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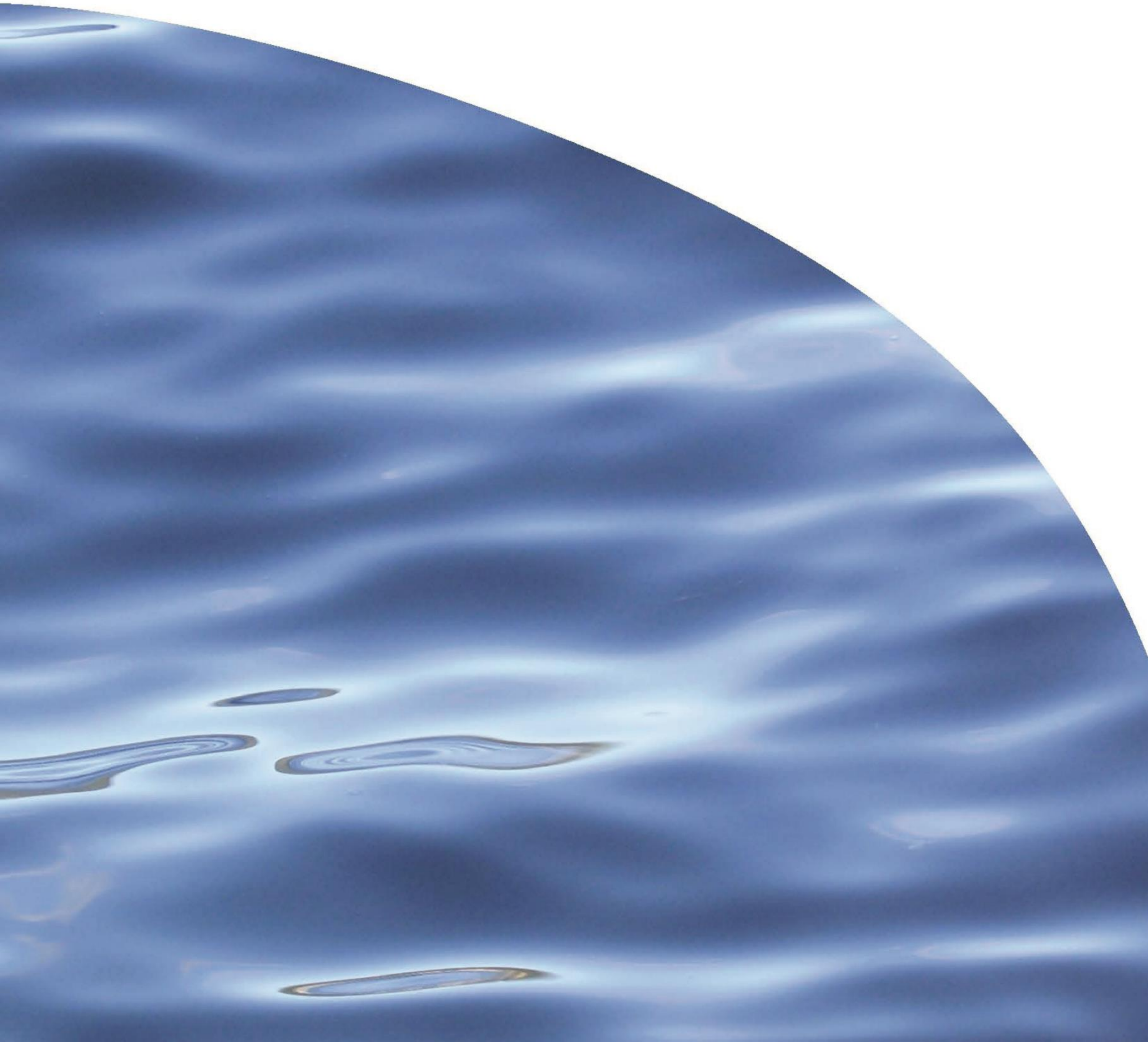

POTENTIAL CUMULATIVE EFFECTS OF INFILTRATION GALLERY INSTALLATION AND MAINTENANCE ON INSTREAM LIFE IN THE AWATERE RIVER

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Prepared for Marlborough District Council

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1. INTRODUCTION

This report was commissioned by Marlborough District Council (MDC) to consider potential effects of instream works associated with infiltration gallery water takes in the Awatere River, including the possibility of cumulative effects arising from maintenance of multiple gallery intakes from the river.

The Awatere River has a naturally elevated turbidity[1] for much of the year due to fine suspended sediments, mainly derived from the highly erodible underlying geology of the mid-catchment (Peter Hamill, MDC, pers. comm.). However, it is generally clearer during summer low flow periods (Figure 1).

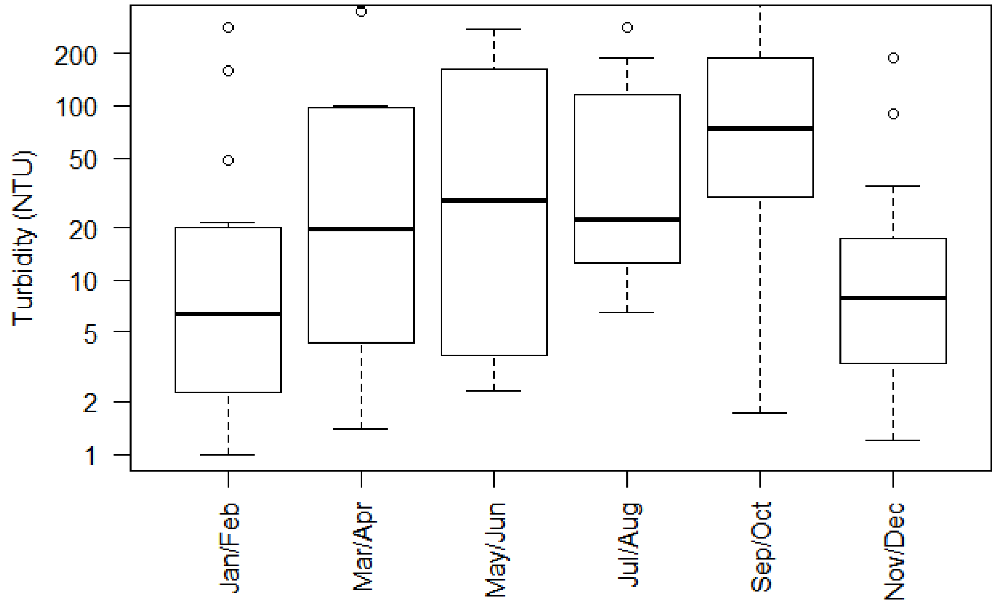


Figure 1. Box plots of monthly measurements of turbidity at the Awatere River mouth monitoring site between February 2007 and May 2016 (data provided by MDC). The y-axis is a log scale and has been curtailed to allow better comparison between periods over the low to moderate turbidity range.

High suspended-sediment loads in the river cause problems for water abstractors. Fine sediment drawn into irrigation infrastructure can increase wear on pumps, block filters and irrigation drippers and so forth. Also, if turbid water is put into storage much of the fine sediment settles out, thereby reducing the capacity of the storage over time.

Infiltration gallery intakes are perceived to offer a potential solution to these problems associated with fine sediment. Infiltration galleries employ perforated intake pipes

[1] Turbidity is often measured in nephelometric turbidity units (NTU), and is correlated with visual clarity as well as with total suspended solids (TSS). Very small increases in turbidity in relatively clear water have a marked influence on water clarity, while at higher turbidity (> 20 NTU) there is less obvious change in water clarity with increasing turbidity.

buried in the substrate below or adjacent to river beds, like a horizontal well. Water infiltrates through the substrate from the river into the intake pipes. Some of the suspended sediment load is filtered out as the water passes through the gravels of the infiltration gallery, reducing the turbidity of the water abstracted.

Infiltration galleries have become popular among water abstractors in the Awatere River, to limit the amount of fine sediment being drawn into the irrigation infrastructure. There are approximately 65 consented infiltration gallery intakes[2] in the lower 40 km of the Awatere catchment (Figure 2), as well as 30 consents with permission to disturb the bed of the Awatere to facilitate the abstraction of water, some of which are also related to infiltration galleries (Peter Hamill, MDC, pers. comm.).

Construction and maintenance of infiltration galleries requires instream works with potential adverse ecological effects. The construction phase involves large scale instream works, including diversion of the river flow. However, infiltration galleries also require periodic maintenance work to retain efficient water abstraction, particularly in systems with high sediment loads (Scales 2014). Unfortunately, the fine sediments filtered by the gravels of the infiltration gallery ultimately build up and begin to clog interstitial spaces in the substrate. This reduces the permeability of the substrate and compromises the efficiency of the abstraction.

[2] In consents for infiltration galleries prior to about 2011 the galleries were usually called infiltration trenches or simply trenches (Peter Hamill, MDC, pers. comm.). The total of 65 infiltration galleries cited here included those referred to by these earlier names.

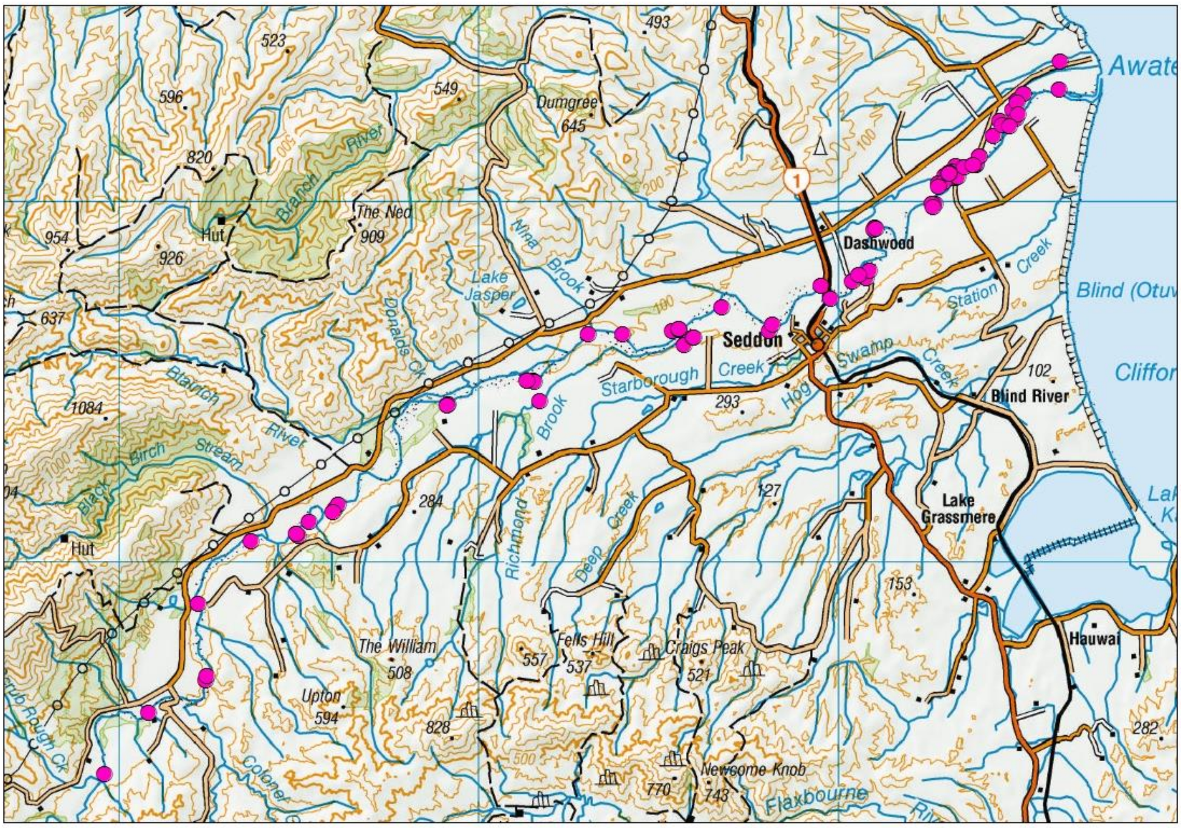


Figure 2. Overview map illustrating the approximate locations of the 65 infiltration galleries in the Awatere River catchment; source: Marlborough District Council.

Common practice in the Awatere River when the galleries become less efficient is to ‘rip’ the bed of the river in order to allow more water into the gallery (Scales 2014). An excavator or bulldozer is used to rip the river bed, to disturb the top layer of substrate to about 0.75 m deep (Burrell 2015). This destroys impermeable sediment layers that have formed due to fine sediments entering the gravels, and allows the water to flow into the underlying gravels and into the gallery once again. This maintenance is usually carried out during summer when irrigation demand is highest, but when river flows are low and generally relatively clear.

In addition, instream works are often undertaken during summer low flow periods in the Awatere to divert river flows over the infiltration galleries, in an attempt to maintain abstraction rates. Maintenance work (e.g. ripping and diversion channels) usually occurs in spring before the commencement of the irrigation season and during low flows in mid-summer, when water demands are high, whereas construction of galleries is generally done in spring, just before the irrigation season starts.

Concerns have been raised over the potential adverse ecological effects of instream works associated with the construction and maintenance of infiltration galleries in the Awatere River. In particular, the potential for cumulative effects resulting from maintenance of multiple galleries in the Awatere River has given rise to concerns. This report was commissioned to consider these potential effects.

2. POTENTIAL ADVERSE EFFECT OF INSTREAM WORK

Instream works involving disturbance of the substrate, such as excavation or ripping, are associated with a range of potential adverse ecological effects. These include:

- habitat disturbance
- fish kills through dewatering or mechanical damage
- sediment release / sedimentation
- interruption of spawning and fish passage
- contaminant leaks or spills, e.g. oil.

2.1. Habitat disturbance

2.1.1. Mechanical disturbance

Instream works cause localised disturbance of habitat, as well as mechanical damage to invertebrates and fish in the area, with some mortality highly likely (Figure 3). While habitat disturbance leading to mortality occurs naturally in river ecosystems during floods, these are preceded by cues, such as rising water levels and velocities, allowing fish and invertebrates to move to refuge habitat (potentially within the substrate or river margins). Instream work associated with maintenance of infiltration galleries is not preceded by similar cues that allow biota to attempt to move to safety. Hence, mortality rates are likely to be higher. Mortality and habitat disturbance associated with a single episode of instream works is likely to cause only a minor local impact on fish and invertebrate populations in the broader catchment. However, if these events occur frequently at a large number of sites they may have a more substantial cumulative impact, and this would exacerbate the impact of naturally occurring disturbance events, such as floods.

Figure 3. A longfin eel severed by an excavator driving through a waterway (photo from Peter Hamill, MDC).

2.1.2. Flow diversion

Flow diversion is often undertaken during summer in the Awatere to direct water toward intakes. Flow diversion can also be used to help reduce sediment release from excavation work, by dewatering working areas. Flow diversion also has the potential to cause local scale disturbance and mortality through stranding and desiccation, and similarly to bed disturbance from instream works, is likely to occur much more rapidly than natural drying events and without cues forewarning resident biota to move out. Again, while individual flow diversions are likely to have relatively minor biological impacts, there is potential for more serious effects to arise if multiple events are considered together.

Recolonisation following mechanical disturbance or drying events may take in the order of days to weeks, depending on the source of colonists. For example, invertebrates may take as little as 15–30 days to fully colonise previously dry channels or margins (Sagar 1983). However, recolonisation also depends on habitat recovery. Restoration of habitat conditions may require freshes or floods of sufficient size to move the substrate, which may take some time to eventuate, especially during the summer months.

2.1.3. Turbidity

Fine sediment disturbed by excavation increases turbidity, reducing light penetration and visual clarity. Elevated turbidity has potential adverse ecological effects, particularly if it is sustained over a long period. It can reduce photosynthesis and growth of aquatic plants and algae, as well as the visual range of animals, such as visually foraging fish. Elevated turbidity can also cause behavioural responses in aquatic organisms, such as avoidance or reduced feeding (Clapcott et al. 2011). For example, upstream migration of banded kōkopu (*Galaxias fasciatus*) has been shown to be reduced when turbidity exceeded 25 NTU (Richardson et al. 2001), resulting in recruitment limitation, and in laboratory trials at turbidity levels of 17 and 70 NTU, elicited a 50% avoidance response in banded kōkopu and kōaro, respectively (Boubée et al. 1997). However, some other species showed no avoidance response, even to substantially higher turbidity levels. Feeding activity and foraging success of both benthic and drift-feeding fish can be reduced by elevated turbidity (Cavanagh et al. 2014), both by limiting their ability to detect prey and by reducing the availability of food. Reduced feeding efficiency of visual-feeding fish and greater energetic costs have been linked to lower growth rates, even when prey are abundant in turbid waters (Cavanagh et al. 2014). Suspended sediment can also damage fish gills and render them more susceptible to disease. Particularly high turbidity can even result in mortality (Rowe et al. 2009), though most New Zealand species tested are able to survive even repeated exposure to relatively high turbidity levels. Consequently, in the Awatere elevated turbidity is more likely to result in adverse effects on fish through impacts on behaviour and foraging success, rather than through direct mortality.

2.1.4. Deposited sediment

In addition to increasing turbidity, if sediment is released during low flows when the river does not have sufficient power to transport the additional fine sediment load, much of the sediment is likely to settle out on the river bed downstream. Deposited fine sediment is likely to persist until the next flow event (with sufficient stream power to flush it on downstream) takes place. Such deposited fine sediment may have more persistent adverse ecological effects than the original, relatively short term, increases in turbidity. Increases in deposited fine sediment has been shown to have detrimental effects on invertebrates (Clapcott et al. 2011), by clogging interstitial spaces and thereby changing habitat and availability of refugia, as well as by directly clogging the feeding apparatus of some invertebrates (Ryan 1991). Deposited sediment generally shifts the invertebrate community composition toward burrowing taxa such as worms and chironomids, which tend to be less accessible and energetically rewarding as food for fish (Cavanagh et al. 2014). Clogging of substrate interstices also alters habitat for fish, particularly many of New Zealand's native fish, which are benthic and spend much of their time within the substrate. In a recent report, Smith (2015) presented qualitative assessments of the expected susceptibility to turbidity and sediment impacts for various New Zealand fish species. He suggested that while torrentfish and bluegill bullies may have low susceptibility to effects from turbidity, their foraging success and preferred food species are both potentially highly susceptible to impacts of sedimentation.

As mentioned earlier, in the Awatere River the majority of instream maintenance work (i.e. streambed ripping and flow diversion) tends to occur during summertime low flow periods (Peter Hamill, MDC, pers. comm.), presumably because this is when reduced permeability of infiltration gallery gravels becomes apparent. During the summer low flow period the turbidity levels in the Awatere are generally reasonably low compared with the rest of the year. Thus, this instream work alters the seasonal sediment/turbidity regime of the river. Stream power to transport sediment is also relatively low during these low flow periods, so sediment is likely to settle out and be deposited on the stream bed. It is common for relatively low stable flows to persist for up to a month during summer[3]. Consequently, deposited sediment may accumulate and remain in place for extended periods. On this basis, surface sediment deposits from re-suspended sediment settling out downstream of instream maintenance works may have more lasting impacts than transient pulses of turbidity.

2.1.5. Disruption of spawning

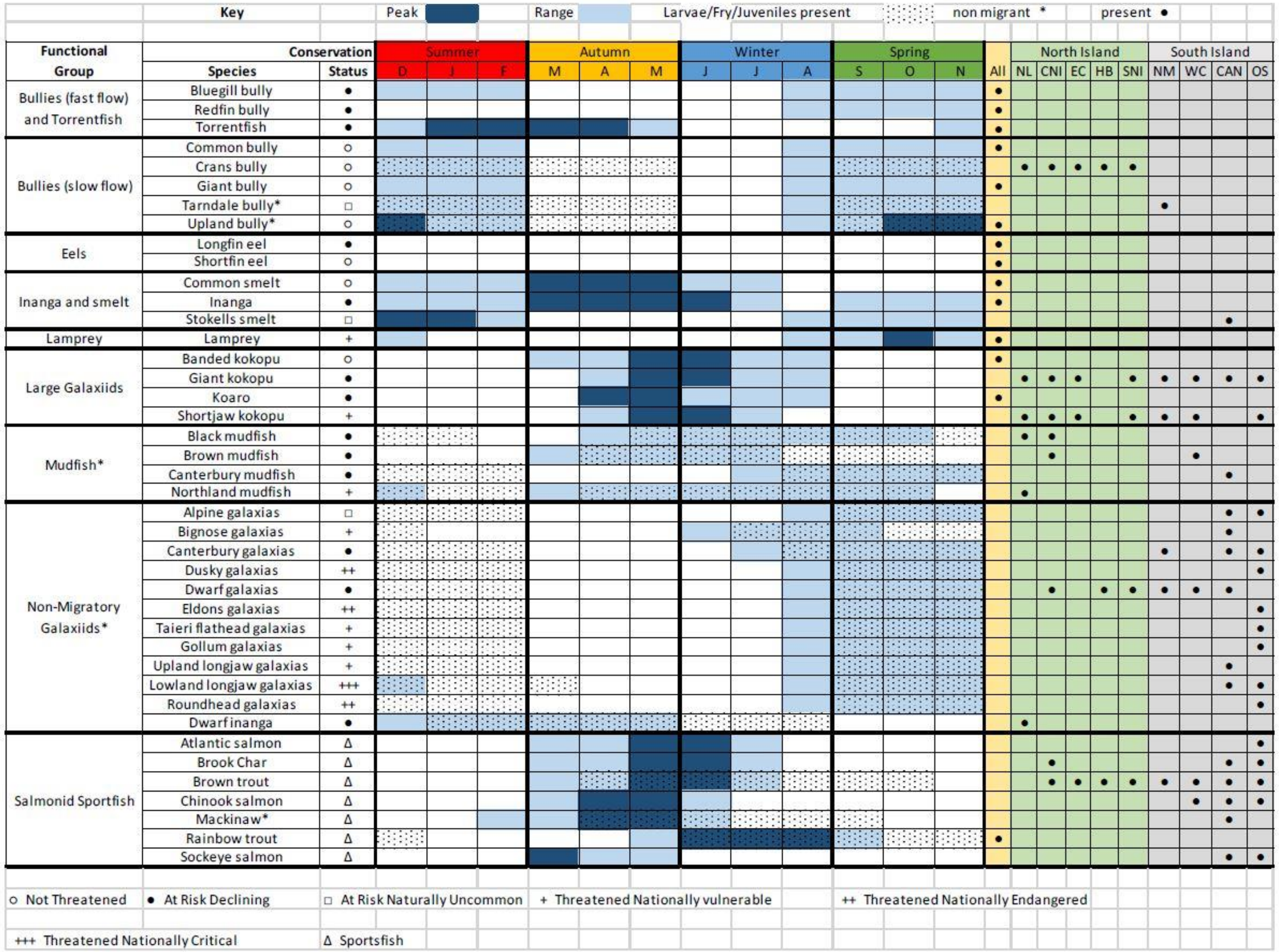
It is likely that fish populations in the Awatere will be more sensitive to sedimentation and turbidity impacts during summer than at other times of year. This is because warmer water temperatures during summer increase metabolic demands, so any reductions in food availability or detectability are more likely to have negative consequences than at other times of year. Also, fishes (such as torrentfish and several bully species) spawn during summer and the spawning and egg incubation life phases may be particularly sensitive to sediment impacts. As discussed above, during summer in the Awatere there are often periods in the order of a month between fresh events, during which time the water is quite clear. These are likely to be productive periods for resident fish, as they can take advantage of favourable conditions for feeding and spawning. Multiple episodes of infiltration gallery maintenance work during summer may well reduce the duration and productivity of these periods of relatively clear water, with the magnitude of effects depending on the frequency and extent of work (as discussed further in Section 2.3). The potential for more significant cumulative adverse effects to arise from work on multiple infiltration galleries, particularly for spawning, was acknowledged by Burrell (2015) in an assessment of environmental effects supporting a consent application to undertake ripping and flow diversion to maintain an infiltration gallery in the Awatere. However, he concluded that there is considerable uncertainty over the scale and significance of cumulative effects due to a lack of monitoring data and because it is unknown whether some species may be more sensitive during spawning. A more precautionary approach would be to limit the extent and frequency of instream works until more information can be gathered.

Spawning and migration calendars have recently been developed for New Zealand fish species (Smith 2015) to help guide the timing of instream works and reduce potential sediment impacts arising from forestry (Figure 4). These calendars are relevant to the instream works and potential sediment impacts associated with infiltration galleries. For comparison with the spawning calendars shown in Figure 4, Table 1 shows the fish species recorded from the Awatere catchment in the New Zealand Freshwater Fisheries Database[4]. Several of the species recorded from the

[3] Based on a visual appraisal of hydrographs from the MDC website.
[4] Accessed 15 June 2016.

Awatere catchment, including torrentfish, bluegill bully, longfin eel, and koaro are listed as 'At Risk, Declining' in the latest threat classification listings (Goodman et al. 2014). We understand that the Awatere is a stronghold for torrentfish and bluegill bullies in Marlborough and supports among the highest densities of torrentfish of all the South Island East Coast rivers (Peter Hamill, MDC, pers. comm.). Given the range of spawning and migration times for various fish species, it is difficult to time instream work to avoid impacts on all species. However, the summer, when most infiltration gallery maintenance work occurs in the Awatere, coincides with spawning and juvenile rearing periods for several species found in the river, including torrentfish, bluegill and upland bullies, as well as the peak in upstream migration from the sea for eel elvers (Figure 5). The qualitative assessments of the expected susceptibility to turbidity and sediment impacts presented by Smith (2015) suggested that torrentfish and bluegill bullies spawning may have a medium susceptibility to impacts of sedimentation, whereas upland bully spawning was thought to be highly susceptible to sedimentation impacts. However, these rankings were largely based on expert opinion since little appears to be known about the spawning sensitivity of these species.

It appears that the northern flathead galaxiid is found mainly in tributaries, rather than the mainstem of the Awatere. However, wherever abstractions influence these tributaries the potential impacts would warrant particularly high scrutiny, given its 'Nationally Vulnerable' threat ranking.



Key:
NM = Nelson Marlborough. NL = Northland, CNI = Central North Island, EC = East Cape, HB = Hawkes Bay, SNI = Southern North Island, ,WC = West Coast, CAN = Canterbury, OS = Otago Southland

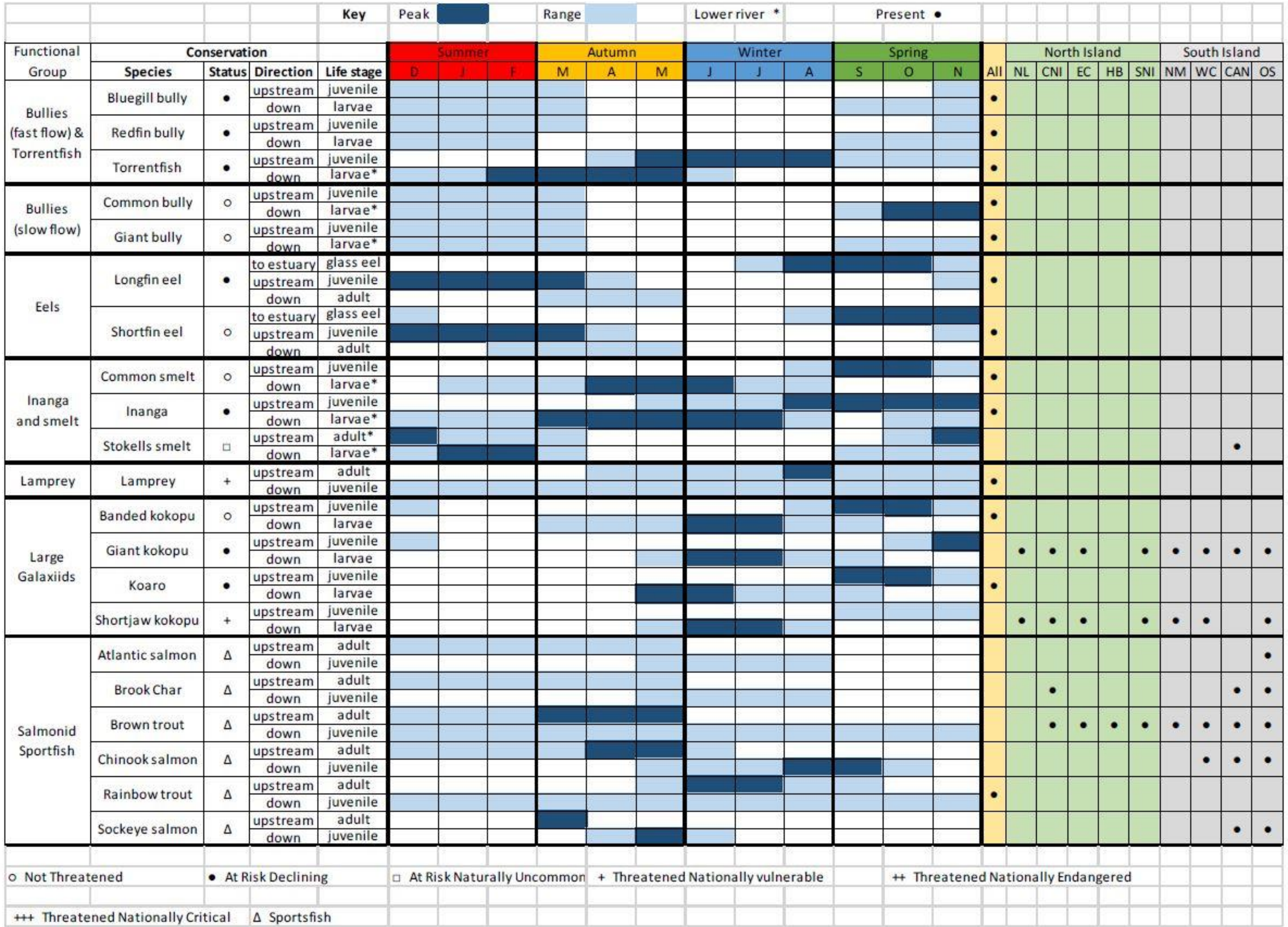
Figure 4. New Zealand freshwater fish spawning calendar from Smith (2015). Showing spawning range, peak and expected occurrence of juvenile fish for nine regions of New Zealand.

Table 1. Fish species recorded in the New Zealand Freshwater Fish Database from the Awatere catchment between 1947 and 2016 and their national threat classification from Goodman et al. (2014).

Common Name	**Scientific name**	**Number of records**	**Threat classification**
Upland bully	*Gobiomorphus breviceps*	27	Not Threatened
Northern flathead galaxias	*Galaxias sp. N*	22	Threatened Nationally Vulnerable
Longfin eel	*Anguilla dieffenbachii*	24	At Risk, Declining
Torrentfish	*Cheimarrichthys fosteri*	22	At Risk, Declining
Chinook salmon	*Oncorhynchus tshawytscha*	1	Introduced and Naturalised
Common bully	*Gobiomorphus cotidianus*	9	Not Threatened
Brown trout	*Salmo trutta*	13	Introduced and Naturalised
Shortfin eel	*Anguilla australis*	10	Not Threatened
Bluegill bully	*Gobiomorphus hubbsi*	2	At Risk, Declining
Inanga	*Galaxias maculatus*	2	At Risk, Declining
Giant bully	*Gobiomorphus gobioides*	1	Not Threatened
Koaro	*Galaxias brevipinnis*	14	At Risk, Declining
Dwarf galaxias	*Galaxias divergens*	3	At Risk, Declining
Black flounder	*Rhombosolea retiaria*	1	Not Threatened

2.1.6. Fish migration

Instream works have the potential to interfere with migration. For example, elevated turbidity may stimulate behavioural avoidance responses, as discussed above for banded kokopu. Also, dewatering and flow diversion may divert or delay migrants. In the assessment of effects for infiltration gallery maintenance discussed above, Burrell (2015) suggested timing work in January and February to reduce effects on peak native fish migration periods in spring and autumn. However, summer is actually the peak migration period for several key species found in the Awatere, including longfin and shortfin eel elvers, several species of bully and torrentfish (Figure 5).



Key:
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Figure 5. New Zealand freshwater fish migration calendar from Smith (2015). Showing migration timing, range and peak, migration direction, and fish life stages involved for nine regions of New Zealand. NM = Nelson Marlborough.

2.1.7. Leaks or spills

Contaminants, such as oil, are another risk of instream work involving machinery (Scales 2014). However, this risk can be minimised by consent conditions requiring storage and refuelling etc. to be keeping outside of the river bed.

The impacts of individual episodes of instream work associated with infiltration galleries are likely to be relatively localised and transient (Burrell 2015). The impacts are mainly likely to be restricted to within a few kilometres of the instream work and may last in the order of a few hours to days or maybe weeks (e.g. for recolonisation of invertebrates and periphyton, or flushing of deposited sediment) following cessation of the work. However, given the relatively high number of infiltration galleries in the lower Awatere catchment it is likely that impacts from multiple sites may overlap in space and time, with the combined effects potentially of greater significance than those arising from each individual site alone. While we acknowledge that there is considerable uncertainty around the scale and significance of potential cumulative effects, we consider there is potential that impacts from infiltration gallery maintenance may compound to produce significant adverse impacts.

Although the works involved in the construction phase probably have greater individual impacts due to the scale of work involved, the ongoing nature of maintenance work and the fact that it is largely concentrated during summer low flow periods together make the potential cumulative adverse effects more likely. We understand that construction of infiltration galleries is mainly carried out during spring (Peter Hamill, MDC, pers. comm.). Springtime construction is likely to have less lasting impacts, due to more frequent flushing flows at that time of year, compared with during summer, when most maintenance work is concentrated. In addition, construction works are more likely to be dewatered so sediment discharges should be better controlled than maintenance work. However, planned dewatering ought to require fish salvage to reduce the potential for stranding.

2.2. Observations of turbidity effects of maintenance work

To elucidate the potential effects of sediment release from maintenance of infiltration galleries, observations were made of turbidity in the Awatere River in January 2016 during instream works. Flow at the time was relatively low (close to the mean annual low flow), the most recent fresh event had occurred approximately ten days earlier (Figure 6). Note the flow recorder site is in the order of 55 km upstream of the study reach, so the slight increase in flow evident on the hydrograph during the monitoring period is unlikely to have reached the study reach during the period of observations.

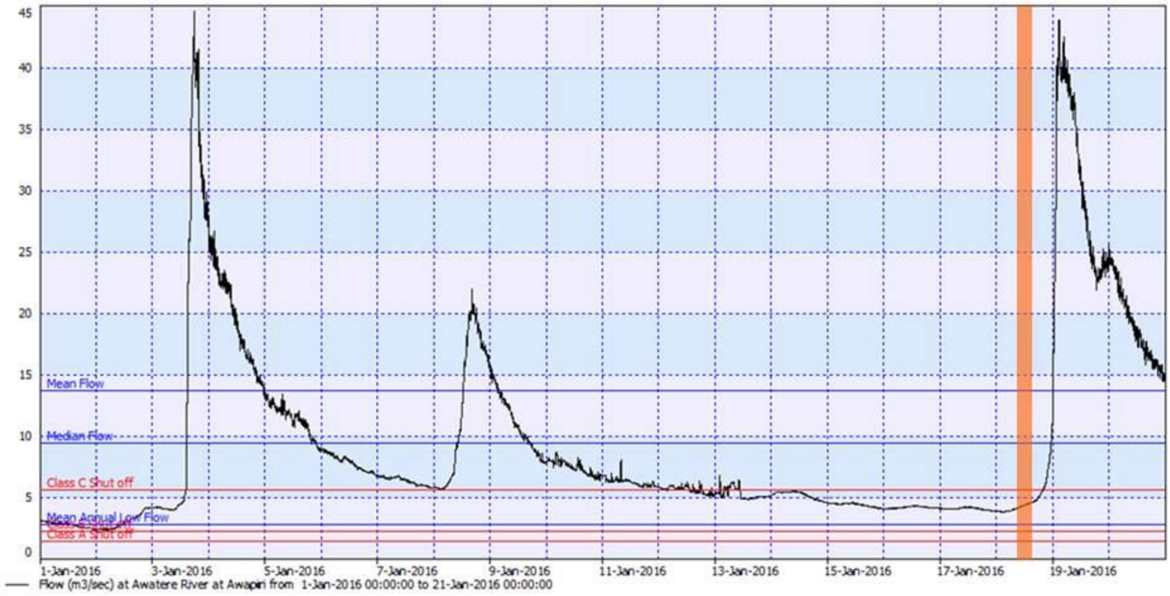

Figure 6. Hydrograph showing flow in m³/s in the Awatere River at the Awapiri recorder site during January 2016 (graph from MDC website http://hydro.marlborough.govt.nz/environmental accessed 21 June 2016). Approximate turbidity monitoring period (7 hours) indicated by the orange highlighted column.

Maintenance of two infiltration galleries in the lower catchment was undertaken during the monitoring period. Both of these involved using an excavator to rip the beds of diversion channels adjacent to the Awatere River (Figure 7).

Figure 7. Maintenance works on an infiltration gallery, using an excavator to rip the bed, in a diversion channel adjacent to the lower Awatere River on 18 January 2016. A sediment plume can be seen entering the mainstem of the Awatere River in the foreground.

Turbidity was measured manually in the vicinity of the instream works using a Hach 2100 turbidity meter, and an automated SeaPoint turbidity meter, (which logged turbidity every 15 minutes throughout the day), was deployed approximately 1.8 km and 3.2 km downstream of the sites of instream works (Figure 8).

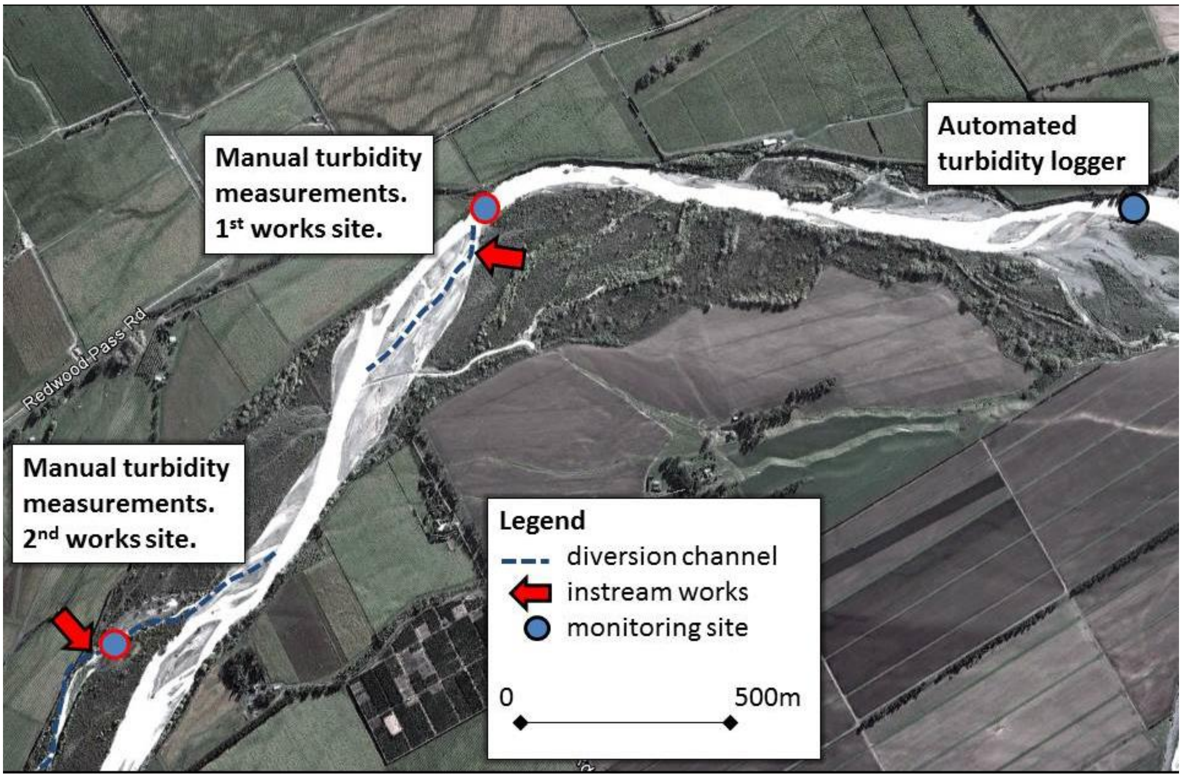

Figure 8. Layout of turbidity monitoring in the lower Awatere River associated with instream works for infiltration gallery maintenance on 18 January 2016. The lower end of the reach depicted is located approximately 700 m upstream of the river mouth. Water flows from lower left to upper right.

Prior to the maintenance work, under relatively clear water base flow conditions, manual measurements of turbidity established that the background conditions in the river were < 5 NTU on the morning of 18 January (mean = 4.32 NTU, StdDev = 0.42; N = 6); Black disk water clarity = 1.19 m.

The instream works at the most downstream site commenced at approximately 08:30 h and lasted for approximately one hour, during which time the turbidity in the Awatere mainstem more than 100 m downstream of the instream works (~50 m downstream of the confluence of the diversion channel with the mainstem), ranged from 880 to over 1000 NTU. A marked increase in turbidity was also detected by the turbidity logger located approximately 1.8 km downstream (Figure 9). Turbidity increased rapidly approximately 1 hour after the work commenced upstream to a peak at approximately 66 NTU at the logger site, in the order of 13 times ambient background levels recorded that morning.

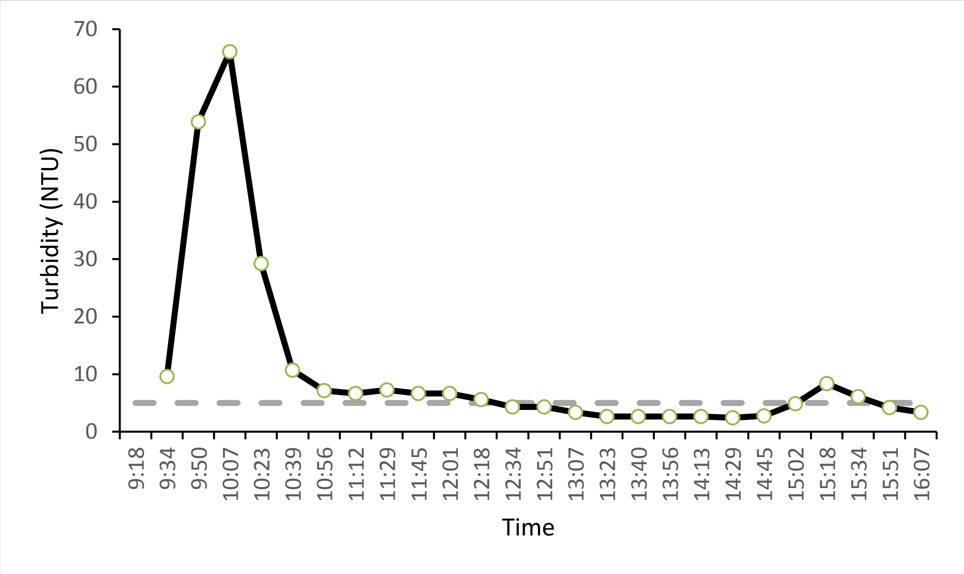

Figure 9. Turbidity (NTU) recorded in the lower Awatere River downstream of instream maintenance works (bed ripping) of infiltration galleries on 18 January 2016. The recorder was 1.8 km downstream of Works Site One and 3.2 km below Works Site Two. The horizontal grey line indicates approximate ambient background turbidity levels of < 5 NTU recorded in the river that morning.

No similar increase in turbidity was recorded at the logger site in association with the maintenance at the second works site, which commenced at approximately 10:30 am. Given the travel time for the turbidity spike recorded from the first maintenance event, a turbidity signal from the second maintenance event would have been expected at the logger about 1.5 to 2 hours following commencement of work (i.e. about 12 noon). Turbidity at the logger site actually declined around this time. However, it is possible flow at the logger site may have been influenced by the tide (high tide on 18 January was at approximately 12:57 pm[5]), perhaps backing up flow to some extent and delaying or diluting any turbidity signal from the second works.

The existing Wairau Awatere Resource Management Plan (WARMP) stipulates that 'The natural clarity shall not be conspicuously changed due to sediment or sediment laden discharge originating from the site of a land disturbance operation' for water managed for fishery purposes (i.e. the underlying/default class). It also stipulates no more than a 33% reduction in visual clarity and no more than a 15% increase in turbidity (measured in NTU). By contrast, turbidity about 100 m downstream of these instream works was more than 176 times the background levels at the time. At the

[5] Source: https://www.niwa.co.nz/node/26820/results accessed 22 June 2016.

logger site 1.8 km downstream turbidity peaked approximately 13 times background levels and remained elevated by more than 15% over background levels until about 12 noon (i.e. 3.5 hours after the work had finished).

The WARMP is in the process of plan review. A new plan has been notified, which includes standards for water managed for fish spawning, including the lower Awatere, stating that turbidity must be no greater than 5.6 NTU. Furthermore, ‘The natural clarity must not be conspicuously changed due to sediment or sediment laden discharge originating from the site of a land disturbance operation.’ Measurements are to be made immediately upstream of the discharge and below the discharge after reasonable mixing. The maintenance works observed in this study clearly beached the standards in the existing WARMP and the newly notified plan.

The observed turbidity levels were not in the range likely to be lethal for a short term exposure (including repeated exposures over time), even for relatively sensitive fish and invertebrate species (Rowe et al. 2002). However, it is not lethal effects that appear to drive variation in fish communities relative to turbidity and sediment load (Rowe et al. 2009). Instead, reduced abundance of some species in turbid systems appears to result from behavioural responses, reduced feeding success and reduced habitat quality. The observed turbidity levels were in the range where reductions in feeding rates would be expected (Rowe and Dean 1998), but only for a short duration. As discussed above, feeding success and food availability may also be reduced by deposited sediment, especially if there were multiple such gallery maintenance events, during what would normally be the period of relatively clear water in the Awatere over summer. The attenuation in turbidity between the site of instream work and the logger site would be partially attributable to deposition of sediment on the river bed. In this instance the deposited sediment was likely removed the following day by a fresh event (Figure 6). However, the potential for adverse effects would have been greater if deposited sediment persisted due to a period of stable low flow, as often occurs during summer in the Awatere. Further monitoring is required to assess the extent and significance of sediment deposition downstream of instream works in the Awatere and the potential for adverse effects, including possible cumulative effects arising from multiple instances of work.

The sediment release and turbidity increases observed in this case could have been reduced using sediment control measures (e.g. sediment fences, bunds, straw bales etc.). We understand that these types of sediment control measures are not required by consent conditions for all instream works in the Awatere due to the impracticability of screening the full flow of the Awatere River. However, for situations such as the work observed 18 January, which was undertaken in relatively small diversion channels, such control measures could mitigate effects.

Burrell (2015) also made some useful suggestions of ways to avoid or mitigate potential effects of gallery maintenance work. These suggestions included:

- Undertake ripping when the river is already naturally turbid. To avoid impacts during clear water periods work could be undertaken during a flood recession while turbidity is still naturally high and stream power is sufficient to transport the fine sediment and avoid sedimentation. However, conducting instream work during high flows may have to be avoided for health and safety reasons. Alternatively work could be undertaken immediately before a fresh, as was the case with the work observed on 18 January, so that any sediment deposits do not remain in place for long, thus minimising the potential for adverse effects. However, if maintenance work continues to be undertaken on a crisis management basis it may not be feasible to schedule work around natural flow events, by the time an appropriate flow occurs crops may have been lost.
- Restrict the duration of instream works when the river is naturally clear (Burrell 2015 recommends limiting duration of instream works to 30 minutes). This would reduce the duration of turbidity pulses, though it may not actually have much impact on sedimentation downstream if the same amount of sediment is simply released over a shorter period. Also it may not be feasible to complete the required work within such tight a timeframe as evidenced by Burrell conceding that his client considered 2 hours to be a more realistic timeframe.
- Restrict ripping frequency, i.e. the number of times a consent holder may undertake the work per year.
- Avoid sensitive migratory periods. Burrell suggests undertaking work in January and February to avoid sensitive migratory periods in spring and autumn. However, as discussed above the summer period when most infiltration gallery maintenance work occurs in the Awatere, coincides with spawning and juvenile rearing periods for several species found in the river, including torrentfish, bluegill and upland bullies, as well as the peak in upstream migration from the sea for eel elvers (Figure 5).
- Provide a stand-down period between completion of ripping by one consent holder and commencement of ripping by a neighbouring consent holder. Again this may not be feasible if maintenance is undertaken on a crisis management basis.
- Fish salvage and re-location prior to ripping activity and flow diversion, if the work is to be undertaken during low flow periods. This would probably be feasible only for the localized area exposed to mechanical disturbance and would not address broader scale impacts. Fish salvage may not be possible for work undertaken at higher flows, but if work is to be undertaken under low-flow clear-water conditions then fish removal by electric fishing should be feasible and would be advisable to mitigate potential adverse effects.

2.3. Frequency and timing of maintenance work

The potential for cumulative ecological effects to arise from multiple episodes of instream work on infiltration galleries depends on the frequency and location of the work. Unfortunately, there remains substantial uncertainty around the frequency of instream work associated with infiltration galleries in the Awatere River. While MDC are notified of some instream work, there are other instances where work is undertaken without notification and some consents do not stipulate requirements for notification of work (Peter Hamill, MDC, pers. comm.). Consequently, it is impossible to precisely quantify the number of maintenance events per summer.

Maintenance requirements for infiltration galleries in the Awatere are apparently high, due at least in part to fine sediment clogging gravels. A recent investigation by Aqualinc (Scales 2014), undertaken for MDC, raised questions about the advisability of using infiltration gallery intakes in the Awatere River, as well expressing concerns over the number of gallery intakes in the river and the potential environmental risks. A survey of water users as part of that report found that the importance of conducting routine maintenance was widely recognised, but the extent and magnitude of maintenance work was a major concern to many users and operators (Scales 2014). Many respondents even questioned the viability of infiltration galleries given the ongoing and uncertain maintenance costs, and clogging of gallery intakes was noted as a reoccurring theme throughout interviews.

There are currently approximately 65 consented infiltration galleries in the Awatere River and each of these is likely to have some degree of maintenance work carried out at least once a year (Peter Hamill, MDC, pers. comm.). Between December 2015 and mid-April 2016 MDC received only 12 notifications of instream works associated with these galleries, half of which were from two consent holders (i.e. four notifications of work at one location by one consent holder and two notifications of work at another location by another consent holder). There were a further three events that MDC staff detected by chance, to give a total of 15 known instances of instream works over this summer. However, there are likely to have been an unknown number of others that went unnoticed.

In his assessment of environmental effects supporting a recent application for flow diversion and ripping work on an infiltration gallery in the lower Awatere River, Burrell (2015) suggested an average of two ripping events per year was likely, but requested flexibility to undertake work more frequently under exceptional circumstances. However, Scales (2014) noted that galleries with yields less than 20 l/s generally have good flow rate performance, while those with higher design yields tend to experience reduction in flow over time. Consequently, frequency of instream maintenance work is likely to be highly variable between abstractions. An excavator operator working on infiltration gallery maintenance in the Awatere stated that he can sometimes be required to break the sediment seal and clean some intake structures every two weeks during summer, depending on the prevalence of sedimentation from high flow events. He also suggested that some of the infiltration galleries he was working on appear to have a 10–12 year life span before their performance begins to decline steadily and then appear to require progressively more frequent maintenance work as they age. On the basis of the available information the total number of instances of instream works in the Awatere may be in the order of 65–160 events per summer (or possibly even higher), although this remains uncertain.

The timing of these events is also uncertain. The potential for cumulative impacts would be greater if maintenance events are clustered in periods when flow is low and stable, with relatively long periods between flushing events. This seems quite likely to be the case given that most maintenance work is undertaken during periods of high irrigation demand. Scales (2014) noted that a rapid reduction in water yield from gallery intakes is more common than gradual decline, and often occurs in peak demand periods when the consequences of reduced water availability are high. The excavator operator we spoke to also indicated that periods of high water demand at sites where there is no on-site water storage tends to result in more frequent clogging and demand for clearing, partly because, without storage, abstraction has to continue during unfavourable conditions (with high sediment load) in order to maintain crops. In effect it appears that maintenance of infiltration gallery permeability is undertaken on the basis of crisis management. It would be preferable if the need for maintenance could be anticipated (perhaps by pump testing before the peak irrigation demand period) and work scheduled to minimise the potential environmental impacts.

Ideally, MDC would gather more definitive data on the frequency, timing and location of instream works on gallery intakes in the Awatere to allow a better assessment of the potential for cumulative adverse effects. However, this will be difficult to achieve if operators do not notify MDC of instream work.

3. CONCLUSIONS AND RECOMMENDATIONS:

Instream work associated with infiltration gallery maintenance (e.g. ripping and flow diversion) has adverse environmental effects. The effects of individual cases of instream work are primarily quite localised and transient. However, in our opinion, there is a potential for more substantial cumulative effects to arise in the Awatere River from multiple instances of gallery maintenance, given the large number of gallery takes in the lower river and the apparently high maintenance requirements. We consider that cumulative effects are more likely to arise from sedimentation downstream of instream works than from elevated turbidity associated with the work *per se*, because sediment deposits have the potential to persist and accumulate in the system during prolonged periods of low flow.

Our observations showed that elevated turbidity associated with instream works was relatively short term (less than 6 hours for instream work taking about 1 hour). However, the works did substantially exceed water quality standards stipulated in the existing WARMP and in the newly notified replacement plan, even in the order of 2 km downstream. Even though elevated turbidity associated with a single episode of instream work is fairly transient, it is possible that the increased occurrence of high turbidity events may have cumulative impacts on fish feeding opportunity and productivity, if the frequency of instream works is very high during summer, when turbidity naturally tends to be reasonably low.

Additionally, mechanical damage to the stream bed and habitat may persist until the next flow event with sufficient power to mobilise the substrate, and the cumulative impact of fish mortality associated with instream works has the potential to become significant if the number and frequency of maintenance events is very high.

Unfortunately, there remains considerable uncertainty around the frequency, timing and location of gallery maintenance works. Additionally, the extent of sedimentation from instream works in the Awatere is unknown. Consequently, conclusively determining the cumulative effects of instream maintenance works associated with infiltration galleries is not currently possible.

We suggest that MDC should:

- Attempt to gather more definitive data on the frequency, timing and location of instream works on gallery intakes in the Awatere to allow a better assessment of the potential for cumulative adverse effects. However, we recognise that this will be difficult to achieve if operators do not notify MDC of instream work.
- Consider continuous turbidity monitoring during the irrigation season in the lower Awatere catchment. In conjunction with information on the timing and location of instream works this would help reveal the extent of turbidity effects.

- Monitor (or require consent holders to monitor) sedimentation in the vicinity of instream works, to attempt to assess any negative impacts over time on aquatic ecosystems, and to help shed light on the potential extent of cumulative sedimentation effects. Consideration needs to be given to how distinguish sedimentation resulting from instream works from background sediment levels. The existing sediment load in the Awatere is probably already higher than natural background levels, due to previous instream works and land use practices.
- Introduce a requirement for sediment control measures wherever these are feasible as consent condition for instream works.

In addition, the efficacy of ripping and flow diversion toward gallery intakes, in terms of maintaining abstraction rates, should also be investigated further. The efficacy of these practices was questioned by Scales (2014) for infiltration galleries designed to intercept horizontal subsurface flow, as most of those in the Awatere apparently are designed to do. If these practices are found not to be having the desired effect on maintaining abstraction rates, or if more effective measures could be found, then potential adverse effects could be avoided by discontinuing these practices. Scales (2014) also questioned the suitability of infiltration gallery intakes for use in the Awatere catchment and suggested that alternative intake options ought to be considered in some instances. They suggested that alternative approaches with less potential for adverse environmental effects may be available, and be better suited to the Awatere catchment. Additionally, recent work on behalf of Irrigation New Zealand has shown the fish screening efficacy of gallery intakes to be lower than commonly assumed for certain species that naturally dwell in the substrate (e.g. bluegill bullies) (Bonnett et al. 2014).

We suggest that until more information can be gathered a precautionary approach would be to avoid issuing consents for new infiltration galleries and to limit the extent and frequency of instream works, to the extent that is possible given existing consents.

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