February 2013

Coopers Creek Ecological Values and Flow Requirements

Submitted to:
Canterbury Regional Council
Nazareth Avenue, Christchurch
PO Box 345
Christchurch
New Zealand

Report Number. 0978110107_002_R_Rev0

REPORT

Golder Associates

Table of Contents

APPENDICES

1.0 BACKGROUND

The Canterbury Regional Council (CRC) has undertaken to review the minimum flow criteria set via consents at sites along Coopers Creek in the Orari River catchment. The purpose of this report is to assess the ecological values of upper Coopers Creek in the vicinity of the springs, and to posit flow requirements to sustain those values. This report does not attempt to balance the potentially competing needs of instream values and water abstractors.

Based on information provided by CRC and Burberry (2011), Golder Associates (NZ) Limited (Golder) understands that Messrs Kerse and Kingston utilise consented groundwater takes considered hydraulically connected to Coopers Creek. Both consents require cessation of pumping when flow in Coopers Creek at SH72 Bridge is at or below 50 L/s. The consent holders have applied to CRC to change their minimum flow location to the Orari River gorge due to irrigation reliability issues associated with the Coopers Creek minimum flow site. The consent holders and CRC are currently monitoring flows and groundwater levels around the Coopers Creek springs to determine the relationship between flows in the Orari River, groundwater levels and flows in Coopers Creek springs.

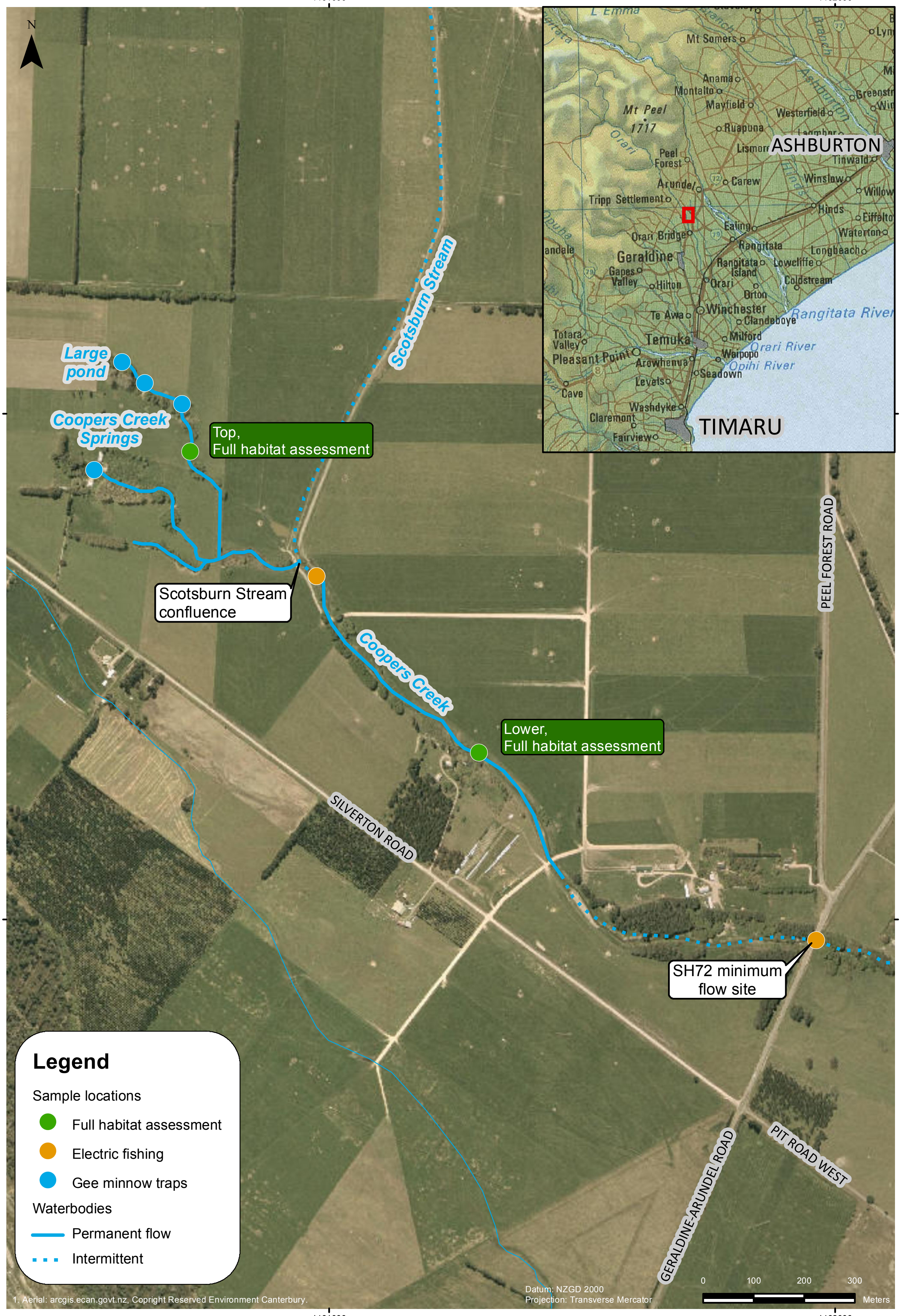
This report is subject to the limitations provided in Appendix A.

2.0 METHODS

On the 17 February 2012 two sites, 'upper' and 'lower', along Coopers Creek were chosen for detailed habitat assessment and ecological survey. Rapid assessments of habitat and fish communities were made at a further two sites to encompass the full habitat variability along the permanently flowing reach (Figure 1). The entire length of the upper Coopers Creek above the confluence with the intermittent Scotsburn Stream was walked and habitat observed.

Calibrated field meters were used to measure water temperature, dissolved oxygen, pH and conductivity at each of the four sites. Streambed cover and composition of periphyton (streambed algae) and macrophyte communities were also visually assessed at each site. Invertebrate communities were sampled at the upper and lower site using Protocol C2 of Stark et al. (2001), which involved disturbing substrates (including macrophytes) and allowing the current to wash invertebrates into a kick net. Substrates were sampled according to proportions in which they occurred using a kick net with a mesh size of 500 µm and the samples provided an indication of the dominant invertebrate species present at each site. Fish sampling was semi-quantitative, using a single pass backpack electric fishing approach over approximately a 30-50 m reach of stream. In areas of more sluggish flow, such as at the spring-head and the top habitat assessment site Gee-minnows traps were also used. Thirteen traps baited with Marmite were left in the stream overnight.

Golder made detailed instream habitat measurements at two locations to assess how aquatic habitat changes with flow. Fieldwork generally followed the standard WAIORA-type field method (Jowett et al. 2008) and was coupled with modelling using the RHYHABSIM (River Hydraulics Habitat Simulation) computer package. In New Zealand, the computer programme RHYHABSIM is widely used for modelling instream habitat changes with flow (Jowett et al. 2008). Fieldwork entailed undertaking one flow gauging per site and measurements of depth, substrate and offset across 6-10 cross sections at each site. A stake was driven into the stream bed at each cross section, and used as a temporary stage. Two follow-up site visits were made by CRC staff who gauged flow (one gauging per site), and measured water level at each cross section. A change in water level of at least 25 mm or a 15 % change in flow during the follow-up gauging is typically required as a minimum, to enable adequate calibration of the flow-habitat model. The relationship between flow and habitat availability is subsequently assessed using RHYHABSIM, with the selection of habitat preference curves being informed by the invertebrate and fish species encountered during the ecological survey (Jowett et al. 2008).



Golder Associates

TITLE SAMPLE SITES

FEBRUARY 2013

PROJECT 0978110107

1

S:\GIS\Projects-Numbered\2009\09781x\10xxx\0978110_107_ECan_Orari_River_Envrio_Flows_CAN\MapDocuments\Figx_SiteLocations_GIS.mxd

3.0 SURVEY RESULTS

3.1 Stream Context

The Coopers Creek springs arise in paleo-channels associated with the Orari River floodplain (Burberry 2011) and are set amidst medium to high intensity agricultural land. Water derives from the shallow Orari River alluvial aquifer and a three day lag is observed between flows in the Orari River and up-welling in Coopers Creek (Figure 2). Approximately 700 m downstream of the springs Coopers Creek joins the intermittent Scotsburn Stream (Figure 1 & Figure 3). Coopers Creek retains permanent flow thereafter until an undetermined point upstream of the minimum flow site at SH72, below which Coopers Creek is currently subject to drying.

Figure 2: The large pond at the head of Coopers Creek looking downstream from the spring upwelling point. May 2011.

Figure 3: The confluence of the Scotsburn (left) and Coopers Creek looking downstream during a period of flow in the Scotsburn Stream. May 2011.

3.2 Habitat Description

Moving upstream from the Geraldine - Arundel Rd (SH72), toward the confluence with the Scotsburn Stream, Coopers Creek is channelised between flood banks. At the lower habitat assessment site, where detailed instream habitat data was collected, the stream bed was dominated by cobble-gravel substrates and alternated between pools, runs and riffles bordered by substantial growths of the macrophytes *Lepidium* sp. and *Mimulus* sp (Table 1). The stream is partially shaded by a range of exotic and native vegetation. Along the reach immediately below the confluence with the Scotsburn Stream, Coopers Creek has a gravel cobble substrate, but was severely choked with macrophytes such that the stream bed could not be easily observed. Above the confluence with the Scotsburn Stream the bed of Coopers Creek is predominantly covered with a thick (>5 cm) layer of fine sediment and continues to be dominated by thick growths of aquatic macrophytes (Table 1). The stream is no longer channelised and the wetted channel is broad and flow sluggish. After approximately 200 m the spring splits into three tributaries of approximately equal size. The southerly pair of streams arise from up-welling points within tree lined paleo-channels adjacent to Spring Farm, while the third stream flows along a short channelised section before meandering across paddocks to an impoundment. The spring source is located in swampy ground at the head of a pond. The entire lengths of the three streams are alternately lined in exotic trees, primarily willows, *Salix* sp., or surrounded by exotic pasture. There is no riparian fencing to prevent stock access to the upper reaches of the main spring, except around the pond, which looks to be used for duck shooting. Flow is generally sluggish along this upper reach of the spring and the stream bed is dominated by a thick layer of fine sediment. Cobble gravel substrates are present beneath the silt layer and can be readily exposed by disturbing the fine sediment. A number of small springs and up-welling points join the primary streams close to their spring heads. The farm pond has a piped outlet and appeared generally shallow with a silty bottom. The pond contained some *Potamogeton* sp., aquatic plants and long filamentous green algae were abundant.

Figure 4: The upper full habitat assessment site on Coopers Creek. May 2011.

Instream habitat measurements were made at two locations along Coopers Creek (Figure 1: upper and lower sites) and are detailed in Table 1. As described above there were some distinct differences between the upper and lower reach as delineated by the confluence with the Scotsburn Stream. The upper reach was on average twice as wide and twice as deep as the lower reach. Therefore, although both sections of stream had approximately 70 % run habitat the characteristics of those runs were quite different; velocity being lower in the upper reach compared to the lower reach. There was limited riffle habitat in the upper reach, but a greater proportion of pool. The overall degree of riparian shading was similar between sites although in the upper reach shading was both present and complete, as the stream was straddled by clumps of Willow (Figure 4 & Table 1), or absent. In the lower reach shading was partial, but present along much of the stream. As mentioned above substrates in the lower reach were composed of cobbles and gravel, while the stream bed in the upper reach was entirely overlain by fine silts.

Table 1: Physical characteristics of sites along Coopers Creek.

Parameters	Upper	Lower
Width(m) [a]	4.9 (3.3 - 8.2)	2.5 (1.5 - 3.4)
Depth (m)[a]	0.44 (0.05 - 1)	0.28 (0.01 - 0.70)
% Riffle	5	15
% Run	70	70
% Pool	25	15
% shade	25	25
Large cobble (128 -256 mm)	-	10
Small cobble (64 - 128 mm)	-	20
Large gravel (32 - 64 mm)	-	20
Med-large gravel (16 -32 mm)	-	20
Small-Med gravel (8 - 16 mm)	-	20
Small gravel (2 - 8mm)	-	10
Silt (<0.063	100	

Note: [a] mean (min - max)

3.3 Basic Water Quality

Water quality recorded in Coopers Creek spring was generally good relative to the objectives set out in the NRRP (2011) (Table 2). The water was cool for mid-summer (mean temperature at all sites was 13 °C) and well oxygenated, although dissolved oxygen (DO) concentrations were low (58 % and 6.2mg/L) at the top site. DO in this stream is likely to be consistently low close to the spring source due to microbial depletion of oxygen in groundwater. Downstream from the spring DO is expected to be higher, but to fluctuate between day and night due to the opposing influences of photosynthesis and respiration by aquatic macrophytes (Allen & Castillo 2007). Thus, DO would be highest in the afternoon of a sunny day and lowest around dawn. Conductivity was consistent along the reach (mean 84 µS/cm). There was a distinct positive downstream gradient in pH (ph range 5.6 – 7.1) which is typical of spring streams and derives from the release of supersaturated groundwater CO_2 to the atmosphere (Gray et al. 2011). When CO_2 dissolves in stream water a weak carbonic acid is formed. However, due to the difference in CO_2 concentration between the water and atmosphere CO_2 is lost from the stream to the atmosphere, the carbonic acid becomes weaker and pH higher. This process is entirely natural. Further water quality parameters, such as nitrate and faecal bacteria concentrations, were not measured. However, given the ready access of stock to the upper reaches of Coopers Creek it is likely that these parameters would exceed acceptable levels particularly in the silt deposits on the stream bed.

Table 2: Water quality measured in the field on 17 January 2012 at several sites along Coopers Creek spring.

Site	Temperature (°C)	DO (%)	DO (mg/L)	pH	Conductivity (µS/cm)
Top Coppers Creek	12.2	58	6.2	5.6	95
Scotsburn Stream confluence	13.0	115	12.1	6.6	82
Lower Coppers Creek	12.7	98	10.4	6.2	81
SH72 bridge	14.3	96	9.8	7.1	81
NRRP target[1]	20	70			

3.4 Invertebrate Communities

The Coopers Creek upper site had 11 invertebrate taxa, while 22 taxa were collected from the lower site. Consequently, invertebrate community composition in the upper and lower Coopers Creek sites was quite distinct (Figure 5). The upper site was dominated by the caddisfly *Oxyethira* sp. which feeds by piercing the stems of aquatic macrophytes and algae. Chironomid midge larvae, some crustaceans and oligochaeta worms were also common at the upper spring site. These taxa are typical of streams dominated by silty substrates and abundant growths of aquatic plants. The lower Coopers Creek site was dominated by the common mayfly *Deleatidium* sp. and the cased caddisfly *Pycnocentrodes* sp. This fauna is typical of a stream with clean gravel substrates, and good water quality. No rare or unusual taxa were observed at either site at the time of the survey.

The QMCI is an invertebrate community index designed to indicate water quality in a stream based on the diversity and abundance of aquatic invertebrates living within it (Stark 1985). The desired water quality outcome for Canterbury spring-fed plains streams suggested by the NRRP (2011) is a QMCI greater than 4.5. This target was achieved at the lower Coopers Creek site where invertebrate communities were indicative of clean water (Stark 1998) (Figure 6). However, the upper site had an invertebrate community indicative of probable severe pollution and did not approach the NRRP guideline.

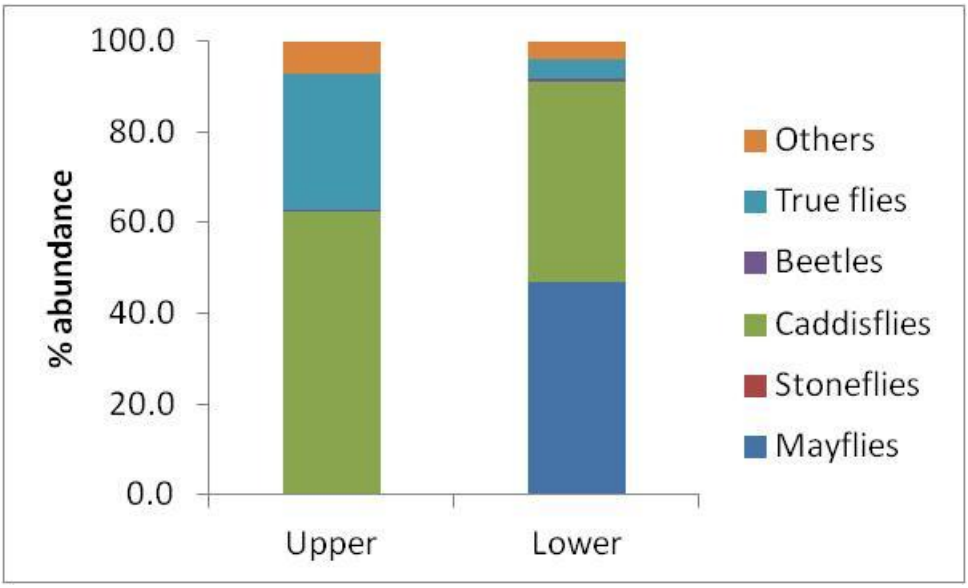


Figure 5: The relative abundance of invertebrate groups recorded in the upper and lower sites at Coopers Creek.

[1] Water quality outcomes for Canterbury rivers which are not in a natural state Table WQL5 (NRRP 2011)

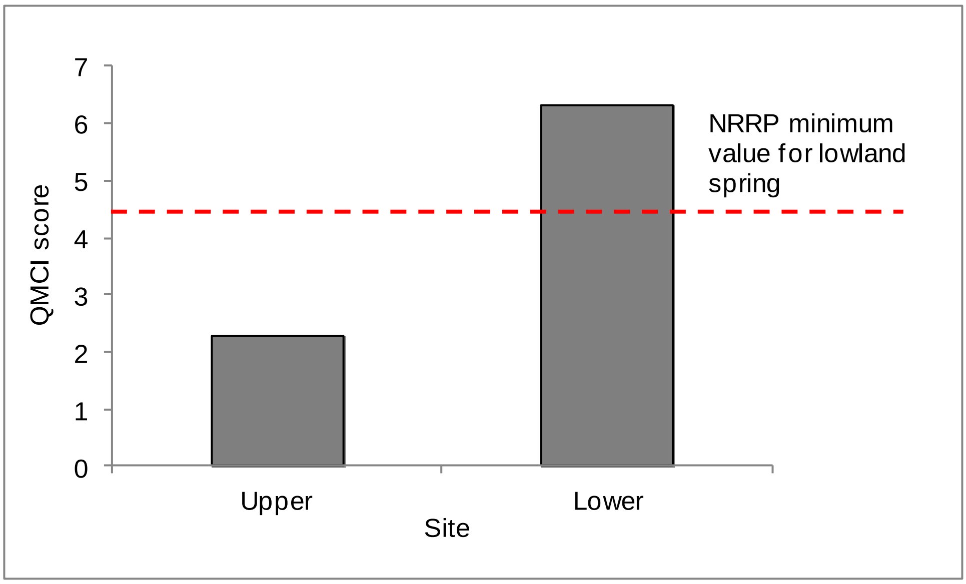


Figure 6: QMCI scores for sites along upper Coopers Creek. The horizontal red line show the desired NRRP (2011) water quality outcome for Canterbury spring-fed plains streams.

3.5 Fish Communities

Thirteen Gee minnow traps were placed overnight at both the source of the springs and in the top habitat study reach, and no fish were captured in any of the traps. Electric fishing disturbed, but did not capture, a single large, unidentified eel, *Anguilla* sp., at the top habitat study reach and a further individual at the confluence with the Scotsburn Stream. Both these sites were difficult to fish with an electric fishing machine (EFM) due to luxuriant growths of aquatic macrophytes. At the lower habitat assessment site nine upland bully, *Gobiomorphus breviceps,* were captured using the EFM, but no other fish were seen. Further downstream at the Geraldine Arundel Road (SH72) fish communities were more diverse. A single large unidentified eel was observed and eighteen upland bully, three juvenile brown trout, *Salmo trutta*, and six Canterbury galaxias, *Galaxias vulgaris* were caught. Based on the aquatic habitat present at the lower habitat assessment site, and its proximity to SH72, it is considered likely that juvenile trout and Canterbury galaxias may also occur at the lower habitat assessment site given suitable water quality.

Table 3: Fish taxa recorded at sites along Coopers Creek.

Site	Eel	Upland bully	Canterbury galaxias	Brown trout
Top Coppers Creek	✓			
Scotsburn Stream confluence	✓			
Lower Coppers Creek		✓		
SH72 bridge	✓	✓	✓	✓

An anecdotal account from Ad Sintenie (8 February 2012) who lives adjacent to Coopers Creek, at the lower habitat assessment site, indicated a decline had occurred in the diversity and abundance of fish communities over the last 20 years. According to this account large (40+ cm) trout and eels, abundant bullies and galaxiids were regularly observed in the creek, but had been notably absent during the last 3-4 years commensurate with a decline in flow (Figure 7).

Similarly, staff from Fish and Game New Zealand have carried out fish salvage operations in Coopers Creek below SH72 during three of the last five years compared to four or five occasions over the preceding twenty five years (Mark Webb Pers. Comm.). Fish become stranded as flow is lost to the alluvial aquifer and the salvage operation is instigated by a resident adjacent to the stream whom contacts the local Fish and Game office when the stream begins to dry. Numbers of large fish (trout and eels) observed during salvage operations have declined. Twenty years ago several hundred fingerling trout and twenty to forty adults would be observed, compared to twenty to thirty fingerlings and one or two adults currently.

Figure 7: Stranded upland bullies in a dry Coopers Creek at the SH72. March 2010.

3.6 Habitat Modelling

Instream habitat measurements were made at two locations along Coopers Creek (Figure 1: upper and lower sites). The flow in Coopers Creek at Mulligans Farm, upstream of the confluence of Coopers Creek and the Scotsburn Stream, was measured over the 2011-2012 spring and summer period. The dates of habitat measurements and subsequent flow gauging are shown in relation to flow in Figure 8. The 2011-2012 irrigation season was abnormally wet and Coopers Creek did not approach the current minimum flow of 50 L/s. During this period there was little variation in flow between gaugings, limiting the ability to calibrate the RYHABSIM flow-habitat model (Table 4). Furthermore, water level changes were found to be inconsistent between the cross sections and with changes in flow, an effect often present in macrophyte choked channels where the macrophyte abundance prevents the water level dropping as flow decreases. These factors prevented any meaningful attempt to model habitat in relation to flow.

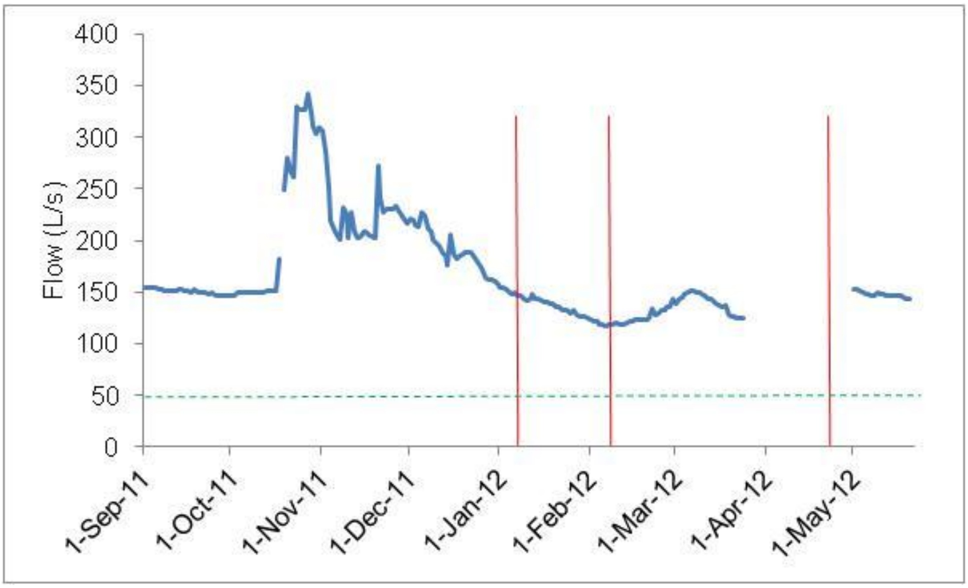


Figure 8: Flow (L/s) in Coopers Creek at Mulligans (site 69516), above the confluence with the intermittent Scotsburn Stream between September 2011 and May 2012.

Note: The vertical red lines indicate the dates of the initial ecological assessment and subsequent follow up flow gaugings, while the horizontal green line indicates the current minimum flow of 50 L/s. Flow data are courtesy of CRC.

Table 4: Flow recorded at upper and lower Cooper Creek spring sites during the initial survey and on two following occasions.

Site	Initial flow (l/s)	Follow up flow (l/s)	Follow up flow (l/s)
Top /Upper	69	72	73
Ads house/Lower	141	137	109

It is widely recognised that it may often be difficult to undertake instream habitat modelling in spring-fed streams (Allen & Hay 2011). The stable flow regimes restrict calibration measurements to a narrow range and prevent extrapolation of flows, while (as noted above) macrophyte biomass can have a significant influence on water levels and confound attempts at flow gauging and the development of ratings curves for flow modelling. The occurrence of such high macrophyte biomass can also impact upon diurnal oxygen concentrations in streams to the extent that water quality becomes of greater concern than water quantity, although the two factors are inextricably linked. Allen & Hay (2011) point out the undesirable subjectivity of the expert panel approach as an alternative to hydraulic habitat modelling but concede there are few refined alternatives in use in New Zealand for spring fed streams.

However, by comparing the width and depth at each site (Table 1) it is possible to assess the potential sensitivity of habitat availability to low flow. When the flow in a stream is reduced the degree of impact upon suitable habitat availability is partially dependent upon the width and depth of the stream. If the stream is generally shallow a reduction in flow may result in a rapid decline in suitable habitat for some taxa as the stream falls below a critical depth, particularly if there are few deeper areas to act as refuge during low flows. This would be the case in the lower reach of Coopers Creek where, by virtue of rapid flows, depths are lower than in the upper reach. Conversely, in the upper reach where the stream is on average deeper the same reduction in flow will have less of a proportional impact on the availability of habitat for those taxa. However, biota are unlikely to be limited by habitat area in the upper reach, rather habitat quality and water quality are likely to determine taxa occurrence.

3.7 Ecological Summary

In summary upper Coopers Creek may be separated into two relatively distinct parts. The upper reaches, including the springs, above the confluence with the Scotsburn Stream appear to contain very few fish and an invertebrate community typical of a macrophyte dominated stream with silty substrates. This reach is assumed to currently have permanent flow. Below the Scotsburn Stream the macrophyte growths are still considerable but substrates are predominantly sand, gravel and cobbles. This is considered to be a result of scouring by occasional floods in the Scotsburn Stream. Invertebrate communities are dominated by taxa which have a preference for those substrates and indicate generally good water quality. Fish become more abundant and diverse further downstream towards SH72. However, currently the stream typically dries downstream shortly thereafter.

Anecdotal evidence suggests there has been a relative decline in the flow and ecological values of the creek, particularly over the last 3-4 years. It would seem that the greatest ecological values are located in the lowest reach of the stream which is a losing reach and currently subject to drying in the vicinity of SH72. Whether fish taxa observed in the lower reach could naturally also inhabit the reaches upstream of the Scotsburn Stream confluence is a moot point; depending on whether the fish are limited by habitat and water quality degradation or natural characteristics of water quality in the springs. Irrespective of this point the length of Coopers Creek which currently provides suitable habitat to a fish and invertebrate fauna is short and regarded as flow sensitive.

Overall, the ecological values of the upper Coopers Creek vary depending upon the location. Above the Scotsburn Stream confluence values are poor and there is considerable potential for improvement given the currently permanent flow. Downstream of the Scotsburn Stream confluence ecological values increase due to the scouring effect of occasional flood flows from the hill-fed Scotsburn Stream. Given the paucity of spring-fed plains streams in Canterbury that have silt free substrates this reach of Coopers Creek may be considered to have high ecological values. However, the reach remains subject to considerable growths of macrophytes and is short by virtue of drying close to SH72. Restoration of the upper reaches of Coopers Creek, above the Scotsburn Stream, has the potential to markedly increase the area of habitat and refuge for the stream biota currently found in the overall reach.

4.0 INSTREAM FLOW REQUIREMENTS

There is a paucity of flow information for Coopers Creek which makes recommendations of a suitable ecological minimum flow difficult. During Golder's initial assessment of the Coopers Creek flows on the 17 January 2012, the upper and lower sites were 69 and 141 L/s, respectively. The minimum flow for Coopers Creek at SH72, 2 km downstream of the springs and 0.5 km below the lower site, stipulates restrictions should occur when flow reaches 50 L/s. Given that the springs lose approximately 54 L/s of flow between Springs Farm and SH72 (Burberry 2011), flows at SH72 during Golders initial assessment would have been in the vicinity of 100 L/s. At the time there appeared to be ample flow in the stream, while fish and invertebrate communities were healthy. However, in our opinion a reduction in flow by half, to 50 L/s, would result in a decline in water quality and a significant reduction in available habitat. Coopers Creek at SH72 is currently known to dry during low rainfall years and presumably the area available for refuge and later supply of colonists for this reach is the permanently flowing section upstream. However, the paucity of fish in the apparently suitable habitat upstream at the lower habitat assessment site suggests water quality in this reach may not be optimal. Given the abundant growths of macrophtyes in the upper reaches of the springs and naturally low DO concentrations in up-welling groundwater it is likely that diel fluctuations in DO may be deleterious to fish in this reach. Consequently, the restriction of fish populations in the lower reach occurs from two directions; drying downstream and poor water quality upstream.

According to Burberry (2011) a consequence of changing the minimum flow conditions for groundwater abstraction in the vicinity of Coopers Creek to a flow of 75 % of MALF at the Orari River Gorge site would equate to an equivalent flow in Coopers Creek at SH72 of 20 L/s. Effectively this would result in an increase to the extent and duration of drying in the lower reach, a degradation of water quality in the permanently flowing reaches and a significant reduction in available habitat. It is Golder's opinion that 20 L/s would not be a sufficient residual flow at SH72 to sustain the ecological values currently present. However as noted below there is considerable uncertainty around the relationship between flow in the Orari River and Coopers Creek. Consequently, the risk to the current ecological values of managing flow in Coopers Creek from a distant minimum flow site is considerable.

5.0 RECOMMENDATIONS

Burberry (2011) suggests that it would be inappropriate to manage Coopers Creek depleting groundwater abstractions from the Orari River due to the flow sensitivity of Coopers Creek and the absence of a robust relationship between the Orari River minimum flow site and Coopers Creek. Golder agrees with these conclusions and suggests that in view of the short and flow sensitive reach of the stream which contains healthy ecological communities this stream should be managed as a separate sub-catchment of the Orari River with its own minimum flow at SH72. A minimum flow on the Orari River is a viable option if a good relationship between flow in Coopers Creek and the Orari River can be established. Unless the relationship between flows in Coopers Creek and the Orari River can be substantially improved there would be significant ecological risks to the fauna of Coopers Creek from water abstraction restrictions based on flows in the Orari River.

Following the report of Burberry (2011) CRC have collected further flow data from Coopers Creek and have also reviewed the location of the minimum flow site in the Orari River. The current CRC recommendation is to tie all surface and stream depleting takes in the catchment to a minimum flow site up-stream of Ohapi Creek. Further hydrological analysis to establish a relationship between the Orari River, Coopers Creek and adjacent groundwater might allow abstraction in the Coopers Creek sub-catchment to be managed with acceptable certainty. However, any minimum flow applied to the stream depleting takes impacting on Coopers Creek should be configured in such a way that the stream at SH72 does not fall below the current minimum flow of 50 L/s as a result of abstraction, so that the ecological values around and upstream of SH72 are protected.

As well as the magnitude of low flows the duration spent at or below that flow has implications for biota in the stream. Sustained low flow below the minimum may occur if restrictions are managed from afar as a result of the lag between the Orari River and Coopers Creek. Even if the lag time is quantified and incorporated into flow restrictions, or indeed if restrictions are managed from Coopers Creek itself, abstraction may cause a stream to be held at a minimum flow for extended periods of time. Under natural conditions flows are seasonally variable and periods of higher flow, be they winter months or wet years, allow for a recovery of biota from low flow events. In the context of spring streams variable flows do not refer to flushes and floods observed in hill-fed stream, but rather to periods of sustained higher flow. Accordingly, allocation and minimum flows should be configured such that they do not increase the duration of low flows and retain a proportion of the natural flow range over any year, i.e., higher minimum flows during periods of higher natural baseflow. However, a reliable naturalised flow series would be required before seasonal flow variations can be adequately quantified.

A flow recommendation that would offer a high level of protection for the stream biota in this small and short spring-fed stream would typically be in the vicinity of 90 % of naturalised seven day mean annual low flow (7DMALF) (Golder 2012). Until a reliable naturalised 7DMALF estimate is made for this section of Coopers Creek, we recommend maintaining the current minimum flow. Golder suggests that any reduction in the current minimum flow could result in a significant decline in the extant ecological values of the stream. Equally, it would not currently be scientifically defensible to increase the minimum flow, in the absence of a good hydrological record.

Finally, habitat and water quality in the upper spring-fed reaches of Coopers Creek could be improved through the management of silt inputs and macrophyte growth. Fencing to prevent stock access would reduce further inputs of fine sediment and allow riparian vegetation to partially shade the stream and suppress macrophyte growth. This in turn will reduce the potential impact of macrophytes on low DO and improve habitat conditions. Thereby, the potential area of available refuge for fish and invertebrates would increase off-setting the negative impacts of low flows.

6.0 REFERENCES

Allen C, Hay J 2011. Setting flows in spring-fed streams: issues and recommendations. Prepared for Environment Southland by the Cawthron Institute.

Allen JD, Castillo MM 2007. Stream Ecology: structure and function of running waters. Second edition. Springer, Dordrecht, Netherlands.

Burberry L 2011. Review of the spring-fed Coopers Creek, South Canterbury. Prepared for Environment Canterbury. Lincoln Ventures Ltd. Report No. 1050-8-R1.

Golder 2012. Te Waihora/Lake Ellesmere catchment flow review: ecological values and flow recommendations at minimum flow sites. Report No. 0978110119 prepared for Canterbury Regional Council. P 24.

Gray DP, Harding JS, Elberling B, Horton T, Clough TJ, Winterbourn MJ 2011. Carbon cycling in floodplain ecosystems: outgassing and photosynthesis transmit soil $\delta^{13}C$ gradient through stream food webs. Ecosystems 14: 583-597.

NRRP 2011. Canterbury natural resources regional plan, chapter 4 water quality prepared by Canterbury Regional Council, operative 11 June 2011.

Jowett I. G.; Hayes J. W.; Duncan M. J. 2008: A guide to instream habitat survey methods and analysis. NIWA Science and Technology Series No. 54.

Stark JD. 1985. A macroinvertebrate community index of water quality for stony streams. Water and Soil Miscellaneous Publication 87: 53 p. Wellington: National Water and Soil Conservation Authority.

Stark JD 1998. SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. New Zealand Journal of Marine and Freshwater Research 32: 55-66.

Stark JD, BoothroydIKG, Harding JS, Maxted JR, Scarsbrook MR 2001. Protocols for sampling macroinvertebrates in wadeable streams, Prepared for the Ministry of the Environment, Sustainable Management Fund Project No.5103. 57p.

APPENDIX A

Report Limitations

REPORT LIMITATIONS

This Document has been provided by Golder Associates (NZ) Ltd ("Golder") subject to the following limitations:

(i). This Document has been prepared for the particular purpose outlined in Golder's proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

(ii). The scope and the period of Golder's Services are as described in Golder's proposal, and are subject to restrictions and limitations. Golder did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Document. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Golder in regards to it.

(iii). Conditions may exist which were undetectable given the limited nature of the enquiry Golder was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required.

(iv). In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. Golder's opinions are based upon information that existed at the time of the production of the Document. It is understood that the Services provided allowed Golder to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

(v). Any assessments made in this Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Document.

(vi). Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Golder for incomplete or inaccurate data supplied by others.

(vii). The Client acknowledges that Golder may have retained subconsultants affiliated with Golder to provide Services for the benefit of Golder. Golder will be fully responsible to the Client for the Services and work done by all of its subconsultants and subcontractors. The Client agrees that it will only assert claims against and seek to recover losses, damages or other liabilities from Golder and not Golder's affiliated companies. To the maximum extent allowed by law, the Client acknowledges and agrees it will not have any legal recourse, and waives any expense, loss, claim, demand, or cause of action, against Golder's affiliated companies, and their employees, officers and directors.

(viii). This Document is provided for sole use by the Client and is confidential to it and its professional advisers. No responsibility whatsoever for the contents of this Document will be accepted to any person other than the Client. Any use which a third party makes of this Document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this Document.

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australia & NZ	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

AUCKLAND

Tel +64 9 486 8068
Fax +64 9 486 8072

Level 2
Nielsen Centre
129 Hurstmere Road
Takapuna
Auckland 0622

PO Box 33-849
Takapuna 0740

TAURANGA

Tel +64 7 928 5335
Fax +64 7 928 5336

78 Maunganui Road
Tauranga 3116

PO Box 13611
Tauranga Central
Tauranga 3141

HAMILTON

Tel +64 7 928 5335
Fax +64 7 928 5336

Ruakura AgResearch Centre
Room 31 in the Homestead
East Street
Hamilton 3214

PO Box 19-479
Hamilton 3244

NELSON

Tel +64 3 548 1707
Fax +64 3 548 1727

Level 3
295 Trafalgar Street
Nelson 7010

PO Box 1724
Nelson 7040

CHRISTCHURCH

Tel +64 3 377 5696
Fax +64 3 377 9944

Level 1
214 Durham Street
Christchurch 8011

PO Box 2281
Christchurch 8140

DUNEDIN

Tel +64 3 479 0390
Fax +64 3 474 9642

Level 9A
John Wickliffe House
265 Princes Street
Dunedin 9016

PO Box 1087
Dunedin 9054

Golder Associates