Assessment of Environmental Effects; Paparua Stockwater Race (PSR) Diversion

Prepared for:
SOL Quarries Ltd

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An upland bully (Gobiomorphis breviceps) found in the Paparua Stockwater Race during the ecological survey on 2 May 2019.

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1 Executive Summary

SOL Quarries Ltd seeks resource consent to extend the existing quarry operation at 83 Conservators Road, Yaldhurst. To allow for this extension, SOL Quarries Ltd also seeks consent to realign a c. 700 m section of the Paparua Stockwater Race (PSR). To fulfil requirements of a section 92 request (ECan and CCC) AEL conducted an ecological survey on 2 May 2019. The objective of the survey was to identify the ecological values associated with the Paparua Stockwater Race, and the potential impacts of the proposed diversion on these values and surface water quality.

The ecological survey was composed of three components: faunal habitat quality, macroinvertebrate community, and fish community. The survey of habitat quality for both fish and macroinvertebrates involved the evaluation of both instream and riparian attributes, using an established habitat assessment protocol. The macroinvertebrate community was assessed by collecting kicknet samples within the waterway, and using the collected macroinvertebrates to calculate standard stream health metrics. The fish community was assessed by conducting electric fishing within the waterway, in combination with historic fish records.

The results of the ecological survey indicated that the Paparua Stockwater Race had low ecological value. Only a single fish species—upland bully (*Gobiomorphus breviceps*)—was found, a species with no conservation status, but was present in moderate numbers. The presence of just one non-migratory fish species was attributed to potential upstream barriers to migratory fish, paucity of habitat variation, and lack of instream fish cover (e.g. boulders, overhanging vegetation, root mats, woody debris, and undercut banks). However, the uniform channel is consistent with its principal role as a water race designed for the efficient conveyance of irrigation and stockwater. The macroinvertebrate community was also of low diversity, consisting of a relatively small number of insensitive species. The calculated macroinvertebrate stream health metrics indicated that the waterway had low stream health. This was similarly attributed to a lack of instream habitat diversity and large amounts of deposited sediment—a natural feature of the waterway.

It is unlikely that the proposed diversion will significantly impact the surface water quality or ecological value of the Paparua Stockwater race. However, the most significant effect is likely to relate to increases in deposited sediment downstream, resulting from the construction and commission of the new channel. To minimise the impacts of construction and commissioning, AEL recommends that dust should be controlled during the construction of the new channel. Furthermore, the new channel should only be commissioned once the banks are stabilised and vegetated. Constructing a temporary filtration barrier at the downstream end of the new channel will also help to reduce sediment output during the commission of the new channel. Finally, the resident fish population should be translocated from the old channel while it is being drained, as well as translocation of gravels (containing macroinvertebrates) into the new channel to aid in the development of the new ecosystem.

2 Introduction

SOL Quarries Ltd seeks resource consent to extend their existing quarry operation at 83 Conservators Road, Yaldhurst. To allow for this extension, SOL Quarries Ltd also seeks consent to realign (i.e. divert into a straight channel) a c. 700 m section of the Paparua Stockwater Race (PSR). This will be the second realignment of the PSR by SOL Quarries Ltd since 2016, with the previous realignment consented under consent: CRC155102.

The Paparua Stockwater Race (PSR) sources water from the Waimakariri River, *via* a coarse-sediment settlement pond. The Waimakariri River in turn rises in the southern alps, and it's hydrology is principally controlled by its upper basin (Cowie et al. 1986), and is partially glacial fed. For this reason, the river, and therefore the PSR, carries a natural high fine-sediment load called 'glacial flour'. The purpose of the PSR is primarily to supply drinking water for stock, with the surrounding land use used primarily for agriculture. The race is typical of an artificial utility-based waterway; highly channelised, lacking any natural meanders, perennial in flow, with riparian vegetation consisting mostly of grass, with some exotic shrubs present.

As part of a section 92 request (ECan and CCC), SOL Quarries Ltd is required to investigate the ecological values associated with the PSR, and the potential effects associated with the proposed realignment of the waterway. The following reports the findings of an ecological investigation conducted by AEL to address these issues.

3 Objectives

- To identify the ecological values associated with the Paparua Stockwater Race.
- To determine the potential effects of realignment of the Paparua Stockwater Race on ecological values and surface water quality.

4 Methods

4.1 Field methods

To identify the ecological values associated with the Paparua Stockwater Race, an ecological survey was conducted on 2 May 2019. This survey contained three assessments components: faunal habitat quality, macroinvertebrate community, and fish community.

4.1.1 Faunal habitat quality

Faunal habitat quality was assessed by using a semi-quantitative approach. Surveyors completed forms that characterised habitat quality (for both fish and macroinvertebrates) based on a both instream and riparian factors. Two habitat quality assessments were conducted, one for each of the electric fishing reaches (Fig. 1, yellow lines). Scoring for the habitat assessment was only based on the sections that were electric fished, but are representative of the general habitat of this physically uniform waterway.

4.1.2 Macroinvertebrate community

The macroinvertebrate community was assessed by collecting kicknet invertebrate samples. Two samples were collected; a hard substrate (i.e. stony bottom) sample and a soft substrate (i.e. aquatic macrophyte) sample. Both samples were collected in a semi-quantitative manner, following the national protocol for macroinvertebrate collection (Stark et al. 2001). As per these protocols, the hard substrate sample (protocol C1) was collected by taking eight kicknet subsamples from the substrate, each with an approximate sample area of 0.09 m^2, and a subsequent composite sample area of 0.72 m^2. This composite sample was collected along a c. 47 m sampling reach (Fig. 1). The soft substrate sample (protocol C2) was collected by taking ten kicknet subsamples from the predominant macrophyte (*Myriophyllum* sp.), each with an approximate sampling area of 0.3 m^2, and a subsequent composite sample area of 3.0 m^2. This composite sample was collected along a c. 76 m sampling reach (Fig. 1). Both samples were then preserved in isopropanol, and transported to the AEL lab for identification. Identification of macroinvertebrates was conducted down to lowest taxonomic level possible, with the aid of a low power stereo microscope, by an experienced macroinvertebrate ecologist.

The collected invertebrate samples were used to calculate MCI scores as well as %EPT taxa. The MCI index quantifies sites in respect to what is loosely termed 'stream health'. Each identified taxon possesses a pre-assigned score, ranked from 1 (most tolerant) to 10 (least tolerant). An MCI ranges from 0 (when no taxa are present, inferring low stream health) to 200 (when all present taxa score 10 points each, inferring high stream health). The MCI is calculated by summing the taxa scores and dividing by the number of taxa, then multiplying by 20, as given by the formula below.

$$MCI = \frac{Site\ score}{Number\ of\ scoring\ taxa} \times 20$$

EPT taxa include all Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) species. These taxonomic orders, with a few notable exceptions, are sensitive to water pollution; therefore, their presence may give indication to the quality of a waterway. They are generally used to calculate a %EPT metric, this being the percentage of the sample represented by EPT species. A high %EPT value is therefore indicative of high stream health.

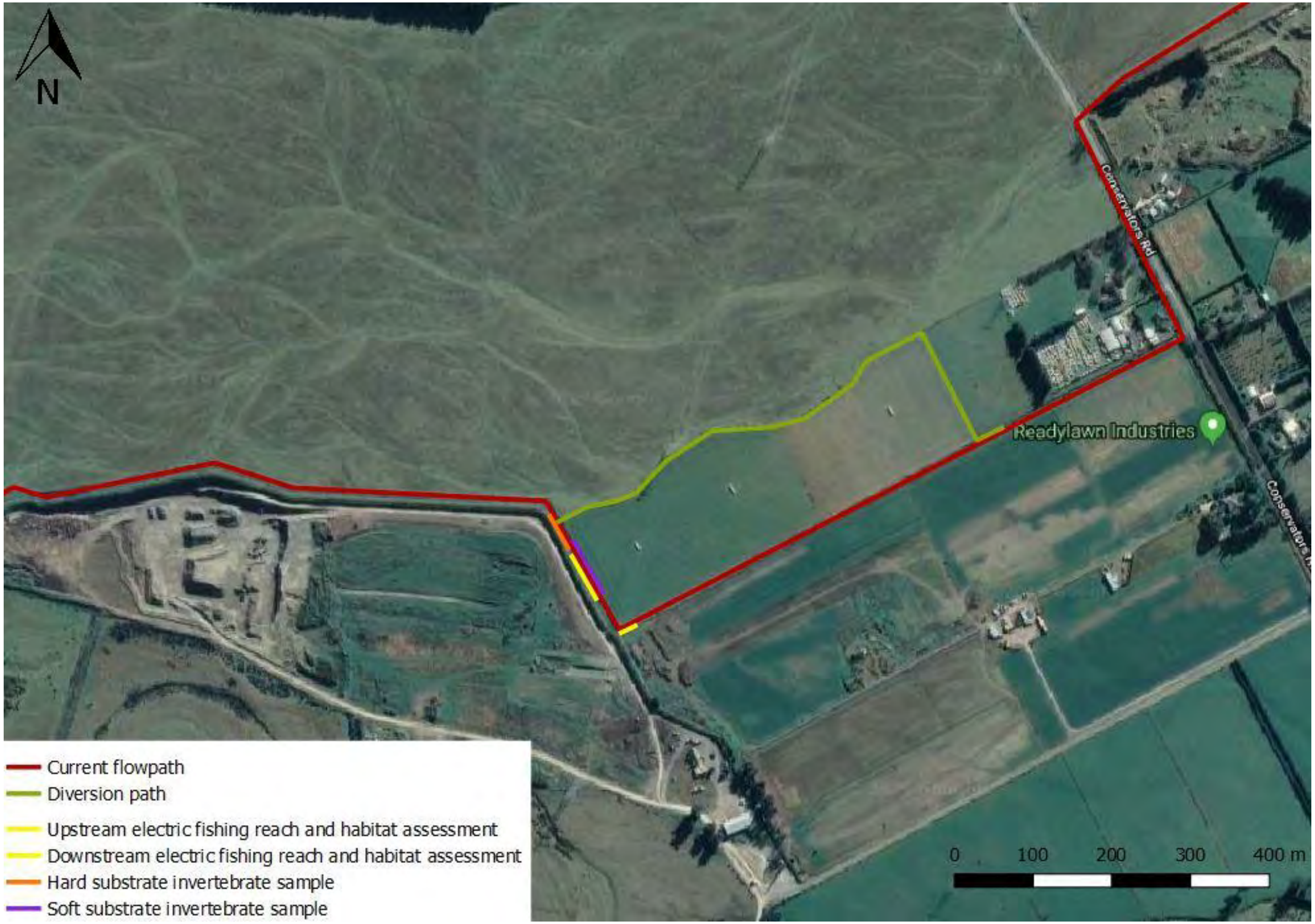

Figure 1. The proposed diversion and the ecological sampling reaches.

4.1.3 Fish community

To assess the fish community, electric fishing was conducted, under AEL's electric fishing permits (MPI Permit 605, DOC 70754-FAU and under authority from NCFGC). Two reaches were electric-fished, both within the area of the proposed diversion (indicated in yellow in Fig. 1), with a total reach length of 83.1 m. In combination, these reaches encompassed all hydrological habitat types in the area, including: pool, riffle, fast run, and slow run habitats. The total sample time (i.e. the total time that the machine was actively electrifying the water) for these reaches was 16 minutes. Captured fish were then anaesthetised, identified, measured, and upon recovery from anaesthesia, released back into their resident habitats.

Historic records from the New Zealand Freshwater Fish Database (NZFFDB 2012) were also examined to identify historic fish communities in other reaches of the PSR.

5 Results

5.1 Faunal habitat quality

The completed habitat assessment forms for both assessed sites can be found in App. I. The faunal habitat assessment indicated that the Paparua Stockwater Race provides poor habitat for fish and invertebrate communities (Table 1). The waterway scored particularly low in the areas of overhead shade and bank vegetation. This was due to a complete lack of canopy vegetation, especially native species. Instead, long grass, clover, gorse, exotic broom species dominate the riparian vegetation (App. II, Fig. i–ii). While this vegetation did little to provide overhead shade, it stabilised the banks effectively, resulting in a high score for bank erosion (i.e. little active erosion) at both sites. Despite little active erosion, the waterway scored poorly for deposited sediments, particularly at the upstream site. Both sites also scored poorly for fish cover diversity and abundance, with encroaching vegetation, macrophytes, and cobbles providing the only available fish cover in the waterway. The area of cobble habitat was also greatly reduced by the amount of deposited sediment at both sites.

Table 1. The results of the faunal habitat assessments. A high score (maximum of 10) indicates greater habitat value in that category. Subsequently the highest total habitat score possible is 100 and the lowest possible score is 10. Complete assessment criteria can be found in App. I.

Habitat parameter	Upstream habitat	Downstream habitat	Average score
Deposited sediment	1	6	3.5
Invertebrate habitat diversity	5	7	6
Invertebrate habitat abundance	4	9	6.5
Fish cover diversity	3	5	4
Fish cover abundance	6	5	5.5
Hydraulic heterogeneity	2	7	4.5
Bank erosion	9	9	9
Bank vegetation	3	3	3
Riparian width	6.5	6.5	6.5
Riparian shade	3	1	2
Total	42.5	58.5	52.5

5.2 Macroinvertebrate community

A complete taxa list for the two macroinvertebrate samples can be found in App. III, Table i. Both collected macroinvertebrate samples were composed of common species, with none of the collected species holding a New Zealand conservation status (Grainger et al. 2018). Both samples were dominated by snails, representing approximately 45% of the macroinvertebrate abundance in the hard substrate sample, and 83% of those in the soft substrate sample. Both samples scored low for the MCI (stream health) metric (Fig. 2), with both samples reflective of a waterway in poor health, as defined by Stark and Maxted (2007). Also reflecting poor health was the low total percentage of EPT taxa identified in each sample, with the % EPT values for hard substrate and soft substrate samples being 3.4% and 2.4% respectively.

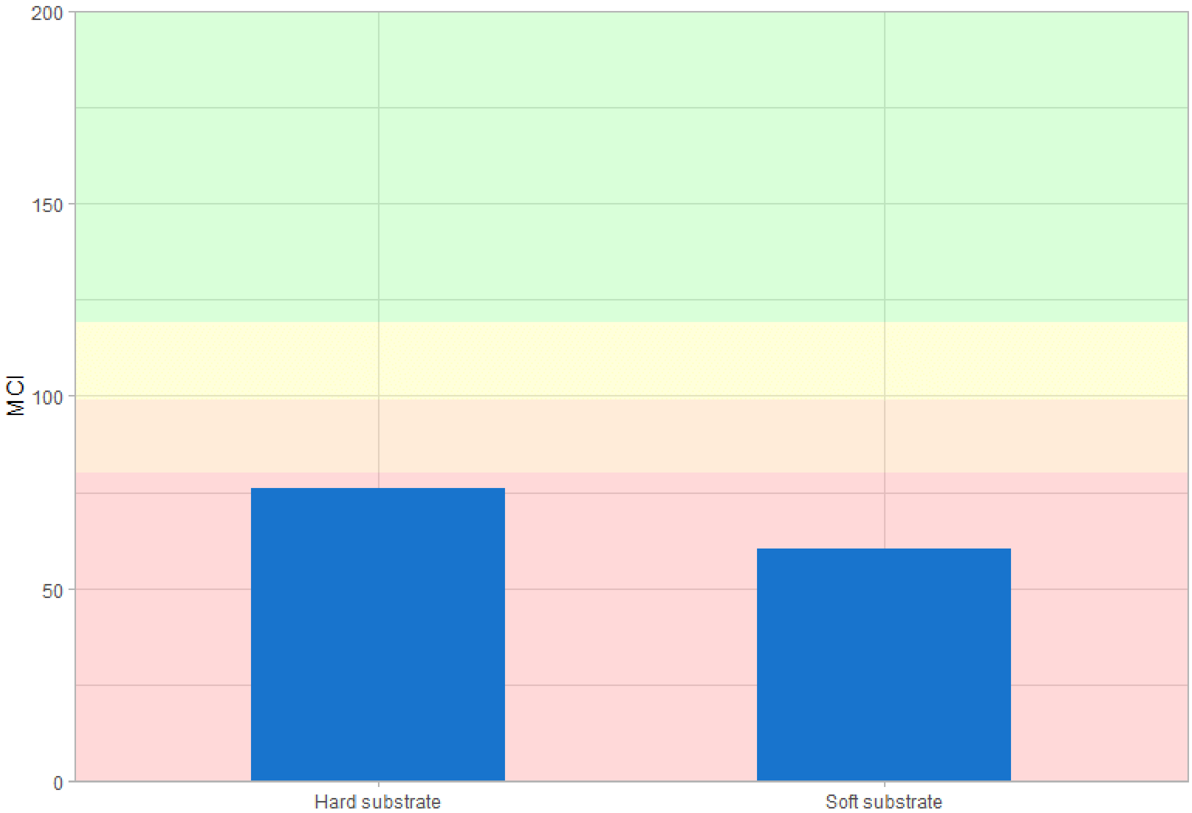

Figure 2. The calculate MCI values for the hard substrate and soft substrate macroinvertebrate samples. Background coloured to indicate the MCI levels of stream health as defined by Stark and Maxted (2007): Excellent = >119, Good= 100–119, Fair = 89–99, Poor = <80.

5.3 Fish community

A single fish species was collected during electric fishing, upland bully (*Gobiomorphus breviceps*). A combined total of 148 individuals were captured from the two electric fishing sampling reaches. This equates to a Catch Per Unit Effort (CPUE) of 9.25 fish/minute (148 individuals/ 16 minutes fishing time). Sizes ranged from 30–94 mm, with most individuals being between 41–55 mm in length (Fig. 3). A small number of particularly large and colourful upland bullies were among the catch (Fig. 4), with a maximum specimen recorded length of 94 mm (T.L).

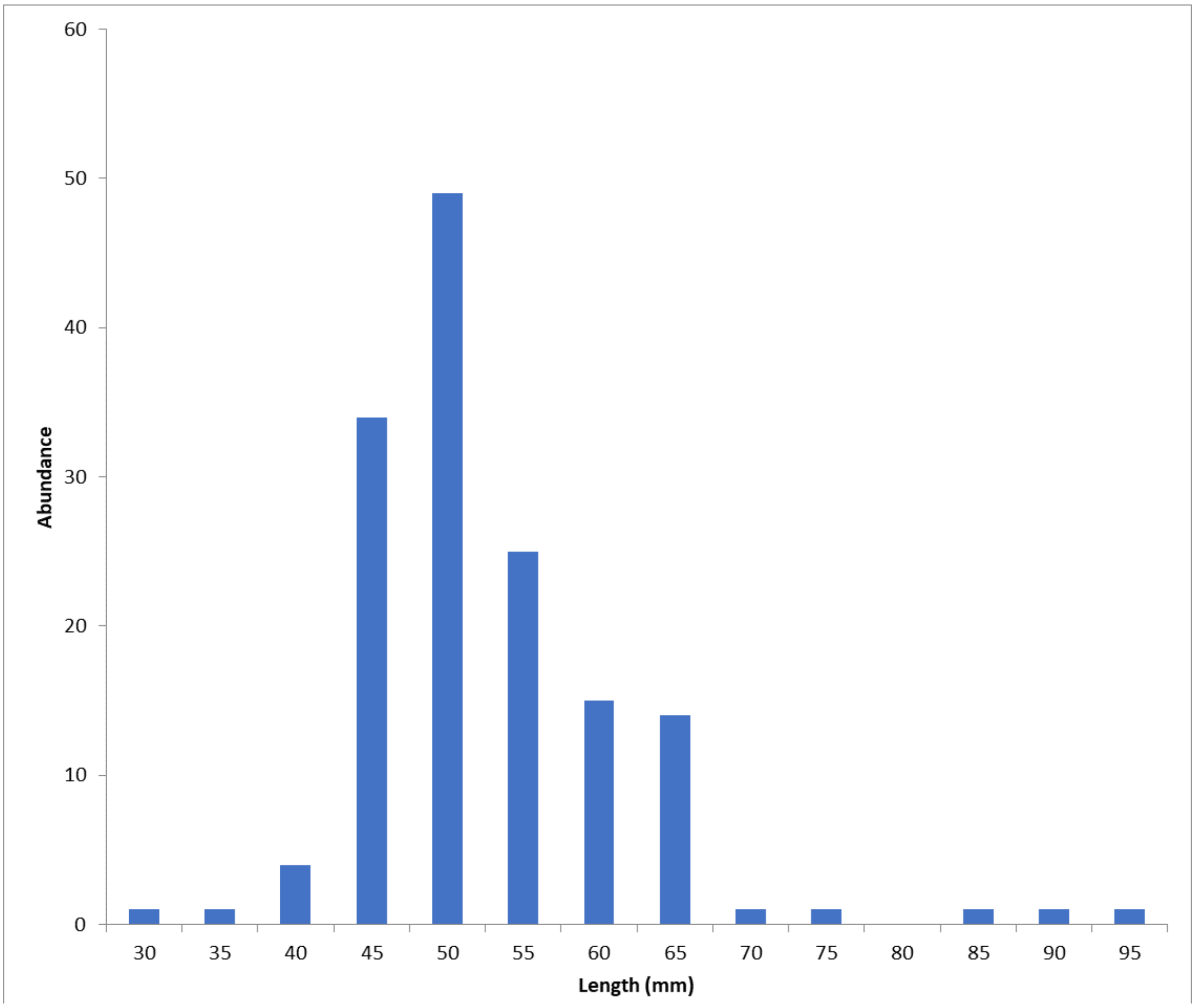

Figure 3. The distribution of size classes of upland bully caught in the survey area. Each data bin indicates the upper limit of that range i.e. bin "45" contains every individual measuring 41–45 mm.

Figure 4. A large and colourful male upland bully caught in the Paparua Stockwater Race.

Examination of the NZFFD found only two previous fish records within the PSR, one c. 7.8 km upstream of the proposed diversion (NIWA, 1997), and one near the confluence with the Waimakariri River, c. 17.0 km upstream of the proposed diversion (NIWA, 1983) (Fig. 5). These records show seven different species as historically present in the PSR, with the greatest diversity occurring near the confluence with the Waimakariri River (Table 2).

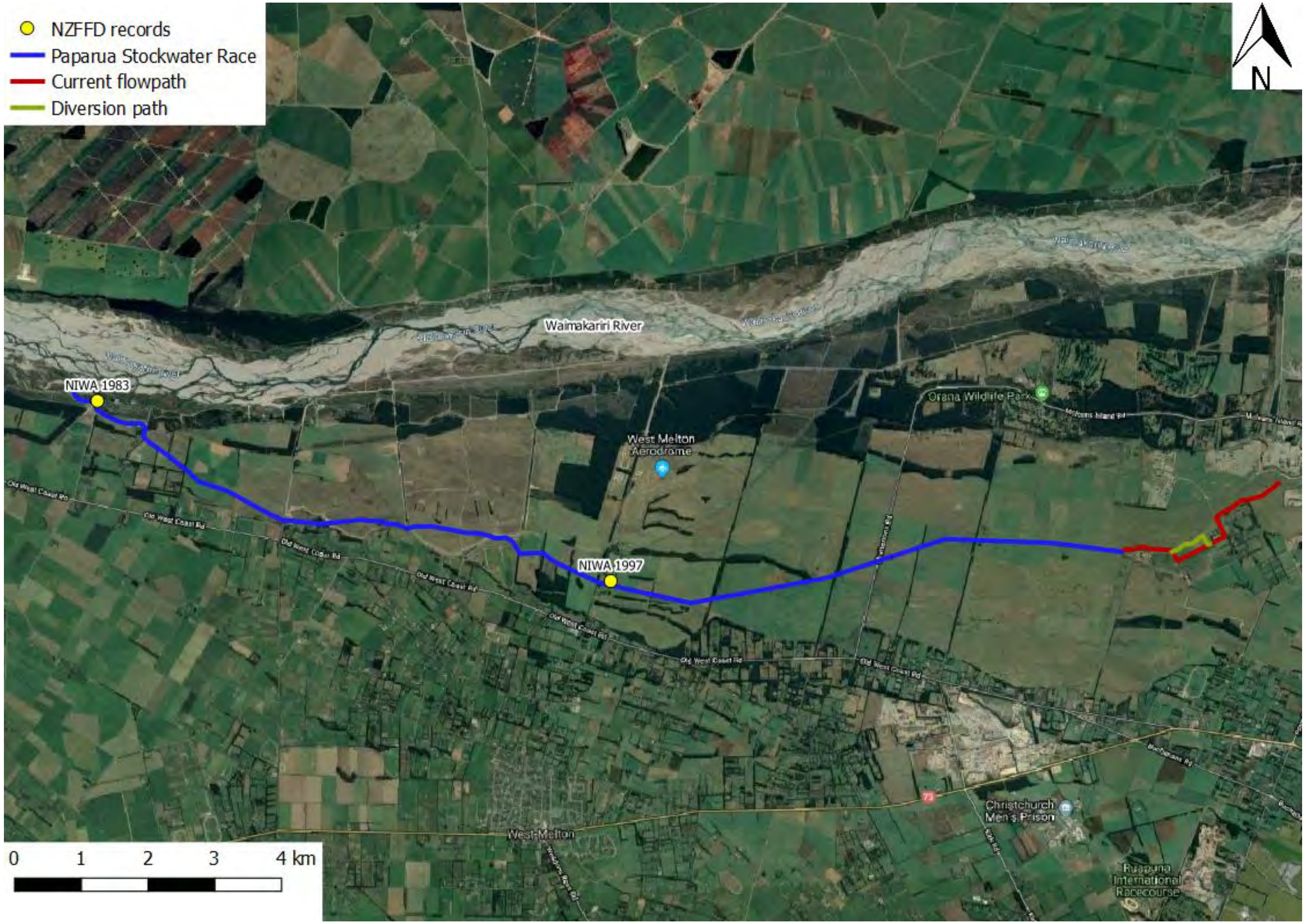

Figure 5. Locations of historic NZFFD records

Table 2. The two historic records from the NZFFD within the Paparua Stockwater Race. Site refers to the locations marked on Fig. 5. All fish were caught using electric fishing.

Site	Species	Number
NIWA 1983	Common bully (*Gobiomorphus cotidianus*)	Rare
NIWA 1983	Torrent fish (*Cheimarrichthys fosteri*)	3
NIWA 1983	Shortfinned eel (*Anguilla australis*)	1
NIWA 1983	Longfinned eel (*Anguilla dieffenbachii*)	Occasional
NIWA 1983	Brown trout (*Salmo trutta*)	2
NIWA 1983	Chinook salmon (*Oncorhynchus tshawytscha*)	8
NIWA 1983	Upland bully (*Gobiomorphus breviceps*)	1
NIWA 1997	Brown trout (*Salmo trutta*)	2
NIWA 1997	Upland bully (*Gobiomorphus breviceps*)	4

6 Discussion

6.1 Current ecological values of the PSR

Much of the substrate was covered in fine sediment, particularly within the upstream electric fishing reach. Deposited sediments may limit habitat availability for fish species by filling interstitial spaces between substrate particles (McDowall 1990; McEwan & Joy 2014). The effects of deposited sediments on macroinvertebrates are even more diverse, including: reduced interstitial habitat availability, covering of food supply for species that feed on periphyton, and reduction of interstitial dissolved oxygen (Lenat et al. 1981; Ryan 1991; Quinn et al. 1992). However, during the habitat survey little active bank erosion was observed, indicating that the deposited fine sediment is derived from an upstream location. The PSR sources water from the Waimakariri River, which is high in glacial flour, which can be seen in satellite imagery of the Waimakariri River, and the pond that feeds the PSR (App. II, Fig. iii). This source is likely responsible for much of the deposited fine sediment in the PSR, while the larger particles (gravels, cobbles, and boulders) represent exposed alluvium from historical Waimakariri River outwash. Aerial photographs indicate that much of surrounding landscape in the vicinity of the SOL quarry represents a historical stony channel of the Waimakariri River. Of course, this is the reason why the alluvium quarry is situated there.

The habitat quality survey also identified the waterway to be relatively low in habitat diversity, and habitat quality, for both fish and invertebrate species. The waterway functions as an irrigation race, therefore the aquatic habitat is relatively hydraulically homogenous, dominated by run-type flow, and lacked shallow fast water (i.e. riffles), or deeper pools. The absence of natural meanders in the waterway and the deficiency of mature riparian vegetation is responsible for the lack of undercut banks. Undercut banks provide habitat utilised by many fish species, especially New Zealand's eel species (Jellyman et al. 2003), and are likely to be a contributing factor to the low fish diversity of the waterway. Furthermore, the absence of mature vegetation on the banks of the waterway prevents the input of woody debris, denying refuge for both macroinvertebrates and fish, but also detrital food for invertebrates. While the absence of mature vegetation along banks can in some cases promotes productivity by allowing more light to reach the bed of the waterway, this will be offset in the PSR by the turbidity caused by glacial flour in the water, reducing the amount that reaches the substrate. Furthermore, the race water must be low in nutrients, as attested by the high voltage required (400 V) to generate an effective electrical field for fishing. This observation, combined with low light levels, would indicate that the PSR is likely to be a waterway with low productivity for instream biota. The low productivity is likely to contribute to the low faunal diversity, particularly within the invertebrate community. Identified species were tolerant of low water quality and none were of high conservational value or have current conservation status (Grainger et al. 2018).

The lack of habitat variation and abundance near the diversion point is likely to limit fish diversity, and may be partially responsible for the presence of only a single resident fish species (upland bullies). However, there may be further contributing factors. The minimal diversity would also be contributed to by the distance and migration barriers for migratory fish between the race intake and the study area. This is reflected by a spatial decline in fish diversity, from the 7 (mostly sea-migrant) fish species recorded from the NZFFDB site near the intake, compared to the 2 species (probably not sea-migrant) recorded 8 km into the raceway system, to the 1 non-migrant species (i.e. upland bully) recorded from the study area, approximately 16 km from the intake. Upland bully do not migrate (McDowall 1990), therefore the distance from the intake to this habitat is immaterial. The absence of fully sea-migratory species in both the NIWA 1997 survey and the current survey indicates that there may be a fish migration barrier downstream of the NIWA 1983 survey location. This may be a contributing factor the lack of fish diversity at the proposed diversion site. Brown trout may either enter the irrigation race as young from the Waimakariri River, or may spawn in the race gravels.

The non-migratory and ubiquitous upland bully will form local populations if they can spawn successfully on local cobbles or other hard surfaces. In this study, the range in observed upland bully size classes would indicate that this is a self-sustaining population, with active local recruitment occurring. This species is of low conservational value, with a current conservation status of “not threatened” (Dunn et al. 2017). Furthermore, the PSR provides typical, albeit homogenous, habitat for upland bullies, which on are found most commonly in relatively slow-moving (averaging 0.4 m/s) and shallow (averaging 0.19 m) waterways, preferring substrates comprised of fine gravels and small cobbles (Jowett & Richardson 2008). In summary, the population of upland bullies found in the PSR is therefore not a surprising result, and consistent with historic records from the NZFFD.

6.2 Ecological implications of realignment and mitigation measures

6.2.1 Construction of the new diversion channel

The new channel, in its function as an irrigation race, is required to maintain the current flow capacity and form of the existing channel. Consequently, it is not expected that the new channel will differ significantly from the low ecological habitat value provided by the existing channel. However, the construction process of the new channel still has the potential to impact of the surface water quality and local aquatic ecosystem. This is primarily through the discharge of dust to surface water, as well as the vibration and noise effects associated with large construction machinery.

The new diversion channel should be constructed at a time of low groundwater level, and unconnected to the current flowing channel. This will prevent construction sediment from entering the flow stream. Construction vehicles and machinery should not enter the current channel during the construction of the diversion channel, as to not introduce sediment from the banks or disturb the substrate. However, it is likely that some amount of dust will enter the waterway via the air during construction of the new channel. This is particularly likely due to the soil in the area being high in fine loess clay particles which could be mobilised by the wind and may settle in the waterway. This scenario may be particularly likely during the strong Norwest winds that are common on the Canterbury Plains. However, it should be noted that during these winds the waterway is likely to be already highly turbid from loess clay transported into the irrigation race from the Waimakariri River water. Norwest winds on the Canterbury Plains are often associated with rain in the Southern Alps. Subsequently, sediment is carried down the Waimak River during these occasions, and which would naturally increase the suspended sediment load in the PSR. With that said, addition to the suspended sediment load should be minimised in order to prevent further reduction in aquatic habitat caused by deposited sediments, as discussed above.

To achieve this, dust mitigation measures should be put in place while the new channel is constructed. Mitigation measures similar to those proposed in the previous application for resource consent and assessment of environment effects (GHD 2015), would be effective at reducing the input of dust during the construction of the diversion. Primarily including: dampening of unconsolidated surfaces hourly when wind speeds exceed 5 m/s, and extraction of materials while in a damp state.

While the construction of the new diversion channel will create some noise and vibration, it is expected that this will have minimal ecological effect on the waterway, and only within a very localised area. This conclusion is based on the premise that the local ecology is acclimatised to a degree of perturbation from noise and vibration of the quarry's existing operation. We anticipate, and recommend, that the vehicles and machinery used in the construction of the new channel will be relatively small and unobtrusive compared to the large machinery used in the active quarry. Therefore, vibration and construction effects are likely to be minor in effect, given that for most of the realigned section length, the race construction machinery is well away (c. 150 m) from the active flowing channel.

6.2.2 Commission of the new channel and decommission of the old channel

Commission of the new channel should only occur once the banks of the channel are stabilised and/or vegetated.

The commissioning process should begin with removal of the downstream separating bund. This will allow some water to backfill into the new channel, avoiding a sudden rush of water down the new channel. The upstream separating bund should then be gradually removed to create the full connection with the existing waterway. The connection of the new diversion channel with the existing channel should not inhibit fish movement through the waterway.

The initial movement of water down the new channel will likely carry a large suspended sediment load, transporting free particles remaining from construction. Broaching the bund between the old channel and the new channel should be done gradually, or staged, to allow mobilised sediment to settle in the new channel, rather than be transported beyond the diversion reach. A further measure to prevent mobilised sediment from being transported beyond the diversion reach, would be for the installation of a filter fence at the downstream end of the new channel. This could a standard Bidim®/haybale construction, impaled in place by metal waratahs into the channel bed. Covering the haybales in a geotextile such as could further improve the filtration ability of the barrier to trap fines. This barrier would be temporary, and could be removed once the worst of the loose construction sediment has been removed. While this method would substantially reduce the amount of sediment that would travel downstream, some sediment output would be unavoidable.

While sudden sediment plumes should be avoided, the gradual siltation of the bed is unlikely to affect the waterway's limited ecological value. Natural sediment, mostly from the Waimakariri River, will be borne into the new diversion race by the race water, but borne away during periods of high flow, and therefore an equilibrium will be reached. The only resident fish species—the upland bully—has a brooding behaviour to mitigate against chronic mild siltation. After a female upland bully has laid eggs, the male will guard the eggs, repelling intruders, and fanning the eggs with his fins to keep them oxygenated and free from silt (Hopkins 1970). This behaviour, not uncommon amongst the native bullies, is probably critical for their survival in habitats where settlement of fines is prevalent.

Finally, there should be a translocation of the aquatic fauna from the old channel. The resident fish population needs to be translocated to avoid stranding fish during the decommission and draining of the old channel. The most efficient way to achieve this would be to divert the channel flow in stages into the new channel as described above. When water levels suddenly drop, and there are no pools, fish tend to flee downstream facilitating translocation to the downstream reach. As the old channel dewaters from the upstream end, an electric fishing machine could be used in a downstream direction on a low voltage to effectively herd the fish downstream and out of the old channel near Conservators Road. Any disconnected pools that form during the draining process will also need to electric fished, and any fish translocated downstream. Once all the fish are translocated beyond the proposed diversion race entry point near Conservators Road, the flow into the old channel can be completely closed off at the upstream bund. The old channel should then be filled, beginning at the downstream end to limit the amount of sediment that will be transported downstream.

To aid in the establishment of the ecosystem within the new channel, the new channel should have cobbles deposited on the bed. This would provide abundant habitat in the new channel for upland bullies, which may represent an improvement from the old channel. Without the addition of these cobbles, the new channel would represent a loss in available habitat, as the clay substrate would not be suitable for upland bullies and their spawning behaviour. To further aid in the establishment of the new ecosystem, some substrate gravels—which will contain macroinvertebrates and quite possibly fish and invertebrate eggs—should be translocated into the new channel, from the old channel.

7 Conclusions

The results of this study indicated that the Paparua Stockwater Race has low ecological value. The fish community in the waterway consisted of a single species, upland bully, which has a conservation status of ‘not threatened’ in Canterbury. Similarly, the macroinvertebrate community was found to be depauperate, consisting of a low number of insensitive species. These findings likely relate to the low habitat quality of the waterway, which is a result of a lack of habitat diversity, refuge for instream biota, coupled with low productivity due to turbid water with probably little nutrients. Upstream migration barriers may also be a contributing factor in the local paucity of fish species.

The proposed diversion is likely to have minimal impact on the waterway, with regards to its water quality and ecological values, as it will remain limited by the habitat features above. The most prominent risk to the local ecological values associated with the construction and implementation of the diversion channel is the input of sediment into the downstream ecosystem. However, these risks can be minimised to a negligible level with appropriate sediment control measures. If the recommendations below are followed, the new channel is likely to hold equal ecological value to the decommissioned channel, without jeopardising the values of the downstream ecosystem.

8 Recommendations

- The new channel should be of equivalent flow capacity and form as the existing channel.
- The new channel should be constructed offline, with commissioning occurring only after banks have been stabilised and vegetated.
- Vehicles and machinery should not enter the existing channel during construction of the new channel.
- Dampening of unconsolidated surfaces should occur hourly when wind speeds are in excess of 5 m/s. This is consistent with the operation of the quarry operation.
- Extracted material should be dampened.
- A filter barrier should be installed downstream in the new channel prior to the new channel being gradually commissioned with irrigation water flow.
- The fish population in the existing channel should be translocated downstream prior to the filling of the channel.
- Cobbles should be used to line the new channel to provide habitat for the establishing ecosystem.
- Gravel from the existing channel should be translocated into the new channel to assist in the development of the new ecosystem.
- The connections between the new diversion channel and the existing channel should not inhibit fish movement through the waterway. For example, no inline control structures or small culvert’s that may prevent fish passage.

9 Acknowledgements

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11 Appendix I. Faunal habitat assessments

Location	**Upstream habitat assessment (Fig. 1)**										
Habitat parameter	**Condition category**										**SCORE**
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										1
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										5
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										4
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										3
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										6
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6. Hydraulic heterogeneity	*The number of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulence, backwater. Presence of deep pools score higher.*										2
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										9
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										3
Left bank AND Right bank	*Mature native trees with diverse and intact understory*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										6.5
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										3
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
TOTAL	(Sum of parameters 1-10)										42.5

Location	**Downstream habitat assessment (Fig. 1)**										
Habitat parameter	**Condition category**										**SCORE**
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										6
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										7
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										9
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										5
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										5
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6. Hydraulic heterogeneity	*The number of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulence, backwater. Presence of deep pools score higher.*										7
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										9
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										3
Left bank AND Right bank	*Mature native trees with diverse and intact understory*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										6.5
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										1
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
TOTAL	(Sum of parameters 1-10)										58.5

12 Appendix II. Field photos

Figure i. Looking upstream (north) at the upstream electric fishing reach. Note that turbidity of water is partially due to surveyors walking in the waterway.

Figure ii. Looking downstream (northeast) at the downstream electric fishing reach. Note that turbidity of water is partially due to surveyors walking in the waterway.

Figure iii. The source of the PSR (arrowed), including the pond and the Waimakariri River. Note the milky colour caused by glacial flour.

13 Appendix III. Macroinvertebrate taxa

Table i. Complete macroinvertebrate taxa list including corrosponding MCI values.

		Hard substrate		Soft substrate	
		No.	MCI-hb	No.	MCI-sb
ANNELIDA					
Oligochaeta		19	1		
Hirudinea		14	3		
MOLLUSCA					
Gastropoda					
Hydrobiidae	*Potamopyrgus antipodarum*	132	4	260	2.1
Physidae	*Physa acuta*	76	3	471	0.1
Lymnaeidae	*Lymnaea*	86	3	238	1.2
CRUSTACEA					
Ostracoda				84	1.9
INSECTA					
Lepidoptera					
Crambidae	*Hygraula nitens*			1	1.3
Diptera					
Orthocladiinae		1	2		
Muscidae				1	1.6
Simuliidae	*Austrosimulium*			8	3.9
Trichoptera					
Leptoceridae	*Hudsonema amabile*	10	6	4	6.5
Hydrobiosidae	*Hydrobiosis*	12	5	24	6.7
Hemiptera					
Corixidae	*Sigara aguta*	1	5	1	2.4
Odonata					
Coenagrionidae	*Xanthocnemis zelandica*			7	1.2
Coleoptera					
Elmidae	*Hydora*	305	6	64	7.2
No. Scoring taxa		10		12	
TOTAL No. of animals		656		1163	
Total indice score		38		36.1	
MCI-hb/MCI-sb		76.0		60.2	
% EPT taxa		3.4		2.4	