Interim update: Flushing flows for the management of nuisance periphyton in the Opuha River, New Zealand

NIWA Client Report: CHC2008-017
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Opuha Water Partnership

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1. Introduction

The purpose of this communication is to update the Opuha Water Partnership on results from NIWA's multi-year periphyton monitoring efforts on the Opuha and Opihi Rivers. A previous report (Arscott et al. 2007) described periphyton monitoring results from 4 flushing-flows released from the Opuha Dam between March 2005 and February 2006. For background information, study sites, methods, and results from previous flushing-flows, please consult Arscott et al. (2007). In October 2006, Opuha Dam Ltd. agreed to fund work proposed by D. Arscott (NIWA Ltd.). That proposal outlined data to be collected between December 2006 and April 2007 with an interim report to be prepared in June 2007. The original intent of that proposal was to conduct surveys of periphyton on the stream bed at several sites downstream from the dam at monthly intervals (5 months during 2006-07 summer period) and before and after three flushing-flows (to occur between December 2006 and March 2007). Do to operational constraints, the three flushing-lows occurred over an entire year (November 2006 and March and November 2007).

The work contracted by Opuha Water Partnership paid for the collection of visual estimates and quantitative samples of periphyton during monthly and flushing-flow surveys and provided staff time to prepare this short report. In addition to this work, NIWA has developed a project in its Water Allocation Programme (funded by the Foundation for Research Science and Technology) that includes research on the effectiveness of flushing-flows for managing periphyton in managed rivers. With these additional funds, we have added several other measurements to our monthly and flushing-flow sampling to better quantify ecological response to flushing-flows. The additional measurements consisted of quantitative sampling for periphyton and invertebrates, basic water quality measurements, suspended sediment in transport, and numerous flow gauging measurements. We collected data on bed sediment movement during flushing-flows and also developed a 1-dimensional hydraulic model of the riverbed in one river reach (near Skipton Bridge). The hydraulic model was calibrated from field measurements of sediment transport during flushes and is then used to predict bedload transport given various flow scenarios. This communication is primarily intended to provide an update on visual and quantitative periphyton observations. However, some data produced during the Water Allocation Programme studies are incorporated here to demonstrate the potential tools that we are developing to better predict sediment movement thresholds and flows necessary for managing periphyton in managed rivers.

2. Study sites

A description of the Opuha River and study sites included in this monitoring programme is presented in Arscott et al. (2007). In brief, our recent monitoring activities occurred at four sites on the Opuha River downstream from the Opuha Dam and at two sites on Opihi River, one above and one below the Opuha River confluence.

Opuha River

1. 200 m downstream from Opuha Dam
2. Skipton Bridge – 12 river km from dam
3. Chota Bari Farm access (February 2006 flush only) – 20 river km from dam
4. Above the Opihi confluence – 25 river km from dam

Opihi River

5. Raincliff Bridge – 500 m upstream from Opuha-Opihi confluence
6. Hanging Rock Bridge – below Opuha River confluence – 34 river km from dam

3. Results from recent flushing-flows

3.1. Hydrology and suspended material in transport

The three most recent flushing flows all had peak discharges (measured ~100 m downstream of the dam) that were greater than any of the first 4 flushing-flows (Table 1). The November 2006 flush had the greatest change in magnitude due to very low pre-flush flow levels (~3.2 m^3/s during previous 7-day period). During the last three flushes we installed temporary stage height recorders and gauged cross-sections at each study site. We use the stage height and discharge data to quantify the travel time and the attenuation of the flood wave moving downstream (Figure 1). These measurements indicated that peak flows at the Opuha confluence were approximately 35% of peak flows occurring at the dam on each of these flushes.

Water samples were collected at 4 sites downstream from the dam during the three most recent flushes. Samples were analyzed for total suspended material (TSM; Figure 1) and TSM concentrations were related to discharges during the flushing-flow. During flushes, very little suspended material was released to the river from the weir pond. Typically, as the flood wave travelled between the dam and Skipton (12 km downstream), it entrained mineral and organic material. Peak TSM concentrations occurred at Skipton and decreased downstream. Peak TSM at the confluence site during these three recent flushes was ~35% of that measured at Skipton.

Table 1: Mean flow just below the Opuha Dam prior to each flushing flow, maximum flow during the flush, and the magnitude of flow change for the 7 flushing flows from March 2005 – November 2007.

Date	Mean pre-flush flow (7-d mean; m^3/s)	Maximum flow during event (m^3/s)	Flushing flow magnitude (x baseflow)
6 March 2005	7.3	18.0	2.5
13 May 2005	2.7	22.0	8.7
17 December 2005	2.7	21.0	7.8
8 February 2006	5.3	21.0	3.9
23 November 2006	3.2	32.0	10.0
10 March 2007	9.3	33.0	3.5
21 November 2007	8.7	42.0	4.8

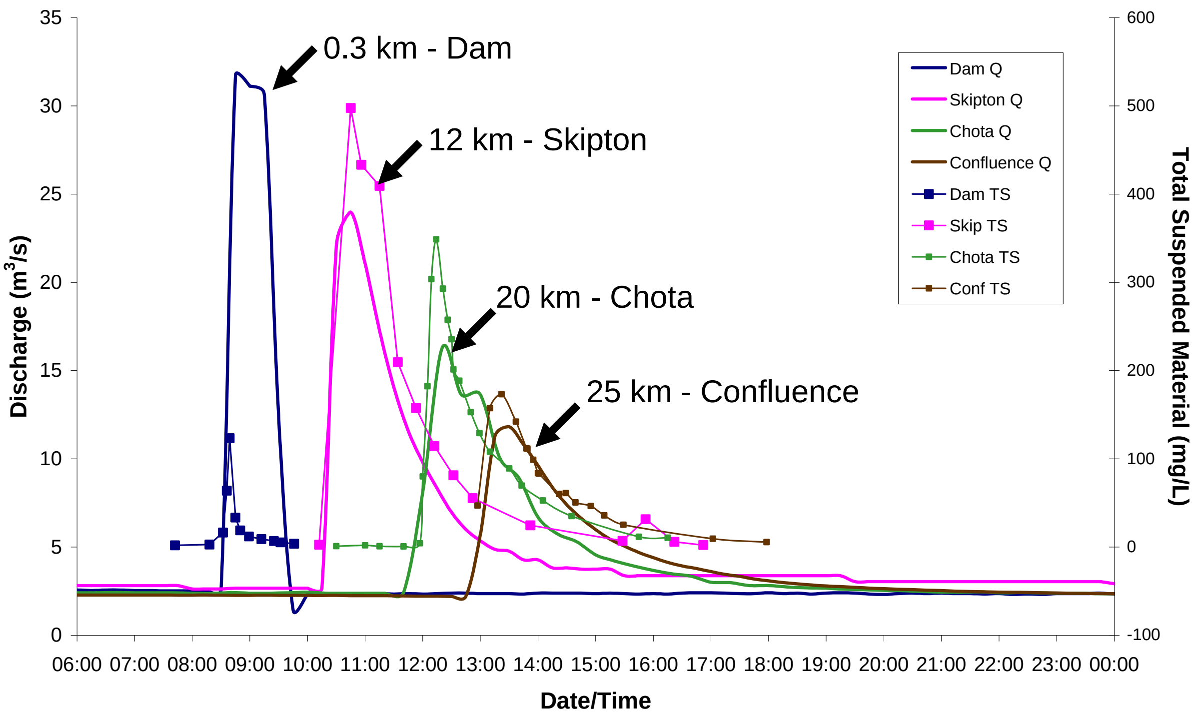

Figure 1: Discharge (m^3/s) and total suspended material (TS in mg/L) at four sites located downstream from the Opuha Dam during a flushing-flow on 23 November 2006. Solid lines define discharge and refer to 1st y-axis and pointed lines define TS and refer to the 2nd y-axis. Distances for each site are river distances and Confluence is a site just above the Opuha-Opihi confluence.

3.2. Periphyton percent cover estimates

Periphyton cover on the stream bed was visually estimated at 20 points across the river at each site during each visit to the river. The standing crop of periphyton across the river channel was described as the relative percentage of 5 cover types: thin (<0.5mm), medium (0.5-3 mm), and thick (>3mm) mats and short (<2cm) or long (>2cm) filamentous algae. The average cover in each category during each visit is shown in Figure 2. The 6 monitoring sites were visited twenty-seven times between February 2005 and January 2008. Visits were approximately monthly but some months were skipped and, sites were visited twice during months with flushes (pre- and post-flushing). The thick mat and long filament categories are highlighted in green to emphasize these categories that indicate nuisance periphyton cover types. Biggs et al. (2000) suggest that >30% coverage by long filamentous green algae (>2cm long) and/or >60% coverage by thick mats (>3 mm thick) may impair aesthetics, recreation, trout habitat and angling. These threshold values are recommended by the Ministry for the Environment (MfE) as guidelines for implementing management techniques to reduce nuisance periphyton.

Periphyton dominated by thick mats and long filaments was most common at the dam and at Skipton. Nuisance periphyton occurred at all sites, but only exceeded the MfE recommended guidelines at the dam, Skipton, and Chota during the study period (Table 2). Most of these exceedances were due to prolific cover by filamentous green algae. One particular nuisance algal taxa, *Phormidium* (cyanobacteria), appears on the stream bottom as a thick black/dark brown mat. Extensive coverage of the stream bed by *Phormidium* can result in high concentrations of a microcystin-like toxin that has been known to cause severe skin rashes, upset stomach, liver damage, hay fever and asthma (Baker et al. 2001, Shutt 2003, Teneva et al. 2005). It has also been known to kill dogs (Milne and Watts 2007). Furthermore, fish growing in the presence of *Phormidium* develop a foul taste. *Phormidium* was observed at all study sites on most survey dates and has occasionally been estimated to cover up to 40-50% of the stream bed at Skipton, Chota, confluence, and at Hanging Rock.

In April 2007, the invasive algae *Didymosphenia geminata* (Didymo), was found in the North Opuha River (a tributary of Lake Opuha). In December 2007, Didymo was positively identified just below the Opuha Dam. As of February 2008, Didymo has been observed downstream of the Opuha Dam and in the lower Opihi. By January 2008, Didymo covered almost 100% of the stream bed below the Dam and at Skipton.

Observations of periphyton percent cover made before and after flushing-flows indicated that flushes of medium sized magnitude (i.e., all flushes were less than the

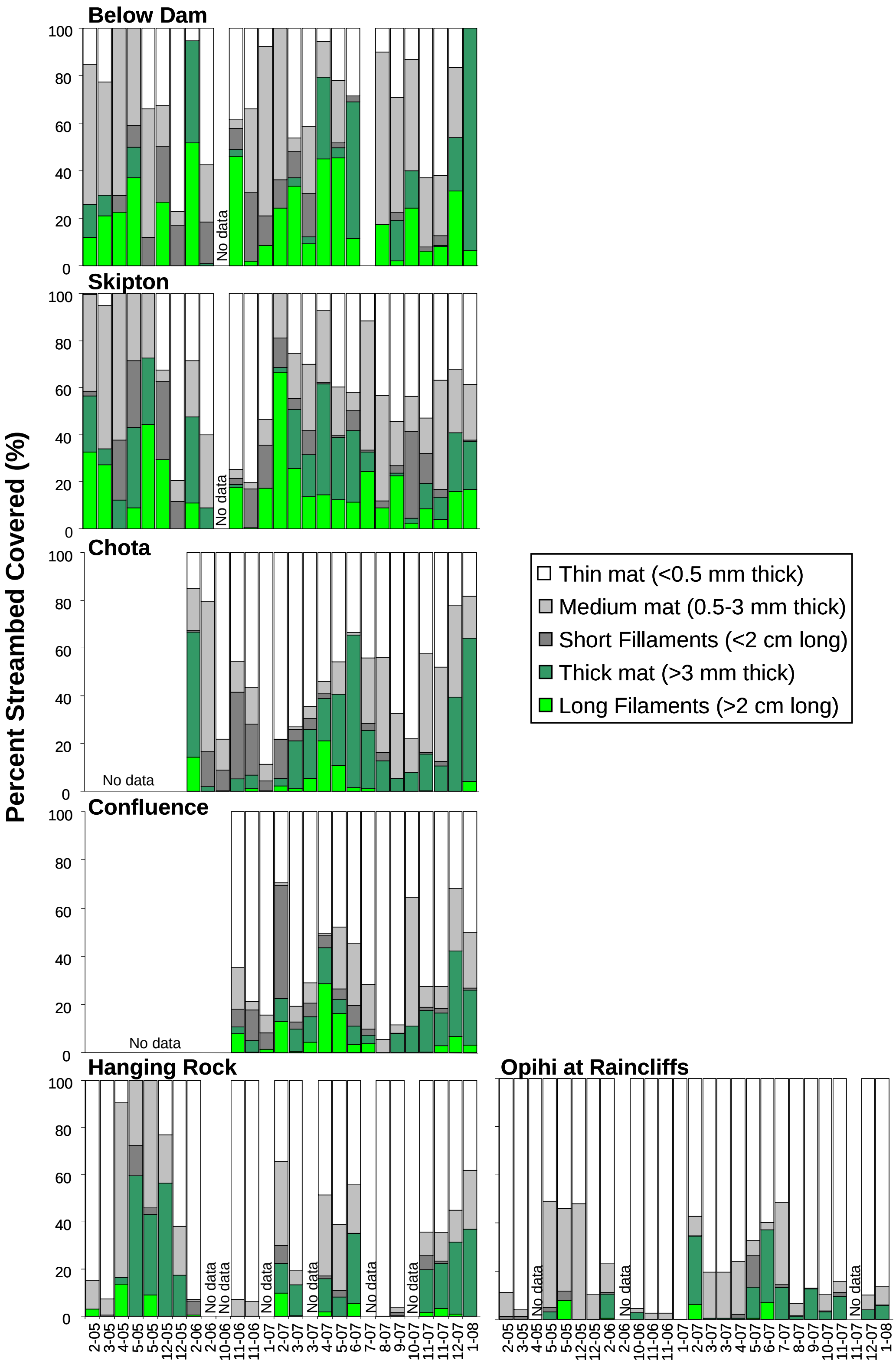

Figure 2: Percent cover of periphyton at 4 sites along the Opuha River and 2 sites along the Opihi River February 2005 to January 2008. Thick mats and long filaments are highlighted with green colours to emphasize these "nuisance" cover types. Each column is the average of 20 visual estimates

Table 2: Number of periphyton % cover observations that exceeded the recommended MfE guidelines of either >60% thick mat (>3 mm thick) or >30% long filaments (>2 cm long) for protection of aesthetics and recreation (Biggs 2000). The Cyanobacteria *Phormidium* spp. was observed on at least 1 date at each site.

Distance from dam (river km)	Site name	# of Observations	# of times MfE guideline exceeded	> 30% long filamentous algae exceeded	% of Obs. where MfE guideline was exceed	*Phormidium* present
0.3	Dam	26	7	6	27%	x
12.5	Skipton	29	3	3	10%	x
19.7	Chota	21	2	0	10%	x
24.8	Confluence	18	0	0	0%	x
34.7	Hanging Rock	21	0	0	0%	x
-	Raincliffs	23	0	0	0%	x

pre-dam annual average flood) did reduce nuisance periphyton cover below the Dam and at Skipton (Figures 3 and 4). Thick mats and long filaments were often only reduced to medium mats and short filaments as a consequence of these flushes, but were rarely removed entirely. Medium mats and short filaments quickly recovered during the post-flush interval, particularly during warm water periods. The effectiveness of the flushing-flows attenuated rapidly downstream from Skipton as the flood wave was attenuated (Figure 1). These results are consistent with those reported in Arscott et al. (2007) and the periphyton biomass and chlorophyll *a* data presented in the next section.

3.3. Periphyton biomass and chlorophyll *a*

Biggs (2000) recommended periphyton biomass guidelines intended to protect three general instream values: benthic biodiversity, aesthetics and recreation and trout habitat and angling (Table 14 in Biggs 2000). These guidelines have been adopted by MfE as trigger values for implementing management techniques intended to minimise nuisance periphyton cover in rivers. These guidelines are used here as reference levels for biomass data and to indicate nuisance periphyton proliferation in the Opuha River.

Since the December 2005 flushing-flow, quantitative periphyton samples (for both ash free dry mass AFDM and chlorophyll *a*) have been collected during pre- and post-flush surveys (refer to Arscott et al. (2007) for collection and analysis methods). Periphyton AFDM and chlorophyll *a* concentration during pre- and post-flush surveys

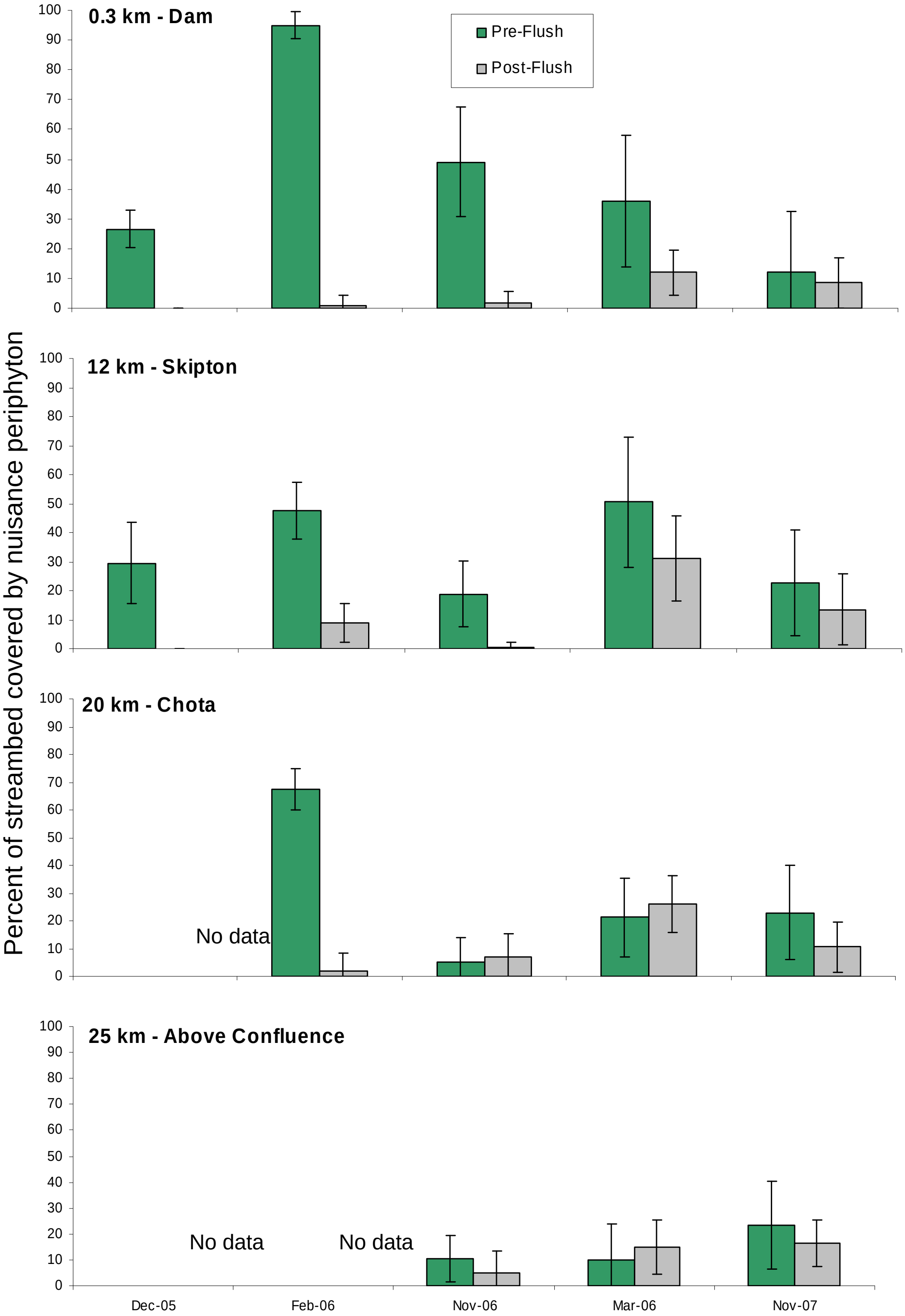

Figure 3: Percent of stream bed covered by nuisance periphyton (thick mats and long filaments combined) at each of 4 sites on the Opuha River during 5 pre- and post-flush surveys.

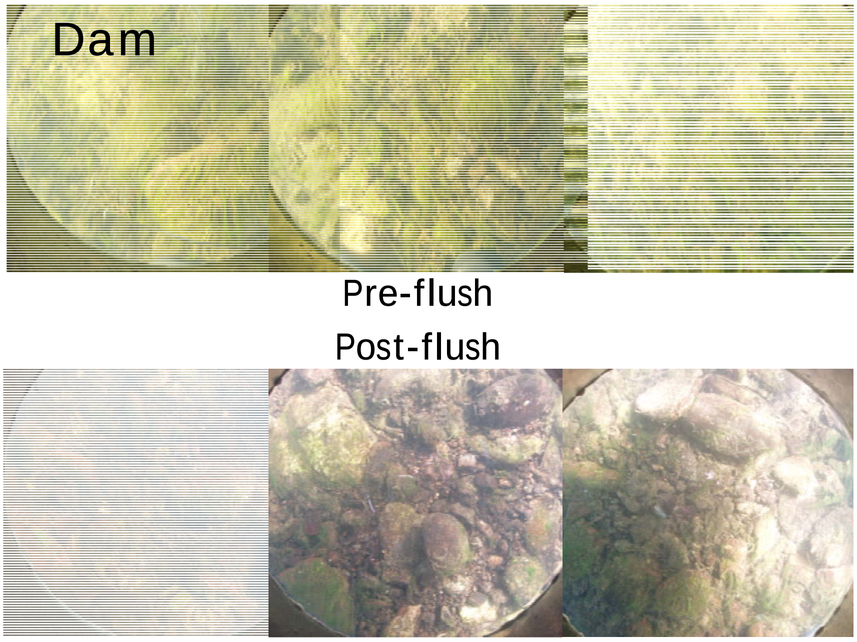

Figure 4: Photographs of the stream bed at the dam site before and after the November 2006 flushing flow.

are shown in Figure 5. These results indicate significant reduction of periphyton biomass just below the dam and decreasing effectiveness of flushing-flows with distance downstream. It is also clear that sites or dates with lower pre-flush biomass have a lower proportion of material removed from the stream bed during flushing. For example, all pre-flush samples with < 50 mg of chlorophyll *a*/m^2 had less than 30% of that material removed by flushing. Pre-flush samples with >60 mg chlorophyll *a*/m^2 typically had >50% of that material removed during these flushing-flows.

3.4. Bed sediment movement and armouring

Past observations of the Opuha riverbed indicated that the bed was heavily armoured. Armouring describes the state of a riverbed where the proportion of fine-to-coarse material on the surface is low compared to the proportion beneath the bed (Vericat et al. 2006). Armouring results in a tightly packed riverbed devoid of fine, sandy material that is essentially locked away in the subsurface. An armoured bed is resistant to deep flushing (overturning sediment to depths beyond 10 cm). Flushing flows that do not turn over or mobilise the river bed may exacerbate armouring by washing fines from the upper surface of the bed (i.e., fines are washed out of the surface bed without replenishment). Surficial fine material plays an important role in bed sediment mobilisation during flooding and is important for the physical scouring of periphyton. The presence of fine sediment on the bed surface increases the relative mobility of sediment and increases physical abrasion that removes periphyton.

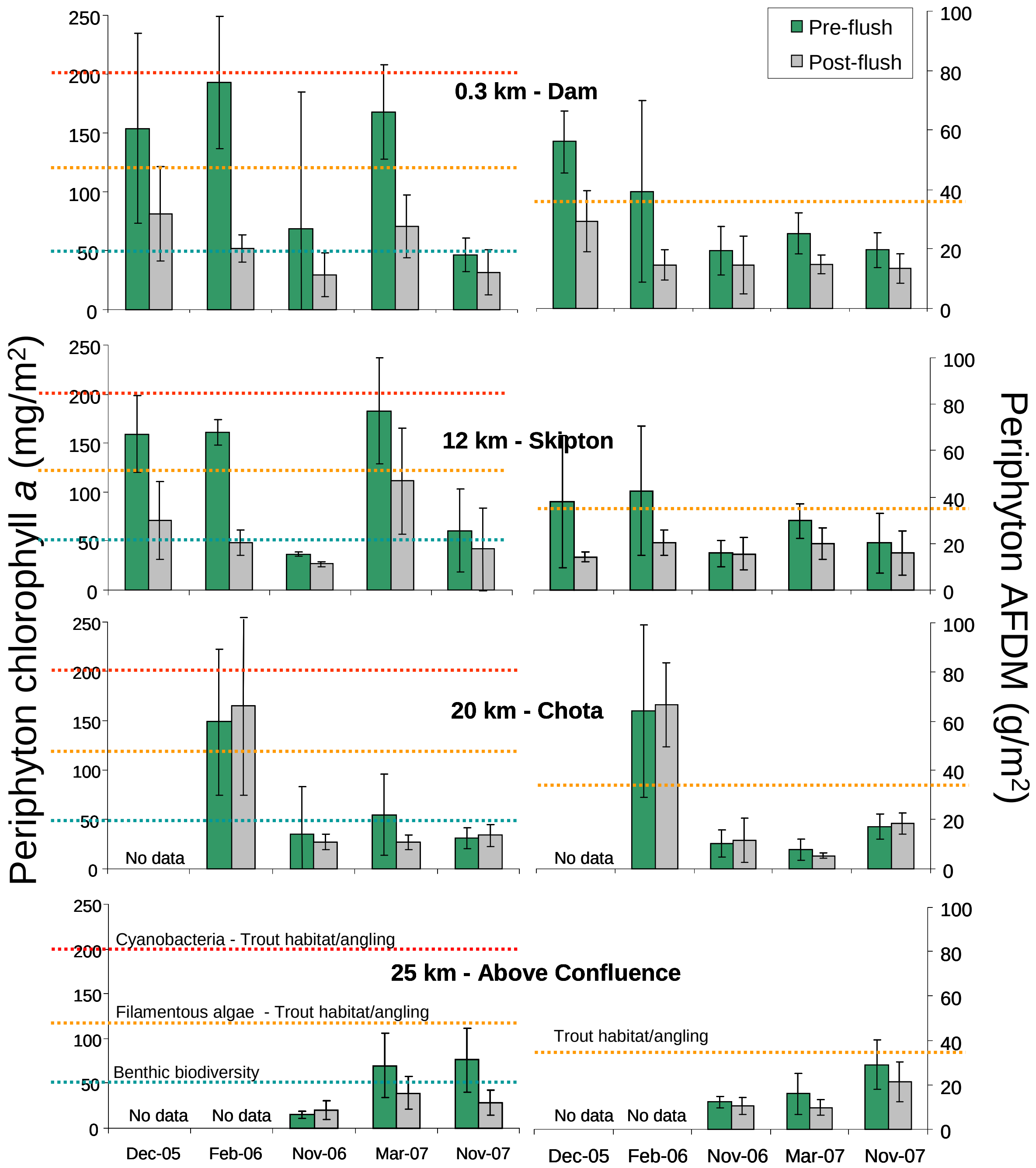

Figure 5: Periphyton chlorophyll *a* and ash free dry mass (AFDM) concentrations measured at 4 sites downstream from the Opuha Dam during pre- (green) and post-flush (grey) site visits. Error bars are ± 1 standard deviation. Coloured lines indicate MfE recommended guidelines for maintaining instream values of benthic biodiversity (no guideline for AFDM) or trout habitat and angling.

In November 2007, we contracted Environment Canterbury to rip up a portion of riverbed below the Skipton Bridge (Figure 6). The bed-ripping work was conducted about 14 days prior to the November 2007 flush and covered about 300m^2 of riverbed. The goal of the work was to release fine material stored beneath the armour layer, determine the mobility of this material (fine and coarse fractions) over the river bed during a flush and determine if the additional fine sediment travelling over the immediate downstream riffle increased periphyton removal during the flush. A preliminary (and tentative) analysis of periphyton biomass before and after flushing (data not shown) indicated that there was no significant difference in periphyton removal below compared to above the "ripped" section.

Figure 6: A photograph of an Environment Canterbury digger fitted with a ripping tine used to loosen the armoured bed of the Opuha River (300 m below Skipton Bridge). NIWA technicians are downstream sampling the sediment plume released from the bed during ripping. Photo taken on 5 November 2007 by D. Arscott.

Data from the bed-ripping experiment were used to calibrate a sediment routing model. We added 1900 painted rocks (ranging from 22-64 mm size classes) to the river bed at the "ripped" section (Figure 7). We recaptured those painted rocks after the flush (lower panel in Figure 7), measured the distance each stone moved (and its grain size) and used this information to calibrate a multi-fraction 1-dimensional sediment routing model. The routing model also incorporated numerous velocity profiles (upper panel in Figure 7) measured during the flush. Velocity profiles quantify hydrodynamic conditions near the bed that are important in predicting bedload transport. During the November 2007 flush, painted stones moved a maximum of 6 m (Figure 8). Nevertheless, the size-specific movement of the 1200 stones provided valuable information for calibration of the model. Eventually, Crossectional view of: velocity contours at tracers (flow = 29.1 m³/s)

Plan view of: gravel tracers along transect after flush

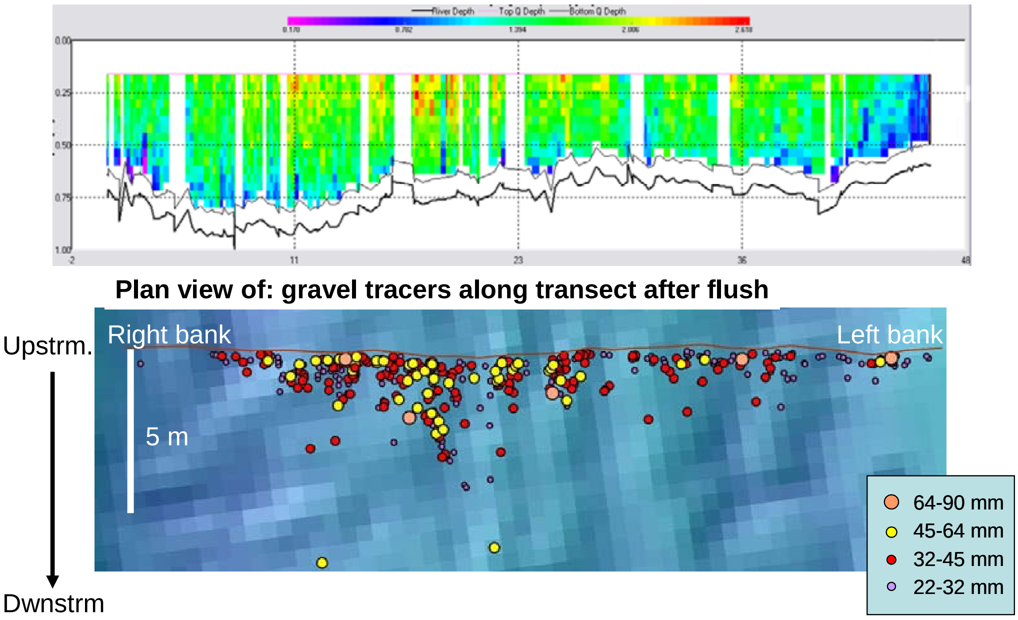

Figure 7: Upper panel: Opuha River channel cross-section showing water velocity profiles during a flush on 21 November 2007 (discharge = 29.1 m^3/s). The channel cross-section was ~300 m below Skipton Bridge. Maximum depth of the channel was ~75 cm and red coloured cells indicate water velocity approaching 2.6 m/s. Lower panel: plan view of the same channel cross-section where ~1200 painted stones of various size were aligned along a transect prior to the flush. Each coloured circle represents a painted stone and its location relative to the original transect (red line) indicates its distance moved by the flushing-flow.

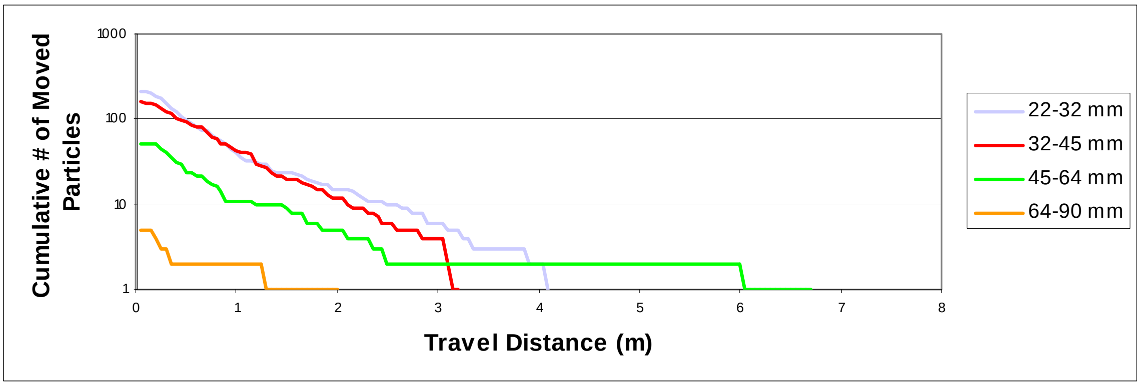

Figure 8: Cumulative number of painted stones moved during the November 2007 flushing flow. Stones of different calibre were painted different colours, deployed on the riverbed at Skipton and then recaptured (noting distance moved) after the flush. Three hundred and seventy-five stones were 22-32 mm, 375 were 32-45 mm, 350 were 45-64 mm, and 100 stones were 64-90 mm.

this model will produce estimates of the flows required to move bed sediment and further disrupt the armour layer. This hydrodynamic model will enhance our ability to prescribe flushes for periphyton management since the factors responsible for periphyton scour include near-bed shear (or drag), sediment mobility, and sediment grain size distributions.

4. Summary

Since the previous report (Arscott et al. 2007), three flushing-flows have been monitored by NIWA to assess the effectiveness of small-to-medium magnitude flushes in removing periphyton in the Opuha River. All three flushes were of greater magnitude (32, 33, and 42 m^3/s) than previous flushes ($\leq$ 22 m^3/s). All flushes monitored since 2005 have had roughly similar effects. Periphyton was significantly reduced below the dam (e.g., ~50% reduction in chlorophyll *a* concentrations) but effectiveness rapidly decreased downstream. Decreasing effectiveness of periphyton removal was related to the decrease in peak flow as the flood wave spread out in time and space during transport downstream. Total suspended material transported with the flood wave also decreased with distance downstream. Further, bed sediment (aside from the limited quantity of fine sand) was not mobilised by any of the flushes and the armoured condition of the riverbed suggests that flows exceeding 100 m^3/s (approximately the pre-dam average annual flood) are required to re-work bed sediments. Mobilising riverbed sediment is the most effective mechanism of periphyton removal.

Didymosephenia geminata has recently invaded the Opuha River and now covers most of the riverbed from just below the dam to the confluence with the Opihi River. This prolific algae is predicted to increase in extent and thickness (currently < 1.5 cm) in the Opuha River. Didymo is expected to alter river ecosystems in several ways. Larned et al. (2007) document changes to invertebrate community structure and chemical dynamics in the Oreti and Waiou Rivers in Southland. They documented the potential for increased diurnal variations in dissolved oxygen and pH as a result of proliferation of Didymo. Extreme diurnal variations in DO and pH have been shown to cause fish avoidance of effected reaches (Serafy and Harrell 1993) and/or death (Quinn and Gilliland 1989, Wagner et al. 1997). However, there is currently no evidence of lethal effects in Didymo-affected rivers in NZ. Questions still remain as to the effect that extensive Didymo cover may have on native and non-native fish.

A pilot study of the effects of Didymo on water chemistry in the Opuha River was carried out in February 2008. Point measurements of pH and dissolved oxygen (DO) were taken at the Dam and Skipton during mid-day. Dissolved oxygen and pH at the Dam were 104% and 6.95, respectively and increased to 125% and 9.12, respectively at Skipton. Measurements occurred during very low water levels (~2 m^3/s). These preliminary measures suggested that increased Didymo biomass may have amplified diurnal variations in pH and DO, particularly during minimum flows. Further studies of diurnal changes in DO and pH in the Opuha are planned for March-April 2008.

Flushing-flows may continue to be an important tool for managing periphyton in the Opuha River. However, the presence of Didymo has changed the nature of the periphyton community. For example, prolific Didymo cover is likely to limit the distribution of *Phormidium* and other nuisance algal taxa (i.e., long filaments). Nevertheless, Didymo replaces these other taxa as a “nuisance” periphyton type. Didymo is also likely to effect the resistance of the riverbed to deep scour and may further stabilise the already heavily armour bed.

NIWA will continue to monitor flushing-flows on the Opuha River through the 2007-08 fiscal year. We hope to conduct an additional experiment in order to better calibrate our sediment routing model. Specifically, we anticipate adding 5-10 m^3 of small pea-gravel to the bed at Skipton just prior to the next flush. This material will be sourced from a local quarry and will be traceable on the river bed. Before-and-after flush surveys will provide valuable information about the mobility of small-to-fine gravel size fractions. Further, before-and-after measurements of periphyton downstream from this addition will allow us to evaluate the usefulness of small-scale sediment additions to improve periphyton removal during flushes.

5. Acknowledgements

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