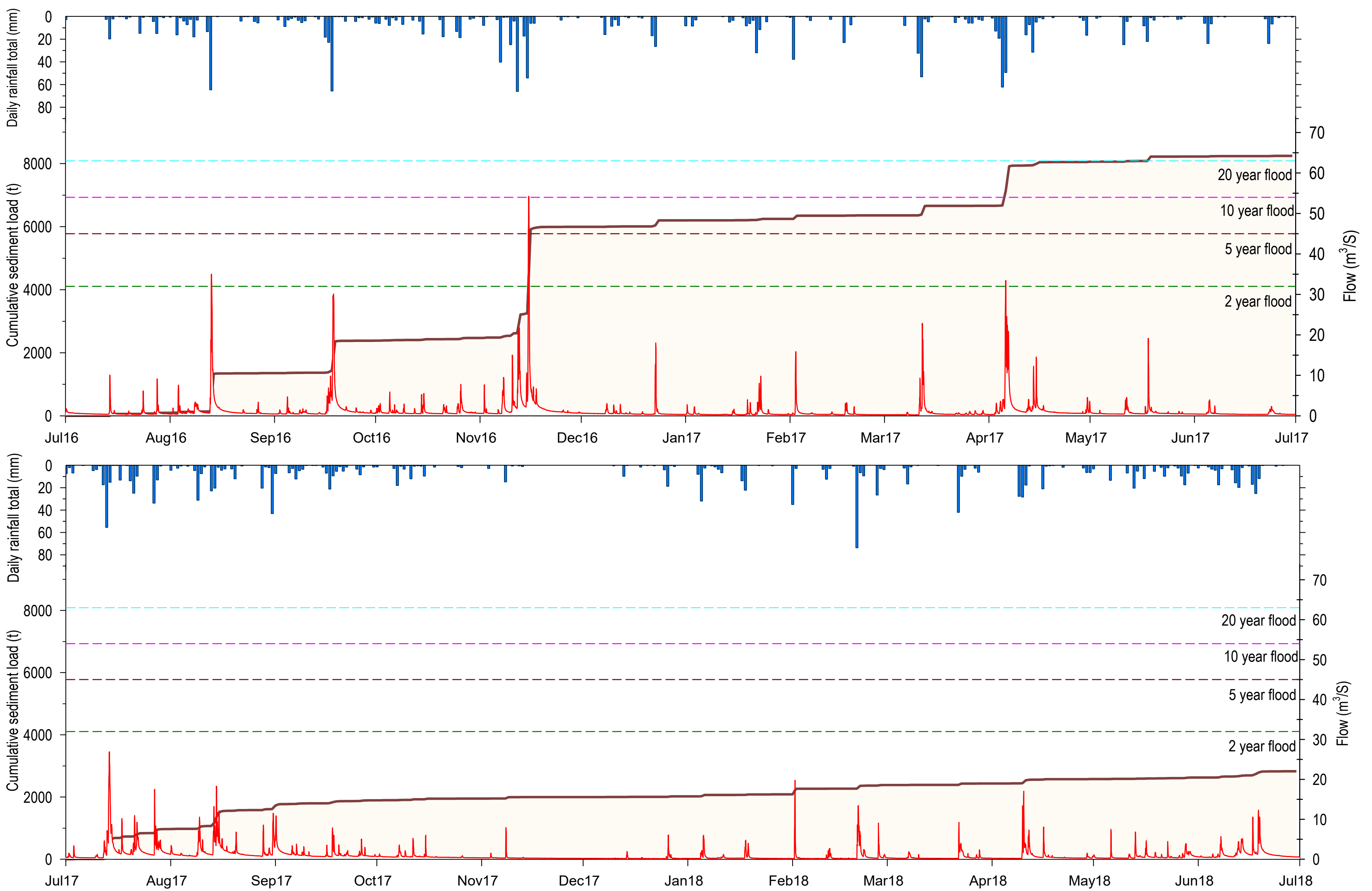

Figure 3.2: Plots of cumulative sediment load (tonnes; brown) and continuous flow (red) at the Porirua Stream monitoring site and total daily rainfall at Seton Nossitor (blue) between July and June of both 2016/17 (top) & 2017/18 (bottom)

(a) Annual suspended sediment yield and loads

The annual load/yield estimates for the Porirua Stream catchment since monitoring began are summarised in Table 3.2. The annual yields for calendar year 2016, 2017 and the first 6 months of 2018 were 1.87, 1.04 and 0.2 t/ha/yr, respectively.

Table 3.2: Estimated annual sediment loads and yields for the Porirua Stream catchment from 29 August 2012 to 30 June 2018. Note these calculations do not account the contribution from the Kenepuru Stream subcatchment

Year	Time	Sediment load (Kt)	Sediment yield (t/ha/yr)	Percentage of load QC300 (%)#
2012	124 days 12 hrs	0.33	0.08	40
2013	365 days	2.57	0.65	1
2014	365 days	1.31	0.33	3
2015	365 days	7.65	1.94	0
2016	366 days	7.38	1.87	0
2017	365 days	4.09	1.04	4
2018	181 days	0.81	0.2	0
Total	*2,132 days 12 hrs*	*24.13*	*6.13*	*2*

data that has been patched in accordance with national environmental monitoring standards (NEMS). Patching occurs when there is a gap in the turbidity record.

(b) Event suspended sediment yield and loads

Table 3.3 summarises the sediment yields/loads of 27 events from the 29 August 2012 to the 30 June 2018 and Figure 3.3 illustrates the contribution of each event to the total sediment load.

The biggest event at this site during the 2016/17 monitoring period occurred on 15 November 2016. This event transported 2.86 Kt of sediment during a 10-year return period flood after nearly 116 mm of rainfall at Seton Nossitor Park (located at the top of the Porirua Stream catchment) in the preceding 24 hours (Figure 3.2). There were three other events in 2016/17 that transported over 1 Kt of sediment (12 August 2016, 16 September 2016 and 4 April 2017).

The biggest event in 2017/18 transported 0.68 Kt. This ≥1-year return period flood occurred on the 12 July 2017 after 55 mm of rainfall in the proceeding 24 hours at Seton Nossitor Park.

In comparison, the 20-year return period flood on 14 May 2015 (the biggest since a 50-year return period event on 20 June 1980) transported 6.07 Kt of sediment (Figure 3.3). This single event accounts for over 25% of the total sediment load for this site since monitoring began in 2012.

Table 3.3: Estimated sediment yields/loads for Porirua Stream at Town Centre during events with ≥ 1-year return period from 29 August 2012 to 30 June 2018

Year	Events (≥ 1 year return period)	Duration (time)	Total sediment load (t)	Sediment yield (t/ha)	Maximum flow (m^3/s)	Flood return period	Missing data (QC200)	Percentage of load QC300 (%)
2012	17 – 18/9/2012	1 day, 3 hrs & 45 mins	127	0.03	16.5	≥1	-	100
2013	4 – 5/2/2013	1 day, 15 hrs & 5 mins	624.8	0.16	44.3	2	-	1.85
	16 – 23/6/2013	7 days, 12 hrs & 45 mins	754.4	0.19	32.7	2	-	-
	20 – 22/9/2013	2 days, 0 hr & 30 mins	176.9	0.04	17.7	≥1	-	-
2014	3 – 4/1/2014	15 hrs & 55 mins	93.8	0.02	22	≥1	-	-
	16 – 18/4/ 2014	2 days, 2 hrs & 20 mins	324.2	0.08	25	≥1	-	-
2015	7 – 9/4/2015	2 days, 1 hr & 35 mins	253.8	0.06	24.7	≥1	-	-
	14 – 17/5/2015	2 days, 20 hrs & 30 mins	6,071	1.49	66	20	-	-
	18 20/6/2015	1 day, 16 hrs & 55 mins	236.3	0.06	17	≥1	-	-
2016	3 – 4/1/2016	14 hrs & 40 mins	75.4	0.02	14.7	≥1	-	-
	5 – 6/5/2016	1 day, 7 hrs & 20 mins	381	0.1	33.9	2	-	-
	27 – 29/5/2016	1 day, 20 hrs & 35 mins	278.1	0.07	20.5	≥1	-	-
	12 – 14/8/2016	2 days, 2 hrs & 5 mins	1,226.1	0.31	35	2	-	-
	16 – 19/9/2016	3 days, 21 hrs & 30 mins	1,024.9	0.26	30.1	≥1	-	-
	12 – 13/11/2016	1 day, 22 hrs & 20 mins	611.9	0.15	21.7	≥1	-	-
	15 – 19/11/2016	4 days, 15 hrs & 20 mins	2,826.1	0.7	54.2	10	-	-
	22 – 23/12/2016	23 hrs & 25 mins	193.6	0.05	18	≥1	-	-
2017	2 – 3/2/2017	21 hrs & 40 mins	98.5	0.02	15.8	≥1	-	-
	11 – 13/3/2017	1 day, 22 hrs & 10 mins	302.1	0.08	22.9	≥1	-	-
	4 – 7/4/2017	3 days, 17 hrs & 50 mins	1,284.6	0.32	33.4	2	-	-
	14 – 15/4/2017	19 hrs & 30 mins	58.4	0.01	14.5	≥1	-	-
	17 – 19/5/2017	1 day, 9 hrs & 25 mins	139.7	0.04	19.1	≥1	-	-
	12 – 16/7/2017	3 days, 22 hrs & 5 mins	678.7	0.17	26.9	≥1	-	-
	27 – 29/7/2017	2 days, 8 hrs & 10 mins	127.9	0.03	17.5	≥1	-	-
	13 – 17/8/2017	3 days, 21 hrs & 40 mins	490.2	0.12	18.3	≥1	-	-
2018	1 – 2/2/2018	1 day, 5 hrs & 30 mins	183.6	0.05	19.7	≥1	-	-
	9 – 12/4/2018	2 days, 17 hrs & 15 mins	120.6	0.03	17.1	≥1	-	-

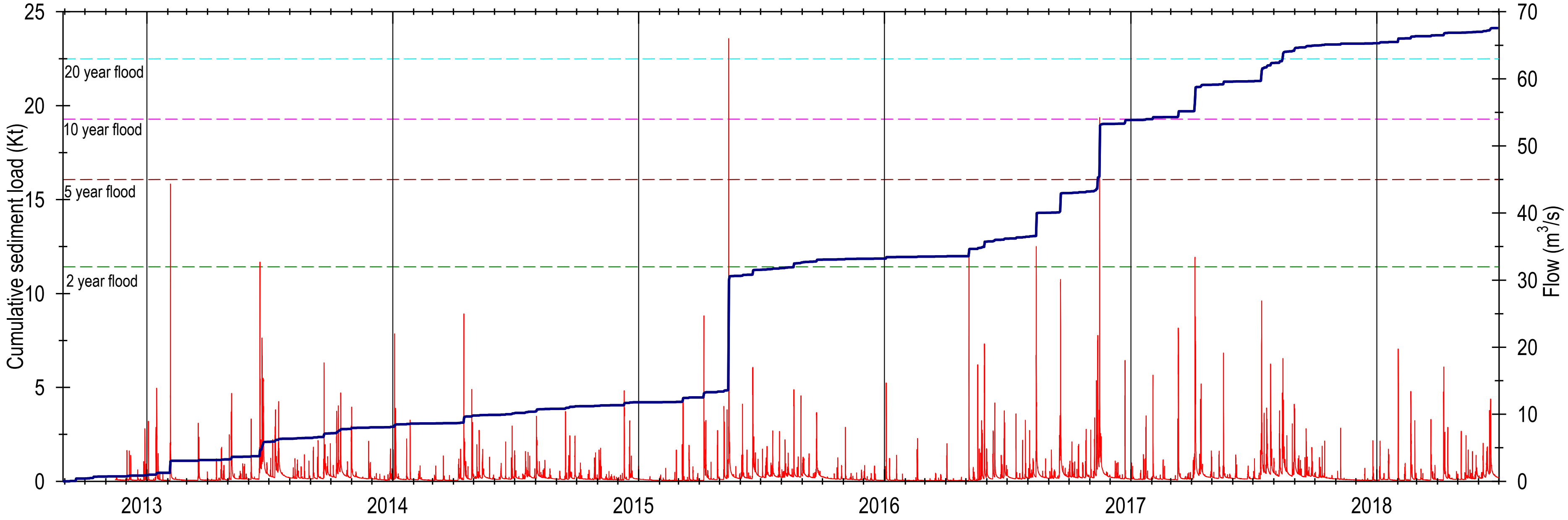

Figure 3.3: Cumulative sediment load (blue line) versus stream flow (red line) in the Porirua Stream at Town Centre from 29 August 2012 to 30 June 2018

3.2 Horokiri Stream

3.2.1 SSC Results

Water samples, 57 in total, from seven different events were sent for laboratory analysis in this reporting period (2016/17–2017/18) to fill gaps in the SSC/turbidity relationship. A summary of the sample results is provided in Table 3.4. Of the 57 stream samples, 47 (82%) recorded turbidity values >500 FNU.

Table 3.4: Range (minimum and maximum) of field turbidity and suspended sediment concentrations (SSC) in water samples taken by the autosampler at Horokiri Stream, along with maximum flow when sampled and total rainfall recorded at Battle Hill monitoring site prior to sample collection. Each date is a separate 'event' (ie, samples collected in sequence)

Date	Total rainfall (mm) prior to first sample		*n*	Field turbidity (FNU)	SSC (g/m^3)	Maximum flow (m^3/s)
	0–6hr	6–24hr				
18/9/2016	19.6	39.2	8	206 - 420	350 - 490	13.1
15-16/11/2016	80.8	32.2	22	840 - 3,335	690 - 3,500	51.7
15/8/2017	7.6	19.2	1	208	280	5.8
17-18/9/2017	21	0.4	3	802 - 1,075	950 - 1390	4.2
1/10/2017	15.8	2.2	4	866 - 967	1,150 - 1,380	5.1
1-2/2/2018	35	0.8	11	17 - 1,117	61 - 1,250	2.5
22/3/2018	33.8	3.4	8	786 - 1,637	780 - 1,460	5.3

The relationship between field turbidity and SSC is shown in Figure 3.4. Results of samples collected during this reporting period are highlighted in red to distinguish them from previous years' results. The storm event on 15 November 2016 transported the highest suspended sediment concentration (3,500 g/m^3) in the 2016/17–2017/18 monitoring period. In the preceding 24 hours 113 mm of rainfall fell in the upper (Battle Hill Park) catchment. This was the highest SSC recorded at this site since monitoring began in 2012, the next highest was 2,400 g/m^3 during the 14 May 2015 flood.

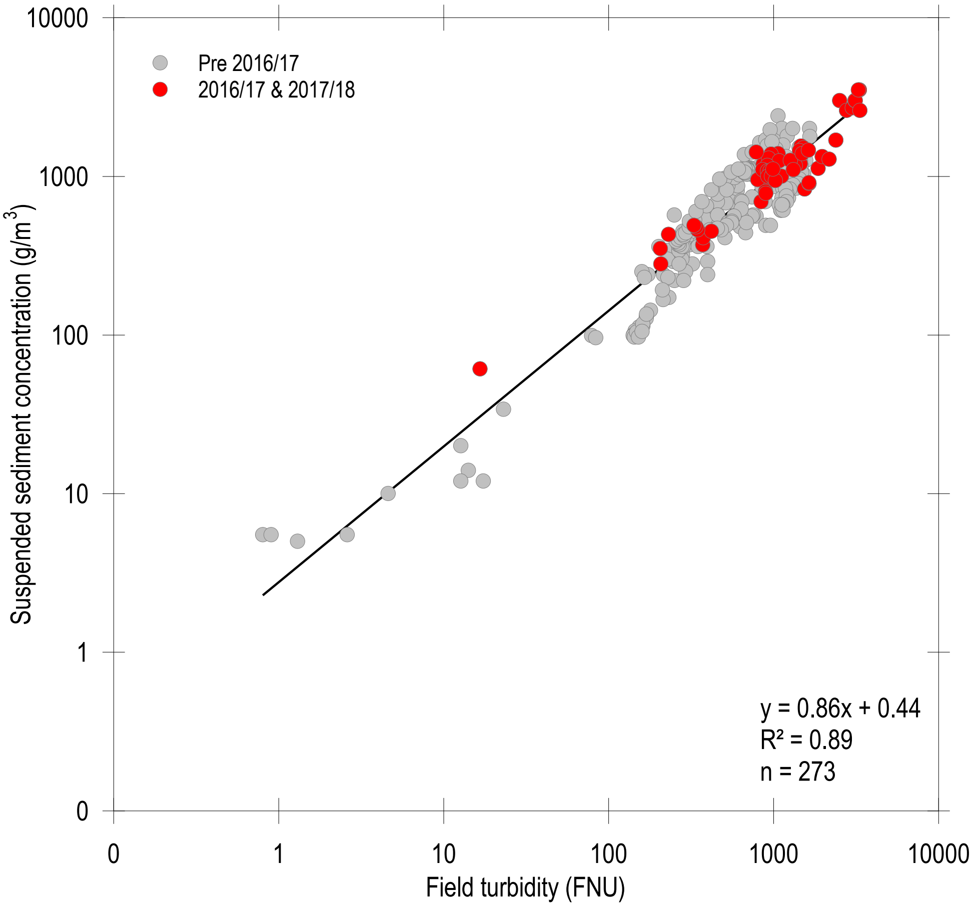

Figure 3.4: Relationship at Horokiri Stream site between suspended sediment concentration (SSC) and field turbidity. Note the log scale. Points in red are for the 2016/17-2017/18 monitoring period, while the points in grey are for all data collected to date

3.2.2 Sediment yield and load calculations

The cumulative sediment loading and continuous stream flow at the Horokiri Stream monitoring site, and the total daily rainfall at Battle Hill Park rainfall site for both the 2016/17 and 2017/18 are shown in Figure 3.5.

(a) Annual suspended sediment yield and load

The annual load/yield estimates for the Horokiri Stream catchment since monitoring began are summarised in Table 3.5. The annual yields for 2016, 2017 and the first 6 months of 2018 were 1.67, 0.63 and 0.13 t/ha/yr, respectively.

A relatively large proportion of the annual yields and loads prior to 2016 were derived from QC300 data. The reasons for this was gaps in the turbidity record due to sensor malfunctions during the rising stages of several large floods (see Morar & Oliver (2017)). However, since then these issues have largely been rectified and as a result only 6% of the yields and loads since the beginning of 2016 have been generated from QC300 turbidity data.

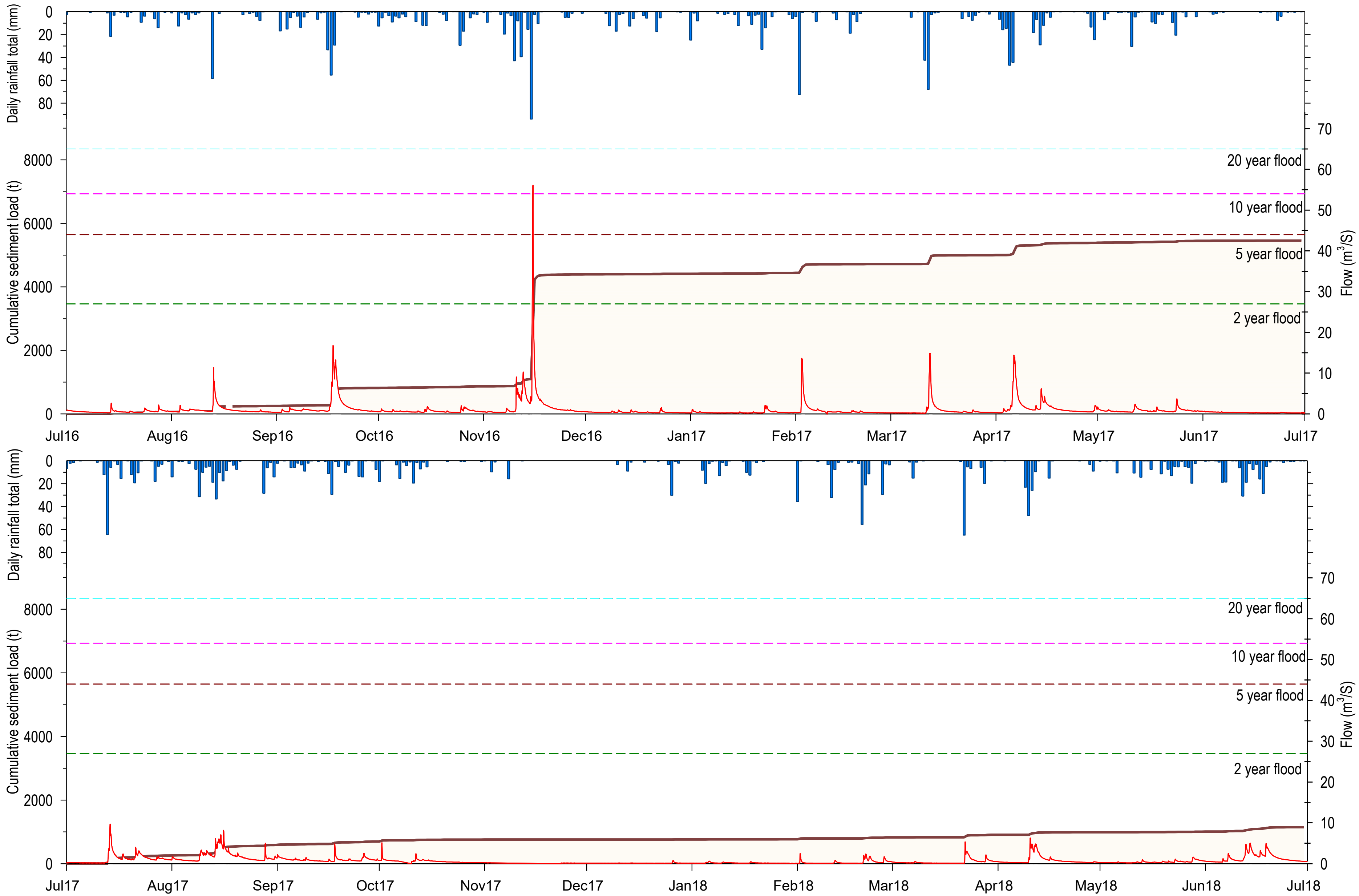

Figure 3.5: Plots of cumulative sediment load (tonnes; brown) and continuous flow (red) at the Horokiri Stream monitoring site and total daily rainfall at Battle Hill Park (blue) between July and June of both 2016/17 & 2017/18

Table 3.5: Estimated annual sediment loads and yields for the Horokiri Stream catchment from 14 November 2012 to 30 June 2018

Year	Time	Sediment load (Kt)	Sediment yield (t/ha/yr)	Percentage of load QC300 (%)
2012	47 days 13 hrs	0.04	0.01	11
2013	365 days	2.55	0.89	31
2014	365 days	0.93	0.32	0
2015	365 days	4.23	1.47	79
2016	365 days	4.8	1.67	5
2017	365 days	1.8	0.63	10
2018	181 days	0.39	0.13	0
Total	*2,053 days 13 hrs*	*14.74*	*5.13*	*31*

(b) Event suspended sediment yield and load

The contribution of each event to the sediment loads of both 2016/17 and 2017/18 is presented in Figure 3.5. The 10-year return period flood event on 15-16 November 2016 was the second biggest flood since monitoring began and contributed 3.29 Kt of sediment over seven days (Table 3.6). Similarly, the largest flood event recorded at this site on 14 May 2015, contributed 3.44 Kt of sediment (Figure 3.6). For comparison the 2015/16 period had only two events with a ≥ 1-year return period; the biggest of which (27 May 2016) only transported 0.181 Kt of sediment.

Table 3.6: Estimated sediment yields for Horokiri Stream at Snodgrass during events with ≥ 1-year return period from 14 November 2012 to 30 June 2018

Year	Events (≥ 1 year return period)	Duration (time)	Total sediment load (t)	Sediment yield (t/ha)	Maximum flow (m^3/s)	Flood return period	Percentage of load QC300 (%)
2013	4 - 7 February 2013	2 days, 16 hrs & 15 mins	934.7	0.33	39.2	2	0
	18 - 20 March 2013	1 day, 20 hrs & 40 mins	213.3	0.07	16.6	≥1	0
	3 - 5 May 2013	1 day, 22 hrs & 40 mins	130.1	0.05	12.8	≥1	0
	16 - 25 June 2013	9 days, 4 hrs & 35 mins	1,021.5	0.36	22.1	≥1	76
	31 October - 1 November 2013	1 day, 4 hrs & 10 mins	23.2	0.01	7.4	≥1	0
2014	18 - 22 September 2014	4 days, 4 hrs & 55 mins	202.7	0.07	10.7	≥1	0
	10 - 12 December 2014	2 days, 19 hrs & 45 mins	381.4	0.13	20.4	≥1	0
2015	7 - 10 April 2015	2 days, 8 hrs & 5 mins	85.0	0.03	8.3	≥1	100
	13 - 19 May 2015	6 days, 11 hrs & 35 mins	3,439.4	1.2	60.1	10	94
	28 - 30 October 2015	2 days, 3 hrs & 45 mins	130.4	0.05	8.9	≥1	0
2016	27 May - 2 June 2016	6 days, 23 hrs & 10 mins	194.8	0.07	12.8	≥1	0
	13 - 15 August 2016	2 days, 7 hrs & 45 mins	144.8	0.05	11.3	≥1	0
	16 - 20 September 2016	4 days, 13 hrs & 45 mins	532.2	0.19	16.8	≥1	0
	10 - 14 November 2016	4 days, 3 hrs & 60 mins	216.6	0.08	10.3	≥1	0
	14 - 22 November 2016	7 days, 15 hrs & 60 mins	3,293.5	1.15	56.1	10	7
2017	2 - 5 February 2017	2 days, 22 hrs & 55 mins	268.9	0.09	13.6	≥1	0
	11 -14 March 2017	3 days, 9 hrs & 40 mins	269.5	0.09	14.9	≥1	0
	4 - 8 April 2017	3 days, 18 hrs & 20 mins	297.7	0.1	14.4	≥1	62
	12 -16 July 2017	4 days, 1 hr& 30 mins	179.2	0.06	9.7	≥1	0
	13 - 19 August 2017	5 days, 14 hrs & 15 mins	214.7	0.07	8.2	≥1	0

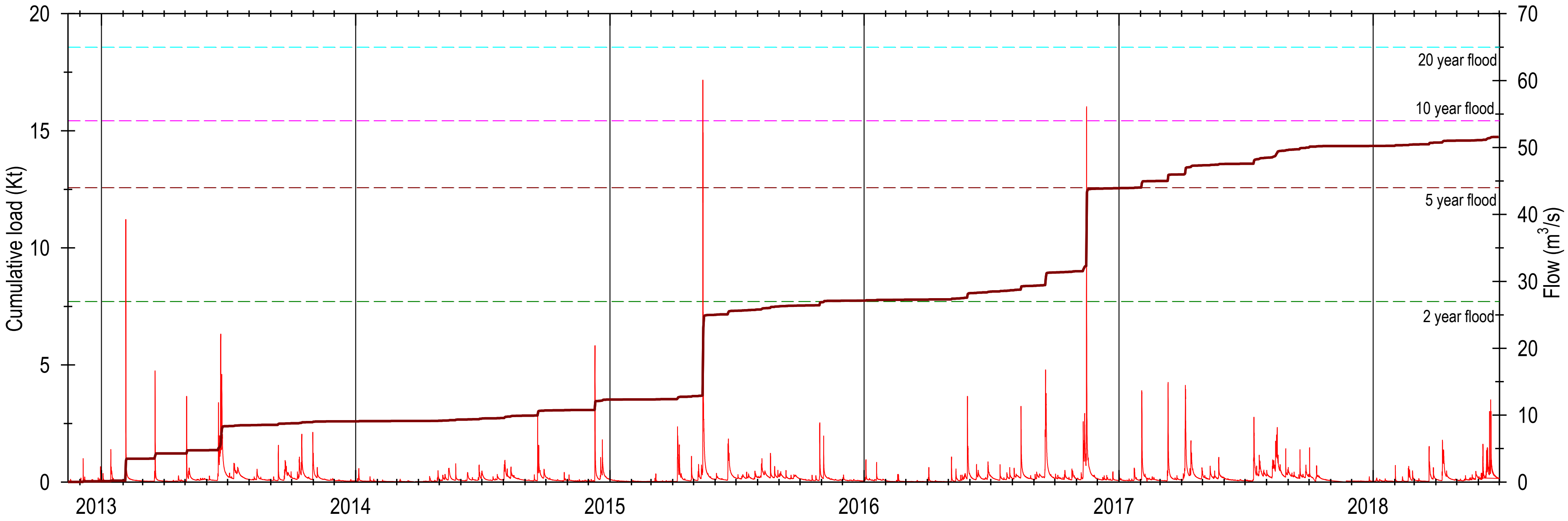

Figure 3.6: Cumulative sediment load (purple line) versus stream flow (red line) in the Horokiri Stream from 14 November 2012 to 30 June 2018

3.3 Pauatahanui Stream

3.3.1 SSC Results

Nine stream samples were sent for laboratory analyses from one event in the 2016/17-2017/18 reporting period to fill gaps in the SSC/turbidity relationship. A summary of the sample results are provided in Table 3.7. Of the nine stream samples during this one event, eight recorded turbidity values >1300 FNU.

Table 3.7: Range (minimum and maximum) of field turbidity and suspended sediment concentrations (SSC) in water samples taken by the autosampler at Pauatahanui Stream, along with maximum flow when sampled and total rainfall recorded at Battle Hill prior to sample collection. Each date is a separate 'event' (ie, samples collected in sequence)

Date	Total rainfall (mm) prior to first sample		*n*	Field turbidity (FNU)	SSC (g/m^3)	Maximum flow (m^3/s)
	0–6hr	6–24hr				
14-15/07/2016	21.5	1	9	8 - 2,882	15 – 2,800	13.1

The relationship between field turbidity and SSC is very strong (R^2=0.96 - Figure 3.7). The results of samples collected in 2016/17 and 2017/18 are highlighted in green to distinguish them from previous years' results.

The highest SSC recorded in the 2016/17-2017/18 monitoring period was 2,800 g/m^3 during the >1-year return period event on 14 July 2016. This sample was taken following 22.5 mm of rainfall recorded at Battle Hill Park in the preceding 24 hours. The highest SSC result recorded at this site since monitoring begun is 5,400 g/m^3 during a >1-year return period event on 20 September 2013.

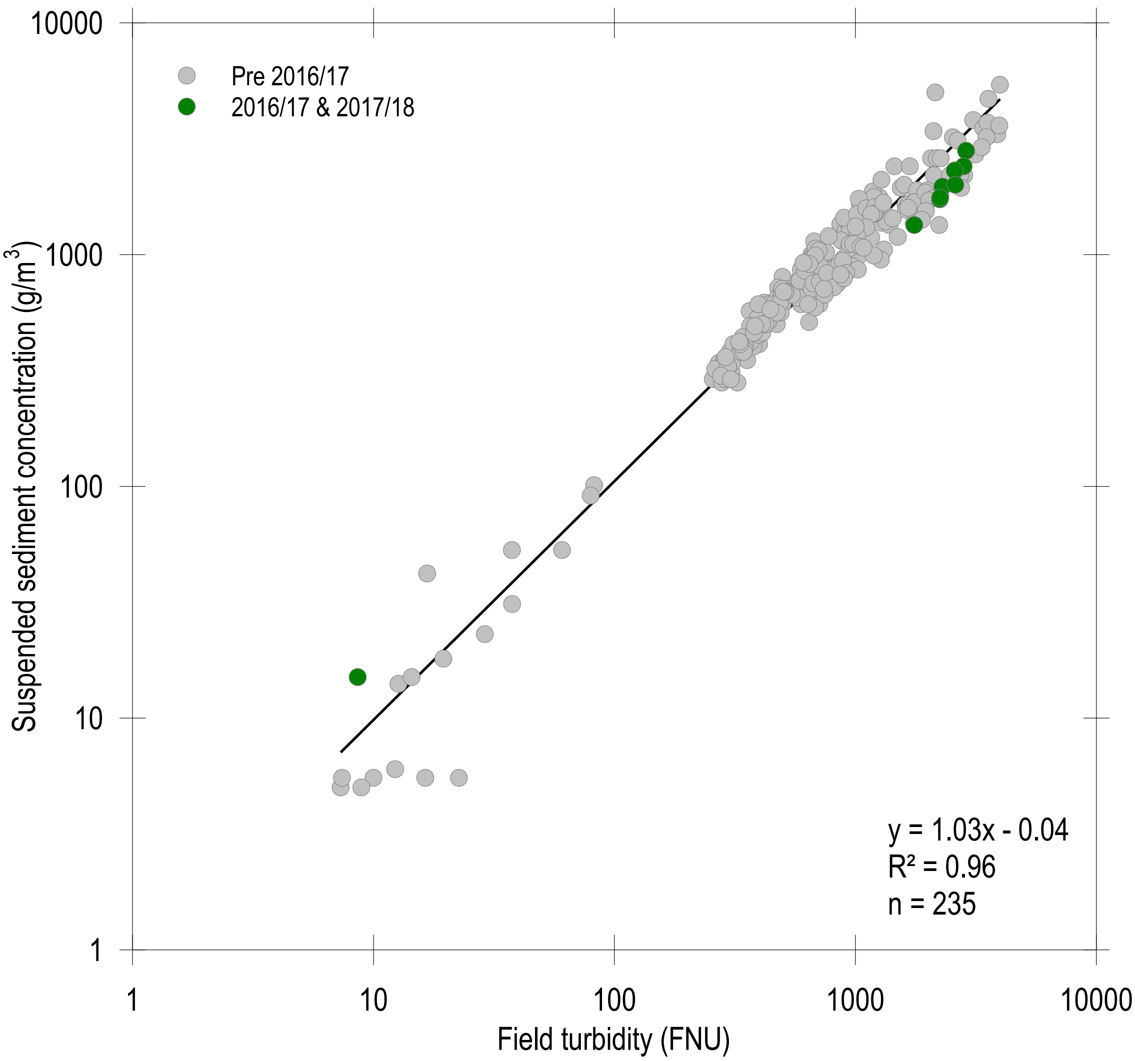

Figure 3.7: Relationship at Pauatahanui Stream between suspended sediment concentration (SSC) and field turbidity. Note the log scale. Points in green are for the 2016/17-2017/18 monitoring period, while the points in grey are for all data collected to date

3.3.2 Sediment yield calculations

The cumulative sediment loading and continuous stream flow at the Pauatahanui Stream monitoring site, and the total daily rainfall at Battle Hill Park for both 2016/17 and 2017/18 are shown in Figure 3.8.

(a) Annual suspended sediment yield

The estimated annual suspended sediment loads and yields for the Pauatahanui Stream catchment are summarised in Table 3.8. The annual yields for 2016, 2017, and the first half of 2018 were 2.29, 0.45 and 0.09 t/ha/yr, respectively.

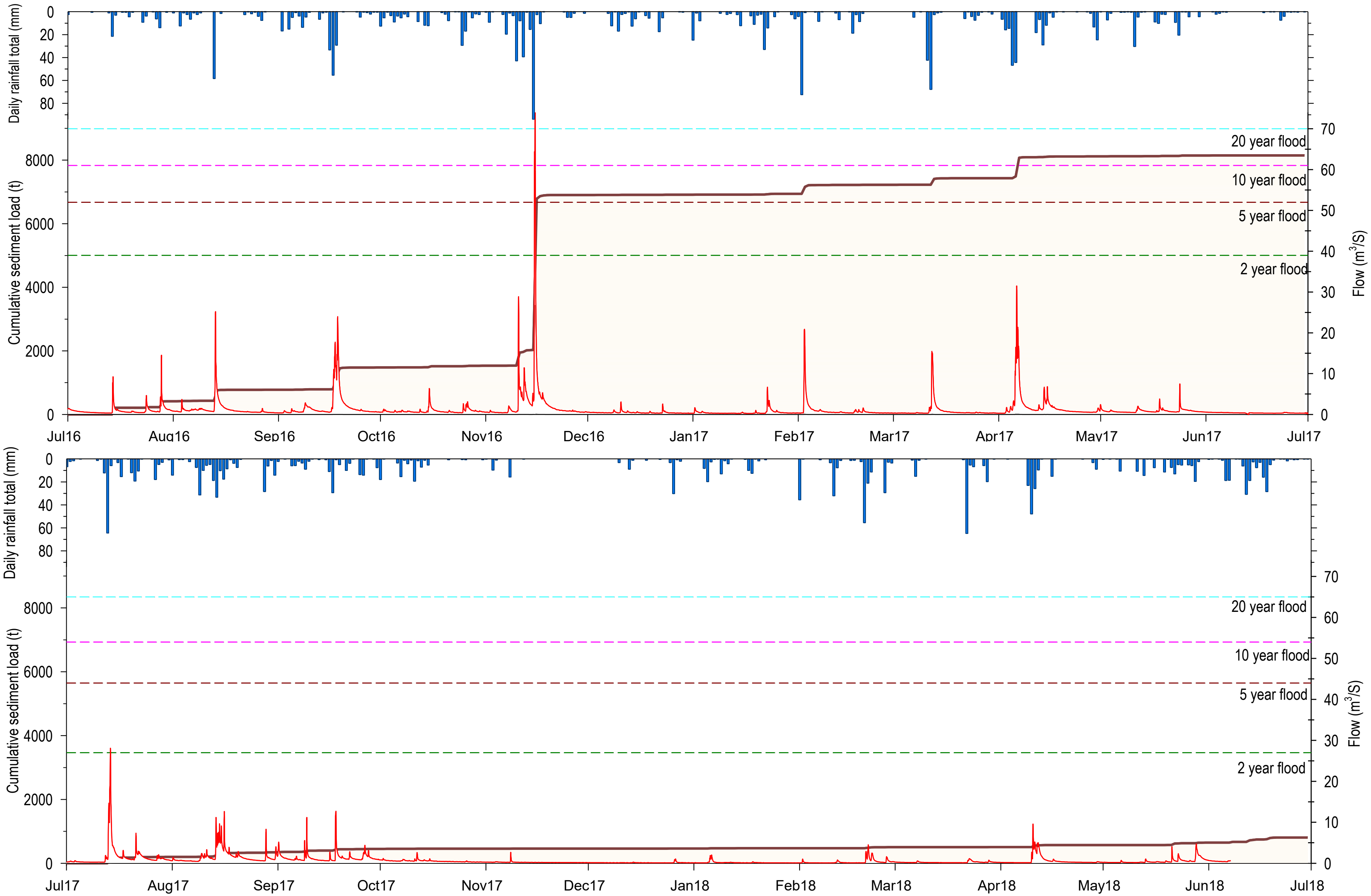

Figure 3.8: Plots of cumulative sediment load (tonnes; brown) and continuous flow (red) at the Pauatahanui Stream monitoring site and total daily rainfall (blue) at Battle Hill Park between July and June of both 2016/17 & 2017/18

Table 3.8: Estimated annual sediment loads and yields for the Pauatahanui Stream catchment from 12 June 2013 to 30 June 2018

Year	Time	Sediment load (Kt)	Sediment yield (t/ha/yr)	Percentage of load QC300 (%)
2013	204 days 7 hrs	2.14	0.57	32
2014	365 days	0.72	0.19	1
2015	365 days	3.49	0.93	1
2016	365 days	8.62	2.29	27
2017	365 days	1.7	0.45	70
2018	181 days	0.34	0.09	0
Total	*1,115 days 7 hrs*	*7.78*	*2.07*	*25*

(b) Event suspended sediment yield

Event-specific suspended sediment yields were calculated for events ≥1-year return period and the results summarised in Table 3.9.

Table 3.9: Event sediment yields for Pauatahanui Stream floods with ≥ 1 year return period from 12 June 2013 to 30 June 2018

Year	Events (≥ 1 year return period)	Duration (time)	Total sediment load (t)	Sediment yield (t/ha)	Maximum flow (m^3/s)	Flood return period	Percentage of load QC300 (%)
2013	16 - 25/6/2013	9 days, 9 hrs & 35 mins	1,235	0.33	37.6	≥1	51*
	14 – 17/10/2013	3 days, 6 hrs & 40 mins	146	0.04	15.9	≥1	4
	31/10 – 2/11/2013	2 days, 22 hrs & 40 mins	194	0.05	17.2	≥1	0
2015	27 – 29/4/2015	1 day, 15 hrs & 50 mins	216	0.06	17.7	≥1	0
	14 – 18/5/2015	4 days, 3 hrs & 20 mins	2,412	0.64	47	2	0
2016	5 - 7/5/2016	2 days, 1 hr & 10 mins	938	0.25	37.5	≥1	0
	27 – 31/5/2016	3 days, 14 hrs & 25 mins	289	0.08	23.9	≥1	0
	13 – 15/8/2016	2 days, 20 hrs & 10 mins	340	0.09	25.2	≥1	0
	16 -21/9/2016	4 days, 14 hrs & 35 mins	680	0.18	24	≥1	0
	10 – 14/11/ 2016	4 days & 30 mins	491	0.13	28.9	≥1	0
	14 – 19/11/2016	4 days, 20 hrs & 5 mins	4,875	1.3	79.6	20	47
2017	2 – 4/2/2017	2 days, 4 hrs & 15 mins	271	0.07	20.9	≥1	100
	5 – 8/4/2017	3 days, 7 hrs & 35 mins	657	0.17	31.5	≥1	99
	12 – 15/7/2017	3 days, 9 hrs & 25 mins	170	0.05	28.1	≥1	0

* The yield for the first event listed in Table 3.9 is likely to underestimate the actual yield given the turbidity sensor malfunctioned for nearly two days during the ten day event, missing the periods of highest sediment concentration.

The contribution of all flood events to the total sediment load is shown in Figure 3.9.

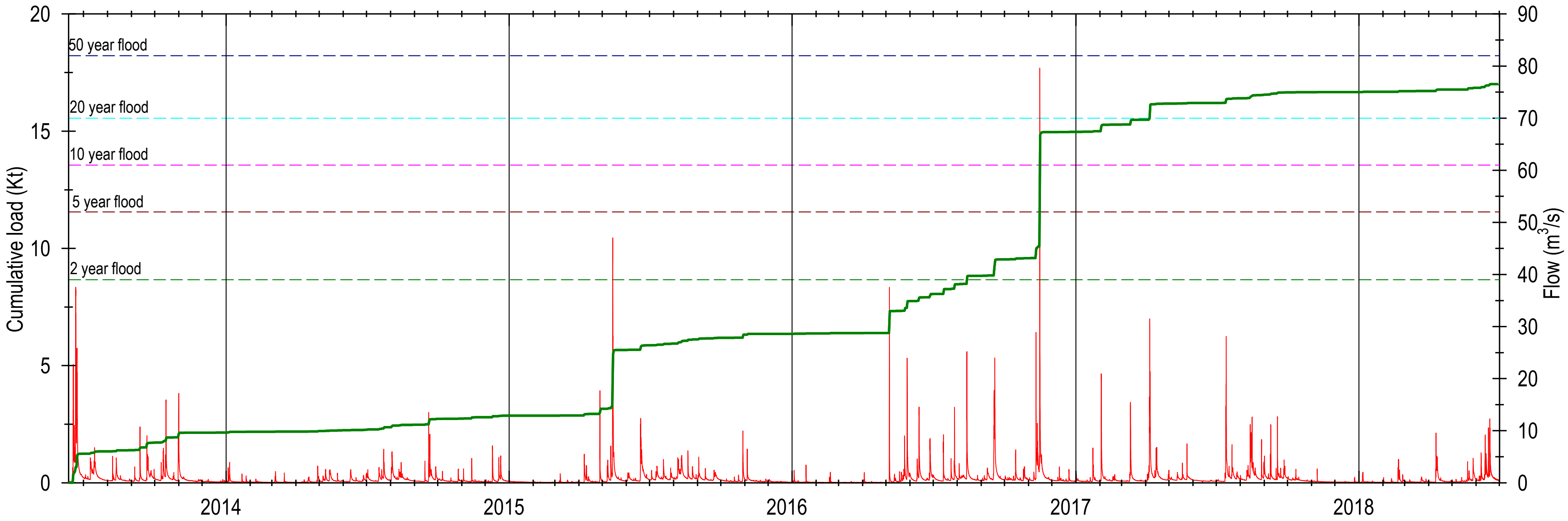

Figure 3.9: Cumulative sediment load (green line) versus stream flow (red line) in the Pauatahanui Stream from 13 June 2013 to 30 June 2018

The 14 November 2016 Pauatahanui Stream flood event

The 20-year return period event on 14 November 2016 was the biggest contributor of sediment at this site (4,875 t) since monitoring begun in 2012. In comparison, the next highest sediment contribution from a single event occurred during a 2-year return period flood on 14 May 2015. At the peak of the flood, the turbidity instrumentation, autosampler and logger were all flooded with water and resulted in no data collection for 134 days (Figure 3.10). The turbidity sensor was reinstalled again on 28 March 2017 once all the sensor infrastructure (tower, autosampler housing, and station box) had been upgraded to withstand a flood of this magnitude in the future. For the data gap, a synthetic turbidity record was generated using rating relationships between stream flow and reliable segments of the turbidity record prior to the flood following the procedures outlined in NEMS (2013) (See Appendix 2).

Figure 3.10: Pauatahanui Stream at Gorge site during 14 November 2016 flood (left) showing station box with turbidity instrumentation (right) being flooded; dashed line is water level at peak of flood

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Appendix 1: Laboratory and field methods

Core water quality variables measured/analysed at each site are presented in Table A1.1. Manual water samples are collected via hand or a standard sample pole approximately 200 mm below the water surface within 0.6 m of turbidity sensor. Autosampler samples are collected from an intake hose attached to the bottom of the turbidity sensor housing. Samples requiring laboratory analysis are placed in chilli bins with ice and couriered overnight to RJ Hill Laboratories in Hamilton.

Table A1.1: Field and analytical water quality methods and detection limits

Variable	Sample type	Method	Detection limit(s)
Field turbidity	In-stream sensor	Hach Solitax T-line sensor (ISO7027 compliant) with SC 200 module. Campbell Scientific OBS-3+ sensor	0.001– 4,000 FNU
Lab turbidity	Water sample collected manually or by autosampler	Analysis using a Hach 2100N, Turbidity meter. ISO7027:Ed. 1999	0.05– 1,000 FNU
Suspended sediment concentration (SSC)	Water sample collected manually or by auto-sampler	Filtration using Advantec GC-50 or equivalent 125mm 1 –12 diameter filters (nominal pore size 1.2 – 1.5µm), gravimetric determination. Entire sample filtered (includes aliquot previously sub-sampled for turbidity [when in autosampler bottle] and returned to bottle). No correction for density. ASTM D3977-97 (Modified).	10 g/m^3

Appendix 2: Site setup and methods

Site set up and maintenance

Table A2.1 lists the specific equipment deployed at each monitoring site and Figures A2.1 to A2.3 illustrate the setup of each individual site.

Table A2.1: Turbidity-related monitoring equipment at each of the three sites

Equipment		Porirua Stream		Horokiri Stream		Pauatahanui Stream	
		Easting	Northing	Easting	Northing	Easting	Northing
		1754669	5443961	1761804	5450652	1761480	5446486
Data logger	Model	Campbell 850 logger					
Turbidity sensor	Model	Hach Solitax T-line sensor with SC 200 module					
	Data collection start date	29/08/2012		14/11/2012		12/06/2013	
	Log interval	5 minutes					
	Range	0.001–4,000 FNU					
	Wipe interval	30 minutes					
Back-up Turbidity sensor (Horokiri Stream site only)	Model	-		Campbell Scientific OBS-3 sensor		-	
	Data collection start date	-		28/10/2014		-	
	Log interval	-		Median value taken over 5 minutes		-	
	Range	-		0.001–4,000 FNU		-	
	Wipe interval	-		No wiper		-	
Automatic sampler	Model	ISCO 6712		ISCO 6712		ISCO 6700	
	Installation date	27/03/2013		29/04/2013		12/06/2013	
	No. of bottles	24					
	Sampler trigger type	Turbidity		Turbidity		Turbidity	
	Sampling interval	5–60 minutes[1]					
	Bottle size	1,000 mL					
Camera	Model	Jablocom EYE-20		Jablocom EYE		Jablocom EYE	
	Log interval	5 minutes		5 Minutes-		5 Minutes--	

[1] Sampling interval varied according to event size and data requirements

The site setup at each of the three turbidity monitoring sites consists of a Hach Solitax T-line in-stream turbidity sensor housed in piping connected to an SC-200 control unit. These units then output the turbidity data to a logger which is telemetered to the GWRC office. An ISCO automatic water sampler was also installed at each site to collect samples for suspended sediment concentration analysis. The results of which, are used to convert the turbidity sensor data into suspended sediment concentration (SSC) record. A back-up turbidity Campbell Scientific OBS-3 sensor is also installed at the Horokiri site in case there are any issues with the primary sensor, especially during high flow.

At each of the three sites routine maintenance is carried out every five weeks, and involves cleaning the turbidity sensor lens and housing. During early summer, algal growth on the sensor lens and housing is a persistent problem and the frequency of maintenance is increased to every three to five days. Each sensor is sent back to the manufacturer annually to be serviced and re-calibrated.

Figure A2.1: Porirua Stream at Town Centre site. Top left inset: Turbidity sensor in the stream with lens and wiper showing. Bottom right inset: SC-200 control unit (top right) and logger (top left) setup

Figure A2.2: Horokiri Stream at Snodgrass site with insets of the SC-200 control unit and logger setup (top left), and primary in-stream turbidity sensor (bottom left inset and pipe near weir). The backup OBS-3 turbidity sensor (not shown) is attached to the outside of the pipe near weir

Figure A2.3: Pauatahanui Stream at Gorge site with insets of the SC-200 control unit and logger setup (top right) and in-stream turbidity sensor with auto-sampler intake hose attached to sensor housing (bottom left)

Data collection

Turbidity, stage and flow time-series data have been collected continuously since site installation was completed. Data are telemetered via HydroTel and checked daily for faults, equipment malfunctions and wet weather events. Data are also collected from the SC-200 logger memory during routine site visits every five weeks.

The ISCO autosamplers can take up to 24 discrete water samples. Sampling is triggered by turbidity at all sites, with the samplers programmed to collect samples at set intervals (eg, 5-15 minutes) (Table 2.1). Sampling ceases when the turbidity has dropped below a set trigger or the sampler has samples in all its bottles. All samples taken by the automatic samplers are dispatched to Hill Laboratories, typically within 48 hours, for determination of turbidity and suspended sediment concentration. Laboratory turbidity data is used to validate whether the field sensor is operating correctly.

For the 2016/17–2017/18 monitoring period, only those autosamples required to fill gaps in the existing SSC/turbidity relationship were sent to the laboratory for SSC and turbidity analysis.

Data processing

Turbidity data can be very 'noisy' and often needs editing to remove spikes in the data (Figure 2.4). 'Spiking' occurs in the data when debris floats past the turbidity sensor face or the sensor lens becomes fouled. When this occurs, erroneous data are manually edited where possible or removed from the record, as per the procedures outlined in NEMS (2013). During the reporting period, the cause of spiking at the three monitoring sites was typically debris (rubbish, leaves, branches, etc.) snagged around or passing by the sensor housing, algal growth on and around the sensor face/housing, and loitering fish.

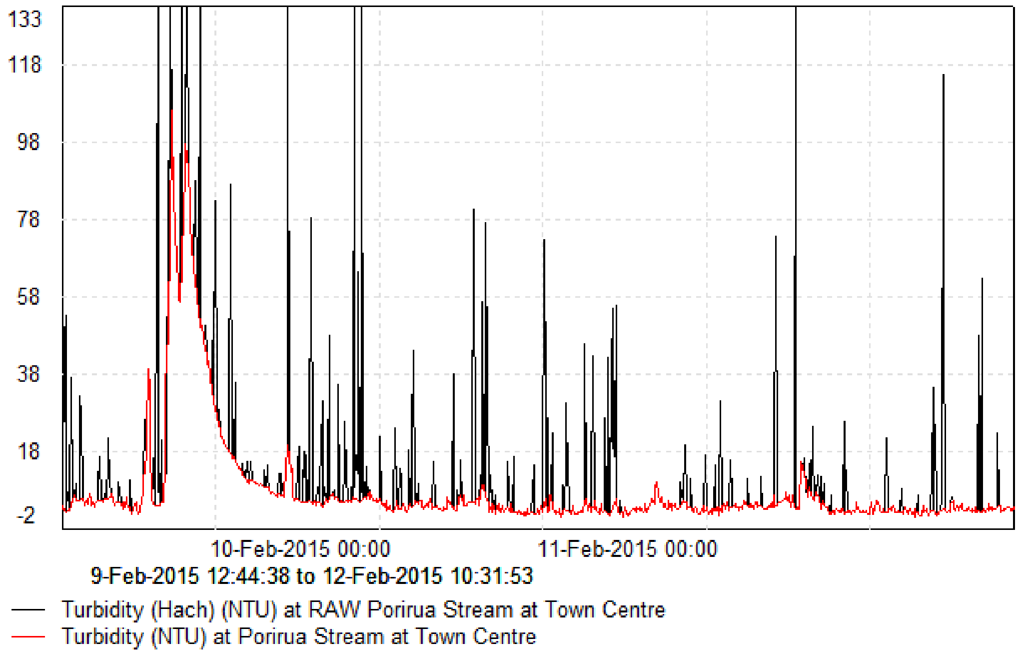

Figure A2.4: Continuous turbidity record illustrating the raw (black) versus edited (red) turbidity data. The original raw turbidity trace shows the amount of noise that typically needs to be removed

The NEMS for turbidity recording (2013) recommends that derived or synthetic data be generated to patch large periods of data lost due to sensor malfunction or discarded as a result of the editing process.

Synthetic turbidity records are generated using rating relationships between stream flow and reliable segments of the turbidity record for the Porirua and Pauatahanui Stream sites. Following the installation of the OBS-3 back-up sensor in the Horokiri Stream in late 2014, overlapping periods of edited data from both sensors were used to build a relationship between the two sensors and the resulting function applied to the back-up sensors record. The procedures for how to create synthetic or derived turbidity data are outlined in NEMS (2013).

Any heavily edited, derived or synthetic data was quality coded QC300 to the specifications of NEMS (2013). Any gaps that cannot be patched is left in the record and quality coded as ‘missing data’ (QC200). A list of Quality Codes and their meanings is summarised in NEMS (2013).

Turbidity and SSC

Site-specific regression relationships between log-transformed field turbidity data and SSC are used to convert the turbidity time series into a record of SSC5. The resulting equations are then used to calculate annual and event-specific suspended sediment loads and yields for each stream catchment. These relationships are constantly being refined as more SSC samples are collected and thus sediment loads and yields in this report will vary from those reported in earlier reports; Morar et al. (2015), Morar & Oliver (2016)[6], Morar & Oliver (2017).

[5] Retransformation bias was corrected for using the smearing estimate of Duan (1983).

[6] Due to an error in calculating the regression relationship between log-transformed field turbidity data and SSC, the sediment yields/loads presented in Morar & Oliver (2016) for the Porirua Stream were underreported. The loads for the Horokiri Stream and Pauatahanui Stream were not affected.