BEFORE INDEPENDANT HEARING COMMISSIONERS APPOINTED BY THE CANTERBURY REGIONAL COUNCIL

UNDER:	the Resource Management Act 1991
IN THE MATTER OF:	Proposed Plan Change 7 to the Canterbury Land and Water Regional Plan – Section 14: Orari-Temuka-Opihi-Pareora

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RESPONSE OF RICHARD JOHN MEASURES TO QUESTIONS FROM THE HEARINGS PANEL ON BEHALF OF THE ADAPTIVE MANAGEMENT WORKING GROUP (SUBMITTER NO.381)

Dated: 14 December 2020

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1 INTRODUCTION

1.1 My full name is Richard John Measures. My experience and qualifications are set out in my primary statement for the Adaptive Management Working Group dated 17 July 2020.

1.2 This statement provides details of the 3 November 2016 trial artificial fresh, to accompany the video located at https://youtu.be/BI3o5_jPPuE. It is provided in response to a request from the Hearing Panel to Mr Tom Lambie (Submitter No. PC7-410) on 5 November 2020. Further detailed analysis of this trial is contained in the report "Opuha flushing trial 3 November 2016" (Hopley and Measures 2017) appended to this statement. The trial, associated monitoring activities, video and report were all funded by Opuha Water Limited as part of their ongoing investigations into improved management of nuisance periphyton downstream of the Opuha Dam.

2 OVERVIEW OF THE 3 NOVEMBER 2016 ARTIFICIAL FRESH

2.1 On 3 November 2016 an artificial fresh was released down the Opuha River downstream of the Opuha Dam. Monitoring was undertaken to measure fresh hydraulics and to establish the effectiveness of the flush at removing periphyton. Footage of the flush was collected using a drone and compiled into a short video.

2.2 The artificial fresh trialled recently completed modifications to the downstream weir which controls discharge from the regulation pond below the dam into the Opuha River. The modifications of the weir involved lowering the weir crest and installing pneumatically adjustable gates to enable the release of higher peak flows than previously possible (for improved flood resilience and capacity to release artificial freshes).

2.3 This artificial fresh had a higher peak flow than any previous flush, with a peak of 85m^3/s measured at the recorder situated 100 m downstream of the weir. Following the fresh a continuous high flow of 16 m^3/s was discharged for 18 hours to ensure all suspended sediment and detached algae was transported out of the river mouth rather than being deposited in the river system. The total volume of water discharged during the fresh and the extended high flow following it was 1.37 million m^3.

2.4 Prior to the fresh didymo was the main nuisance algae present at monitoring sites in both the Opuha and Opihi rivers. The fresh was effective at removing most periphyton at the two monitoring sites in the Opuha River but was not effective at removing didymo 30 km farther downstream in the Opihi River at Saleyards Bridge due to the attenuation of peak flow, and the higher pre-flush flows (which enabled didymo to grow further up the banks where the fresh was less effective).

3 NOTES TO ACCOMPANY VIDEO

3.1 The notes in Table 1 below accompany the 4 minute 19 second long video of the artificial fresh trial which can be seen at https://youtu.be/BI3o5_jPPuE. The times listed in the table correspond to different times in the video.

3.2 It should be noted that the flow rates and volumes in the captions shown in the video were preliminary estimates (the video was produced immediately after the fresh and prior to more detailed analysis of the monitoring data). The flow rates and volumes in Table 1 come from the detailed analysis and supersede the video captions.

Table 1 Notes to accompany video of 2016 artificial fresh trial

Time	Notes
0:15	Due to recent rainfall the main dam was filled to above the spillway crest, with water retained behind the adjustable 'Obermayer' (tilting) gates. This allowed additional water (~20 m^3/s) to be released from the dam into the regulation pond via the main spillway (this would not be possible during freshes released when the lake was not full).
0:22	The power station operated continuously throughout the fresh release, discharging approximately 15 m^3/s into the regulation pond.
0:50	The regulation pond had been pre-filled (via the power station) and was completely full prior to the fresh release (300,000 m^3).
1:03	The downstream weir controls the release of water from the regulation pond into the Opuha River. It was upgraded in 2016 to allow discharge of higher flow rates
1:09	Under normal operation the radial gate is under automatic control, continuously releasing a steady flow set as required to maintain the minimum flow at Saleyards Bridge (varied according to the amount flow in the Upper Opihi and the rate of water takes). During the artificial fresh the radial gate was fully opened, and the adjustable weir gradually lowered. Together these release water from the regulation pond faster than it can be filled.
1:18	Flow gauging in the river immediately downstream of the weir (using a remote control jetboat due to health and safety considerations) measured the peak flow at 85m^3/s. The flow subsequently reduced as the level in the regulation pond dropped.
1:35	The artificial fresh mobilised sand, silt, gravel (and didymo) from the riverbed resulting in high turbidity (as happens during natural freshes).
1:58	The fresh reached Skipton Bridge approximately 2 hours after being released from the downstream weir. The peak flow measured at Skipton Bridge was 70 m^3/s (lower than released from the downstream weir because of the way the flood wave spreads out as it travels downstream attenuation).

Time	Notes
2:45	The drone is overtaking the leading edge of the artificial fresh. The footage shows the artificial fresh is not a sharp wave, but water level and turbidity does increase rapidly. Further downstream (for example in the Opihi) the rate of change is much more gradual and less hazardous.
4:01	This fresh was released during dry weather, with no natural fresh so the difference in turbidity at the Opihi confluence was obvious. When possible artificial freshes are released to coincide with a natural fresh. The most recent artificial fresh, released on 27 October 2020, was successfully timed to coincide with a small natural fresh. This maximised its effectiveness and minimised safety risks and impacts on turbidity.
4:09	The peak flow measured at Saleyards Bridge was only 47 m^3/s, well below the 70 m3/s recorded at Skipton (because of further spreading of the fresh peak, and storage of water in the braidplain gravels of the Opuha and Opihi riverbeds).

Richard John Measures

14 December 2020

Opuha flushing trial 3 November 2016

Prepared for Opuha Water Limited

March 2017

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The upgraded Opuha Dam regulation pond weir operating during the 3 November 2016 flushing trial. [Richard Measures, NIWA]

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Executive summary

On 3 November 2016 a flushing flow was released down the Opuha River downstream of the Opuha Dam. The flush trialled the recently completed modifications to the regulation pond weir, which enables release of higher peak flows than previously possible. The modifications of the weir included lowering the weir crest and the installation of pneumatically adjustable gates. Monitoring was undertaken to understand flush hydraulics and to establish the effectiveness of the flushes at removing periphyton.

The modifications to the weir allowed the flush to have higher peak flow than any previous flush, with a peak of 85 m^3/s at the recorder situated 100 m downstream of the weir. In comparison, peak flows during flushing events in 2013 and 2014 were 32.8 m^3/s and 39.1 m^3/s respectively.

The November 2016 flush was effective at removing most periphyton at two monitoring sites in the Opuha River (Gorge and Skipton Bridge), except that some periphyton cover remained in the river margins at Skipton Bridge. The flush was not effective 30 km farther downstream at Saleyards Bridge in the Opihi River due to the attenuation of peak flow, and the higher pre-flush flows.

A natural flood event following the flushing trial, with peak flows on 17 November 2016 exceeding those of the flush (except immediately below the dam where they were similar), and durations and volumes much higher than the flush at all sites. Peak recorded flow at Skipton Bridge was 90 m^3/s during the flood compared to 70 m^3/s during the flush; equivalent peak flows at Saleyards Bridge were 218 m^3/s and 47 m^3/s. A periphyton survey completed shortly after the flood as part of a fortnightly monitoring programme showed almost total removal of periphyton cover at all sites.

1 Introduction

1.1 Background

Nuisance periphyton growths occur frequently in the Opuha and Opihi Rivers downstream of the Opuha Dam. The potentially toxic cyanobacterium *Phormidium* and, to a lesser extent, green filamentous algae were the main nuisance alga types prior to 2008. After 2008 the bloom-forming diatom *Didymosphenia geminata* (didymo) become the main concern in the Opuha River, particularly when it formed large mats covering the river bed.

The presence of dams in rivers reduces the magnitude and frequency of natural high flows that help clear the river bed of periphyton (Young et al. 2004, Lessard et al. 2013). This is thought to be a major factor in allowing periphyton to remain in place and grow to nuisance levels in dam-controlled rivers. Releasing flushing flows has been identified as a possible way to mitigate the reduction in natural floods caused by dams. Monitored flushing flows have been trialled previously in the Opuha River (Lessard et al. 2013, Measures and Kilroy 2013, 2014). Analysis of these flushing flows identified that the volume and peak flow of flushes was limited by the volume and gate capacity of the regulation pond, located downstream of the main dam (Measures and Bind 2012).

In order to improve the capability to pass natural floods without damage to the weir infrastructure, and to allow release of higher peak flow during flushes, Opuha Water Limited commissioned Breen Constructions Ltd to undertake modifications to the weir of the regulation pond, below the main dam. This work was started mid-2016 and was completed in November 2016. The modifications involved lowering the weir crest and installing pneumatically adjustable “Obermayer gates”. These modifications allow significantly higher peak flows to be released from the regulation pond.

1.2 Study aims

This report covers a hydrological analysis on the flushing flow undertaken on 3 November 2016 and the results from the periphyton monitoring prior to and following the flushing flow. A comparison is also made between the 3 November 2016 flush and previous flushing flow trials in 2013 and 2014 (Measures and Kilroy, 2013, 2014).

The aim of the study was to ascertain the effectiveness of the new gate and its ability to generate enough flow to reduce nuisance periphyton growth downstream of the weir. This was accomplished by undertaking the following:

- flow gaugings at a suitable location near the downstream weir flow recorder to calibrate the rating curve for higher flows than previously measured;
- an analysis of the gauging data and data from three permanent gauging sites situated at different locations on the river (Figure 1-1);
- periphyton surveys to determine the abundance of different types of periphyton before and after the flush to measure the effectiveness of the flush at different locations on the river (Figure 1-1).

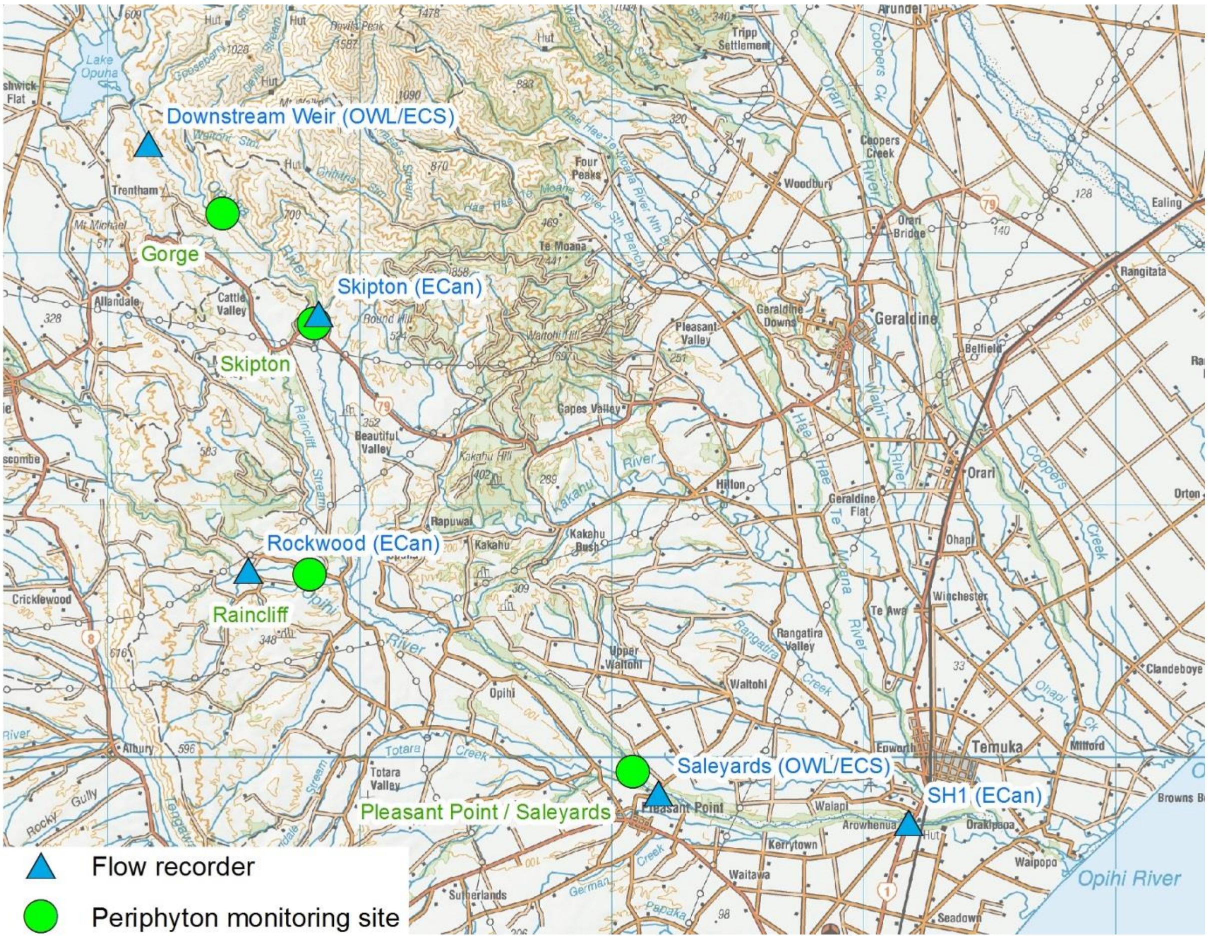

Figure 1-1: Permanent flow recording sites and NIWA periphyton monitoring site locations on the Lower Opuha and Opihi Rivers.

2 Flushing flow

2.1 Overview

The monitored flushing flow described in this report was released on 3 November 2016, starting at approximately 10:15 am (9:15 NZST). Prior to the flush the regulation pond was filled nearly to capacity by running the power station to discharge water into it from the main dam and reducing the discharge into the Opuha River to 1.3 m^3/s for 10 hours prior to the flush. During the flush the power station ran continuously, releasing 16 m^3/s into the regulation pond. In addition the spillway gates on the crest of the main dam upstream of the regulation pond were opened, discharging approximately 25 m^3/s into the regulation pond during the period that the new gates at the weir were open. This differed from all previous flushing trials (Measures and Kilroy 2014) and was possible because the water level in Lake Opuha was high enough for the spillway to function.

2.2 Flow data collection

The magnitude of the flushing flow was measured at permanent water level recorders situated 100 m downstream of the regulation pond weir (Downstream Weir, operated by Environmental Consultancy Ltd (ECS), site number 69661), upstream of Skipton Bridge on State Highway 76 (Skipton Bridge, operated by Environment Canterbury, site number 69614) and farther down the system in the Opihi River at Saleyards Bridge, near Pleasant Point (Saleyards Bridge, operated by ECS, site number 696501). These sites utilise a calibrated level – flow relationship (rating curve) to calculate flow from an observed water level.

To ensure accuracy of the rating curve at the weir for the high flows expected during the flushing event (higher than had been previously gauged), flow gaugings were carried out by NIWA staff during the event. The gauged site was 200 m below the weir structure and approximately 100 m below the Downstream Weir flow recorder. Flow gaugings were accomplished by using a radio controlled jet boat with a Teledyne ADCP unit inside (Model RiverPro1200_1_UG1) to measure cross-sections of depth and water velocity. A GPS tracking unit was also used with the ADCP unit to help improve accuracy of the data. The gauged flows are shown in Table 2-1 and were used by ECS to calibrate/extend the rating curve of the Downstream Weir flow recorder station for higher flows.

A further gauging was intended to be undertaken at the Skipton Bridge site by Environment Canterbury staff, but unforeseen problems with equipment prevented this from happening.

Table 2-1: Flow gaugings measured at the Downstream Weir site during the flushing trial. Each recorded flow is the average of several repeat measurements.

Measurement start (NZST)	Measurement end (NZST)	Recorded flow (m^3/s)
9:18 am	9:24 am	38.510
9:23 am	9:25 am	45.010
9:26 am	9:32 am	62.316
10:56 am	11:00 am	48.221

2.3 Flushing flow time-series

Figure 2-1 shows the time-series flow data calculated from the three water-level monitoring stations (Downstream Weir, Skipton Bridge and Saleyards Bridge). The figure also shows estimated flows released from the regulation pond based on pond level and gate position data.

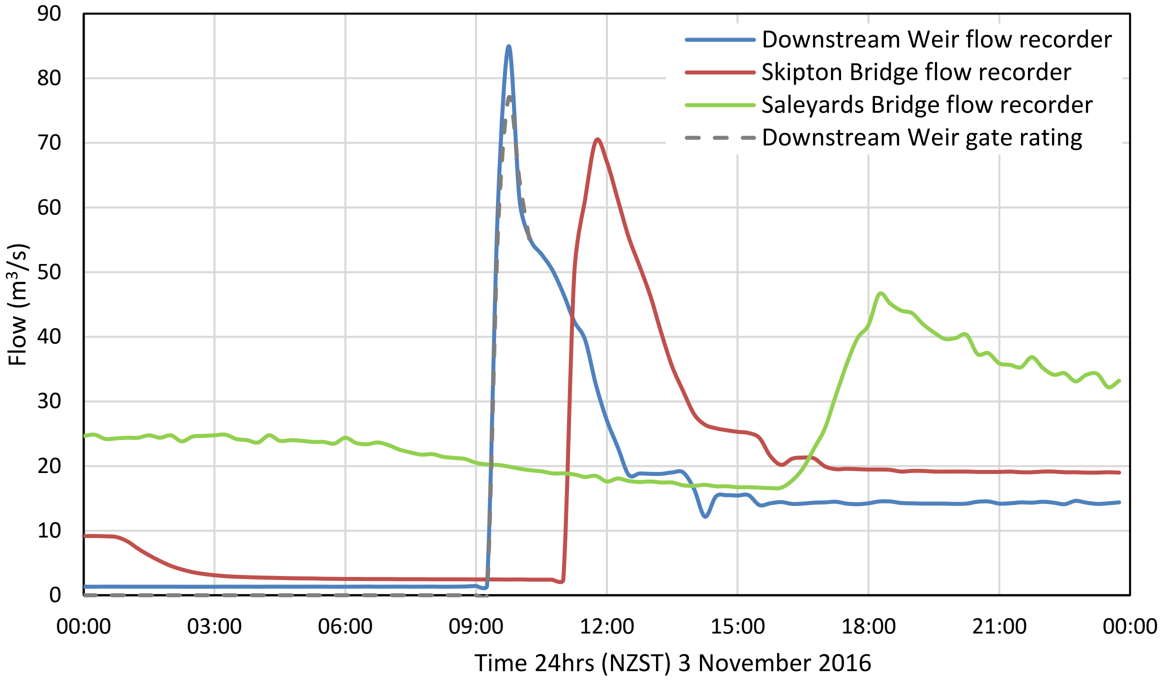

Figure 2-1: Propagation of flushing flow from the dam to the Lower Opihi River. Downstream Weir gate data provided by Opuha Water Ltd and Saleyards provided by Environmental Consultancy Ltd.

The instantaneous peak of 85 m^3/s measured at Downstream Weir was attained in approximately 15 minutes, from a discharge of 1.3 m^3/s before the start of the flushing release. Figure 2-1 shows the steep increase in flow followed by steep decline.

The weir outflow estimated from pond level and gate position was the same as that recorded at the Downstream Weir site except that estimated peak flow was 77 m^3/s, 8 m^3/s below the peak calculated at the recorder station. This difference in peak flow may be related to differences in timing of the recorded data points as the duration of peak was very short. Overall flows determined by the two methods were reasonably consistent.

Table 2-2 summarises key flow data from the Downstream Weir, Skipton Bridge and Saleyards Bridge flow recorders. The instantaneous peak recorded at Skipton Bridge was 70 m^3/s. The peak flow took approximately 2 hours to travel the distance between the Downstream Weir site and the Skipton Bridge recorder. It took approximately 30 minutes to attain peak flow from the preceding flow of 3.6 m^3/s.

Saleyards Bridge flow recorder had an instantaneous peak of 47 m^3/s. Travel time to Saleyards Bridge was approximately 8 hours and 30 minutes. The increase in flow was prolonged, taking approximately 2 hours and 15 minutes. The subsequent decline in flow was also prolonged compared to that at the two Opuha sites (Figure 2-1).

Between the Downstream Weir and Skipton Bridge recorders there was an attenuation in peak flow of 15 m^3/s. Between Skipton Bridge and Saleyards Bridge there was a further reduction of 24 m^3/s.

Table 2-2: Peak flows recorded at the three sites during the flush on 3 November 2016. Pre-flush flow was calculated as average recorded flow from midnight till just before the rise in water flow from the flush.

Site	Distance from downstream weir (km)	Pre-flush flow (m^3/s)	Peak flow (m^3/s)	Time of peak flow (NZST)
Opuha @ Downstream Weir	0.1	1.3	85.0	0945
Opuha @ Skipton Bridge	12.7	3.6	70.3	1145
Opihi @ Saleyards Bridge	41.6	21.2	46.6	1815

2.4 Natural floods following the flush

Shortly after the flush on 3 November a series of large rain events commenced in the Opuha and Opihi catchments, culminating in a significant natural flood event peaking on 17 November. To pass the flood, the spillway gates on the main dam were operated, releasing flows into the Opuha. On 17 November the Downstream Weir site recorded an instantaneous peak of 58 m^3/s, Skipton Bridge site recorded a peak of 90 m^3/s and the Saleyards site recorded a peak of 217 m^3/s. Flows during this flood event are shown in Figure 2-2.

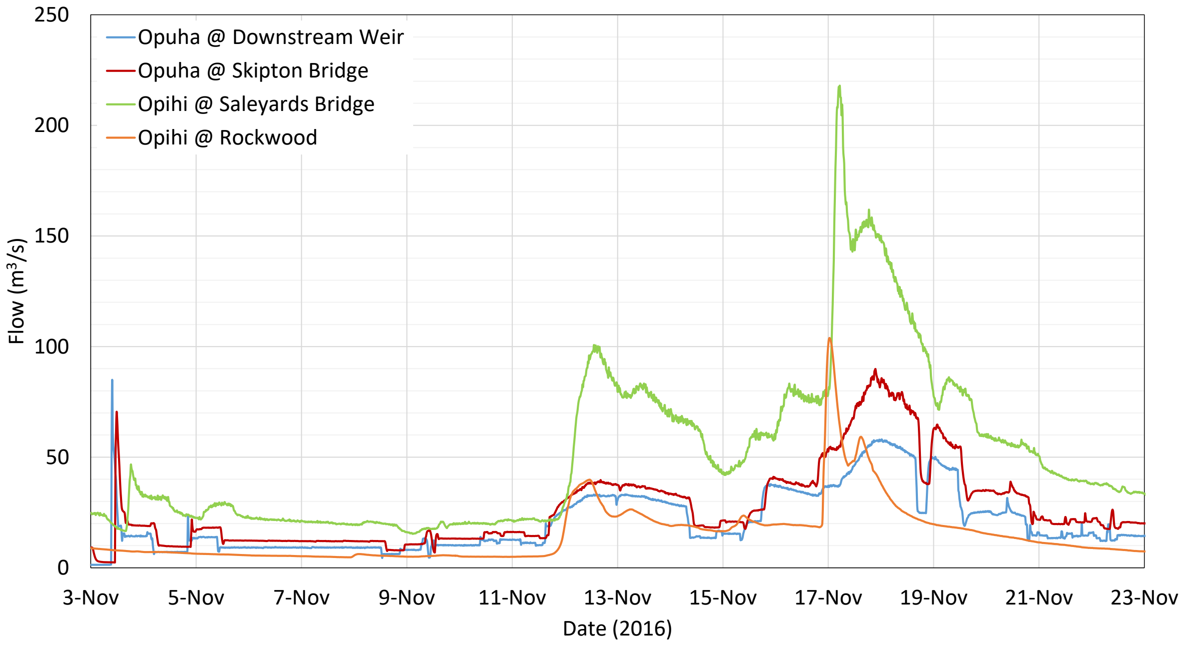

Figure 2-2: Recorded river flow in the Opuha and Opihi Rivers during November 2016. Includes the flushing flow release on 3 November and the natural high flows peaking on 17 November 2016.

The volume of water released from the dam during the flood was significantly higher than during the flush, although the peak flow recorded at the Downstream Weir (on 17 November) was slightly lower. Additional inflow from small side streams downstream of the dam increased the peak flow at Skipton Bridge to higher than that recorded during the flush. The Opihi River upstream of its confluence with the Opuha was also in flood (104 m^3/s peak flow recorded at Rockwood). This, as well as inflows from the Tengawai River and other tributaries to the Opihi between Rockwood and Saleyards Bridge, resulted in flows at Saleyards Bridge higher than the peak flushing flow for most of the time between 12 and 20 November.

3 Periphyton surveys

Regular periphyton monitoring in the Opuha and Opihi rivers consists of fortnightly surveys during summer and monthly surveys over winter. The surveys are done at four sites: Gorge and Skipton Bridge on the Opuha River, and Raincliff and Saleyards Bridge on the Opihi River (site locations shown on Figure 1-1). Three of the sites (Gorge, Skipton Bridge and Saleyards Bridge) are influenced by the Opuha Dam. Raincliff is a comparison site on the Opihi River upstream of its confluence with the Opuha and is not influenced by the dam. Further details of the monitoring programme design are given by Kilroy et al. (2016).

The periphyton surveys at each site involve estimating the percentage coverage of nine periphyton categories (Table 3-1) using a 350 mm-diameter underwater viewer (Nuova Rade, Genova Italy). At each site periphyton coverage is viewed and recorded at 10 points along two transects across the river (20 in total). These points are located at fixed positions to ensure that we are recording changes in periphyton cover over time in the same areas. The overall percentages at each site are calculated as the means of the 20 point estimates.

Where didymo is present the mean thickness of didymo mats (in millimetres) is estimated in each viewed area by measuring thickness at several points in the mats using a graduated pointer. The thickness data are used to calculate a “standing crop index” (SCI) for didymo at each site, computed as percentage cover multiplied by mat thickness (mm). For example, coverage of 50% by mats 6 mm thick would have an SCI of 300.

Table 3-1: Definitions of the nine periphyton categories that were measured via visual estimates.

Category	Definition
No algae	Rocks have no green/ brown algae colour and are not slimy/slippery to touch
Film	Rocks are slimy/slippery to touch and have a visible coating of algae, less than about 1 mm thick
Sludge	Loose, unconsolidated, non-filamentous algae often found in slower flowing areas
Mats	More consolidated layers of algae
Phormidium	Distinctive black, dark brown or greenish shiny or mottled mats
Didymo	Wool-like mats with whitish stalks underneath and brown cells at surface
Fils green	Bright green filamentous algae, short or long filaments, sometimes overgrowing other algae
Fils other	Other filamentous algae, generally brown
Macrophytes	Vascular plants rooted in the river bed

A pre-flush survey was carried out on 1 November at the Gorge and Skipton Bridge sites as these were likely to be the most affected sites. On the day after the flush, 4 November, a post-flush survey was undertaken at all four sites as part of the regular fortnightly monitoring. Further monitoring was completed on 25 November and 8 December. Periphyton percentage cover and didymo SCI data are shown in Figure 3-1.

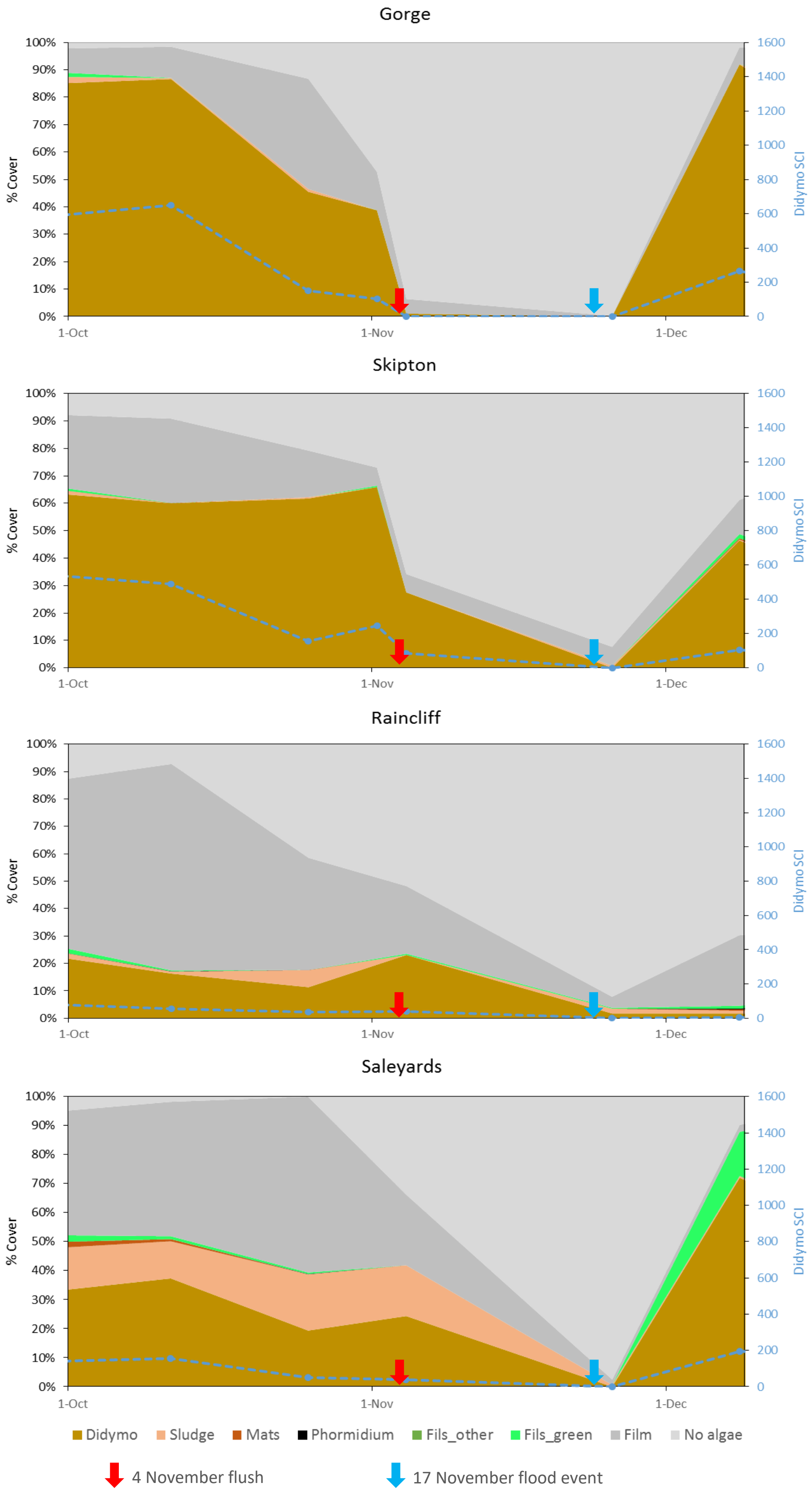

Figure 3-1: Periphyton cover at the four sites before and after the flushing flow. Also shown is the effect on periphyton of the 17 November natural flood.

The flushing flow on 3 November reduced periphyton cover (not including film) from 39% to 1% and didymo SCI from 102 to 2 at the Gorge site. Only small patches of film remained (5%) and this was usually on the protected downstream side of large rocks.

At Skipton Bridge periphyton cover was reduced from 66% to 28% by the flush and didymo SCI was reduced from 245 to 84. The periphyton that remained was observed on the edges of the river where the flow velocity would have been lower due to the nature of the river bed that included a faster flowing channel towards the true left and slow flows along the margins.

The flush appeared to have little effect at Saleyards Bridge with periphyton remaining at 42% after the flush. A clear indication that the flush was not effective at Saleyards Bridge is that in the post flush survey, 18% cover by sludge was observed, mostly at the margins. Sludge is generally the first periphyton type to be removed in an elevated flow due to its loose and unbinding structure, but was not completely removed at Saleyards during this event. Sludge as described in Table 3-1 is “Loose, unconsolidated, non-filamentous algae often found in slower flowing areas”.

4 Discussion

The November flushing trial was by far the biggest artificial flushing flow that has been released since the construction of the dam. This is clearly shown in Figure 4-1. During the February 2013 flush there was an unexpected limitation on how quickly the gate at the weir could be opened resulting in a slower increase in flow (Measures and Kilroy 2013). This was rectified in the February 2014 flush which achieved the maximum size of flush possible at that time (Measures and Kilroy 2014). The new gate system installed at the weir allowed the November 2016 flush to achieve more than double the peak flow previously possible.

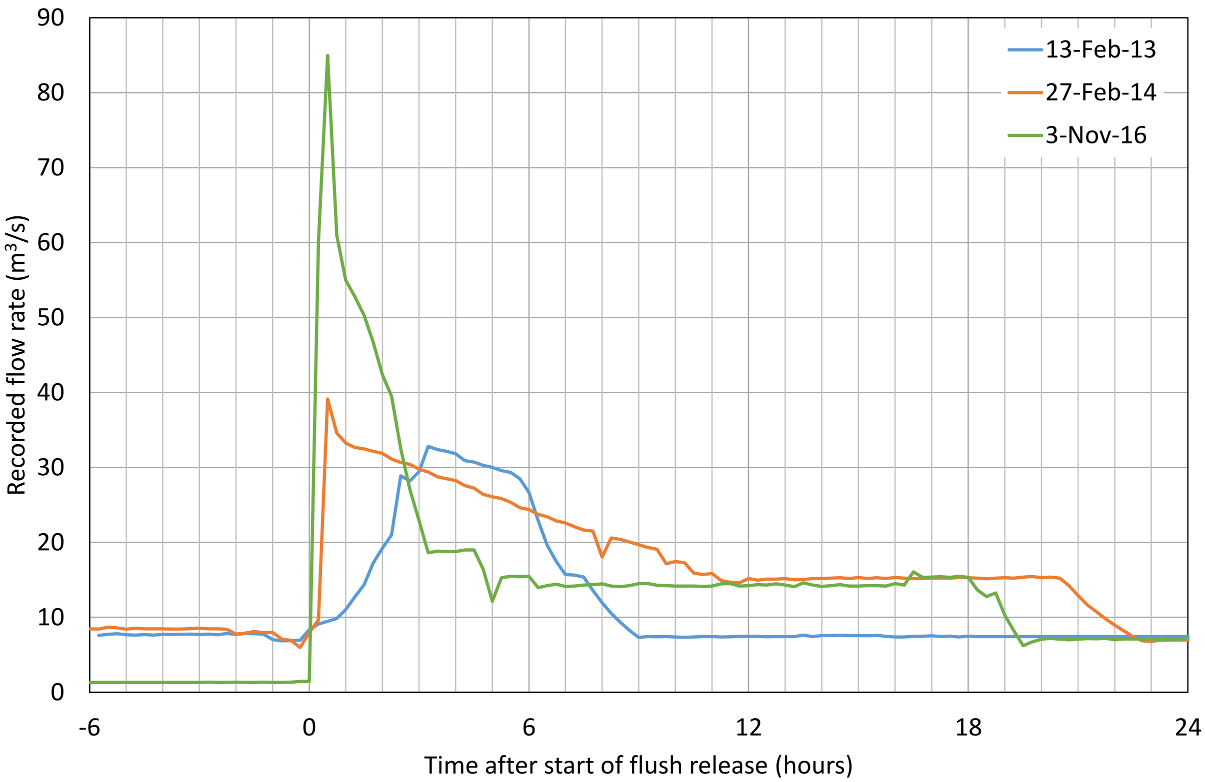

Figure 4-1: Comparison of 2013, 2014 and 2016 monitored flush releases. Flows recorded at Downstream Weir flow recorder for all three events.

Table 4-1 compares key attributes of the 3 November 2016 flush with previous monitored flushes and the natural flood event which peaked on 17 November 2016. Due to the short duration of the peak flow of the 3 November 2016 flush there was more attenuation of peak flows between the dam and Skipton Bridge than in the previous monitored flushing trials. However, the 2016 flush still achieved significantly higher peak flows than in previous flushes at both Skipton Bridge and Saleyards Bridge.

Despite the higher peak flow of the 3 November 2016 flush, the February 2014 flush had a slightly higher volume. The 2014 flush retained elevated flows from the flush as much as the regulation pond allowed whereas the 2016 flush reduced quite sharply from the flush peak to approximately 20 m^3/s three hours after the peak (Figure 4-1). This meant that despite the much higher peak flow the early part of the 2016 flush released similar volume as the 2014 flush. Both the 2014 and 2016 flushes had a sustained flow of approximately 16 m^3/s released following the main flush peak, but the 2014 flush was sustained for an additional three hours accounting for its slightly larger overall volume.

Table 4-1: Comparison of flow, duration and volume for the 13 February 2013, 27 February 2014 and 3 November 2016 monitored flushing flows and the 17 November 2016 flood. Volume and duration were calculated from Downstream Weir data. For flushes they were calculated from the start of each flush event until the flow returned to preceding levels. For the natural flood volume and duration were taken for the period the flow was greater than 16 m^3/s (16 m^3/s corresponds to the maximum flow which can be released through the power station).

	Site	13 Feb 2013	27 Feb 2014	3 Nov 2016	17 Nov 2016
Peak flow (m^3/s)	**Opuha @ Downstream Weir**	32.8	39.1	85.0	58.0
	Opuha @ Skipton Bridge	32.1	32.5	70.3	89.8
	Opihi @ Saleyards Bridge	25.9	29.1	46.6	217.9
Flush/flood release duration (hours)		8.75	22.50	19.25	129.00
Flush/flood volume (m^3)		669,000	1,578,000	1,374,000	17,226,000

Table 4-2 compares the percentage remaining periphyton coverage following the different monitored flushes as well as the 17 November 2016 natural flood. Although percentage cover remaining is influenced by the pre-flush coverage (both total percentage and periphyton type) it was found to be less dependent on pre-flush conditions than other metrics (such as percentage removed).

Table 4-2: Remaining periphyton cover following monitored flushes and the natural flood event on 17 November 2016. Remaining coverage is the total of all classes of periphyton excluding film.

Site	% Periphyton cover remaining after flush			
	13 Feb 2013	27 Feb 2014	03 Nov 2016	17 Nov 2016
Opuha @ Gorge	67.0%	54.0%†	6.4%	0.2%
Opuha @ Skipton Bridge	62.0%	44.2%	34.2%	7.7%
Opihi @ Saleyards Bridge	NA‡	NA‡	66.3%	2.5%

†No periphyton monitoring data was undertaken at the Gorge site for the 27 Feb 2014 flush so values given are from periphyton monitoring at the Downstream Weir site.

‡Periphyton monitoring at Saleyards Bridge commenced in November 2014. No data is available prior to this.

The high peak flow of water released during the 3 November 2016 flush was effective at removing almost all periphyton from the Gorge monitoring site and much of the periphyton at Skipton Bridge, although it failed to remove persistent periphyton located near the river margins at Skipton Bridge. Compared to previous flushes the 2016 flush was more effective at both of these sites.

At Saleyards Bridge the flush was much less effective at removing periphyton compared to upstream in the Opuha. There are two likely causes of this reduced effectiveness. First, attenuation caused by the relatively short peak flow spreading over a longer time period, as well as infiltration into the permeable gravel bed, reduced the peak flow significantly by the time it reached Saleyards. Second, pre-flush flows in the Opihi were high relative to the size of the flushing flow, meaning that the change in shear stress resulting from the flush was proportionally smaller. To improve flush effectiveness at Saleyards Bridge it might have been possible to maintain longer duration peak flows to reduce attenuation. However, this would not be possible under 'normal' conditions when the water level in Lake Opuha is below the spillway crest on the main dam. Under normal conditions, the capacity to extend the duration of the flush is limited by the volume of water available in the regulation pond. Due to the limitations on flush volume it is likely that artificial flushing flows would need to be timed to coincide with natural freshes in the Opihi for them to be effective at removing periphyton in the Lower Opihi.

The higher peak flow and much longer duration of the natural flood which peaked on 17 November was very effective at removing periphyton from all monitored sites including Saleyards Bridge. The flows recorded during the natural flood on 17 November provide an upper bound for the types of flows required for effective removal of periphyton from all sites.

5 Conclusions

Peak flow in the 3 November 2016 flush was more than double that recorded in any previous flushing flows, although its volume was similar to that of the flushing flow in February 2014. The higher peak flow in November 2016 was made possible through the recent modifications to the downstream weir.

The flush was effective at removing most periphyton at the two sites monitored on the Opuha River but had limited effectiveness at a site farther downstream in the Opihi River, due to the attenuation of peak flow and the higher pre-flush flows in the Opihi.

The natural flood that peaked on 17 November 2016 removed almost all periphyton at all monitored sites in both the Opuha and Opihi.

6 Acknowledgements

Thanks goes out to the many people who helped during the flush and this report: Hayden McDermott and Davide Fedrizzi from NIWA who helped with the gauging effort below the weir; Environment Canterbury for supplying data from the Opuha Skipton Bridge site and Opihi Rockwood site; Lindsay Anderson at Environment Consultancy Ltd for supplying hydrological data from the Below Weir site and Saleyards site.

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