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The Nevis River fishery: A review

Prepared for

Clutha Fisheries Trust

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A Review.

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by

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Cover Photo: Upper Nevis River, Dean Olsen, December 2002.

EXECUTIVE SUMMARY

The Nevis River has a reputation among anglers as a back-country fishery where anglers can spot and target large fish amongst a spectacular high country Central Otago setting. It is currently included in the Water Conservation (Kawarau) Order (WCO). However, there is a provision within the WCO that would allow hydroelectric development in the Nevis, something that has the potential to have significant adverse effects on the fishery. This report reviews information on the Nevis River, including the natural characteristics of the Nevis catchment, the fishery and the likely consequences of hydroelectric development and outlines aspects of the Nevis fishery that require further research.

The Nevis has high natural and historical values, flowing through a typically treeless and largely unmodified Central Otago landscape. The fishery consists solely of brown trout upstream of the lower reaches, possibly as a result of barriers to fish passage in the lower gorge. The fishery receives relatively low angling pressure, a characteristic of backcountry trout fisheries, but is highly valued for its reputation for producing trophy trout (ranking 3rd out of 256 rivers in angler usage surveys). Anglers travel long distances to fish the Nevis (ranking 3rd out of 175 rivers in the mean distance travelled by anglers), providing further evidence of how highly it is valued as a fishery.

The impoundment resulting from proposed hydro-electric development in the Nevis will flood half of the low-gradient reach upstream of Nevis Crossing, the reach of river supporting the greatest number of fish in the catchment. The proposed scheme will also result in residual flows in a section of river of about 8.2 river kilometres in the lower gorge and fluctuating flows in the 3.6 km from the power house to the Kawarau confluence are likely to reduce the suitability of this section of river as habitat for trout and macroinvertebrates.

The fishery value of any impoundment formed by damming the Nevis will depend on the management of water levels. However, lake and reservoir fisheries are already common in Otago whereas river fisheries, especially high quality backcountry river fisheries are uncommon in comparison with other regions. Damming will disrupt the movement of fish from the lower gorge to Nevis Crossing. However, fish passage must be maintained under the provisions of the Kawarau WCO so any planned hydro-electric development needs to include structures to enable fish passage past the dam.

Further fisheries survey work is recommended in the Nevis including a drift-diving program in 5 reaches of the river to fill current knowledge gaps on the distribution and size structure of fish within the catchment and a tagging or radio tracking exercise to identify any patterns of movements of fish within the catchment. This information will enhance our understanding of the fishery and how it is likely to be affected by proposed development.

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Report reviewed and approved for release by:

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1. INTRODUCTION

The Nevis River rises in the Garvie and Hector Mountains and flows through a basin of extensively grazed tussock grassland before entering a rugged gorge, through which it flows until its confluence with the Kawarau River downstream of Nevis Bluff. The Nevis has a reputation among anglers as a back-country fishery where anglers can spot and target large fish amongst a spectacular high country setting. It is currently included in the Water Conservation (Kawarau) Order, with provisions to protect its scenic and recreational values (See Section 1.2). However, Pioneer Generation has publicly expressed an interest in pursuing hydroelectric development in the Nevis, something that has the potential to cause significant disruptions to the existing fishery.

This report reviews information on the Nevis River, including the natural characteristics of the Nevis Catchment, the fishery, fishery flow requirements, and the likely consequences of hydroelectric development. It then outlines aspects of the Nevis fishery that require further research.

1.1 Site characteristics

The Nevis River drains a catchment of 689 km^2, most of which is unmodified tussock grassland. Recorded flows in the Nevis at Wentworth Station between April 1977 and February 2004 range from 2.9 m^3s^{-1} to a maximum of 954 m^3s^{-1}, with a mean annual flow of 17.8 m^3s^{-1}, a median flow of 12.3 m^3s^{-1} and a mean annual low flow of 5.1 m^3s^{-1} (Table 1). Upstream of Nevis Crossing, the substrate is dominated by gravels (36.4%), cobbles (29.4%) and boulders (17.7%) (Jowett 2004). Instream habitat is dominated by runs (48%) and riffles (40%) upstream of Nevis Crossing, with pools representing approximately 12% of instream habitat (Jowett 2004).

Table 1 Flow statistics for the Nevis River at Wentworth Station, based on flow records from April 1977 to February 2004 (Otago Regional Council, unpublished data).

Flow statistic	Flow (m^3s^{-1})
Mean flow	17.8
Median flow	12.3
Minimum flow	2.9
Mean annual low flow	5.1
Highest flow	954

1.2 Water conservation (Kawarau) order (WCO)

The Nevis is included in the Water Conservation (Kawarau) Order, which was gazetted on 20 March 1997 (for full text of the order, see Appendix 1). The WCO includes a provision that allows hydro electric development in the Nevis River, subject to restrictions regarding the flows and fish passage and the extent of impounded water (Appendix 1). The latter states that any impounded water must not extend beyond F42:943468, which is approximately 6 km upstream of Nevis Crossing (Figure 1), and that fish passage must be maintained.

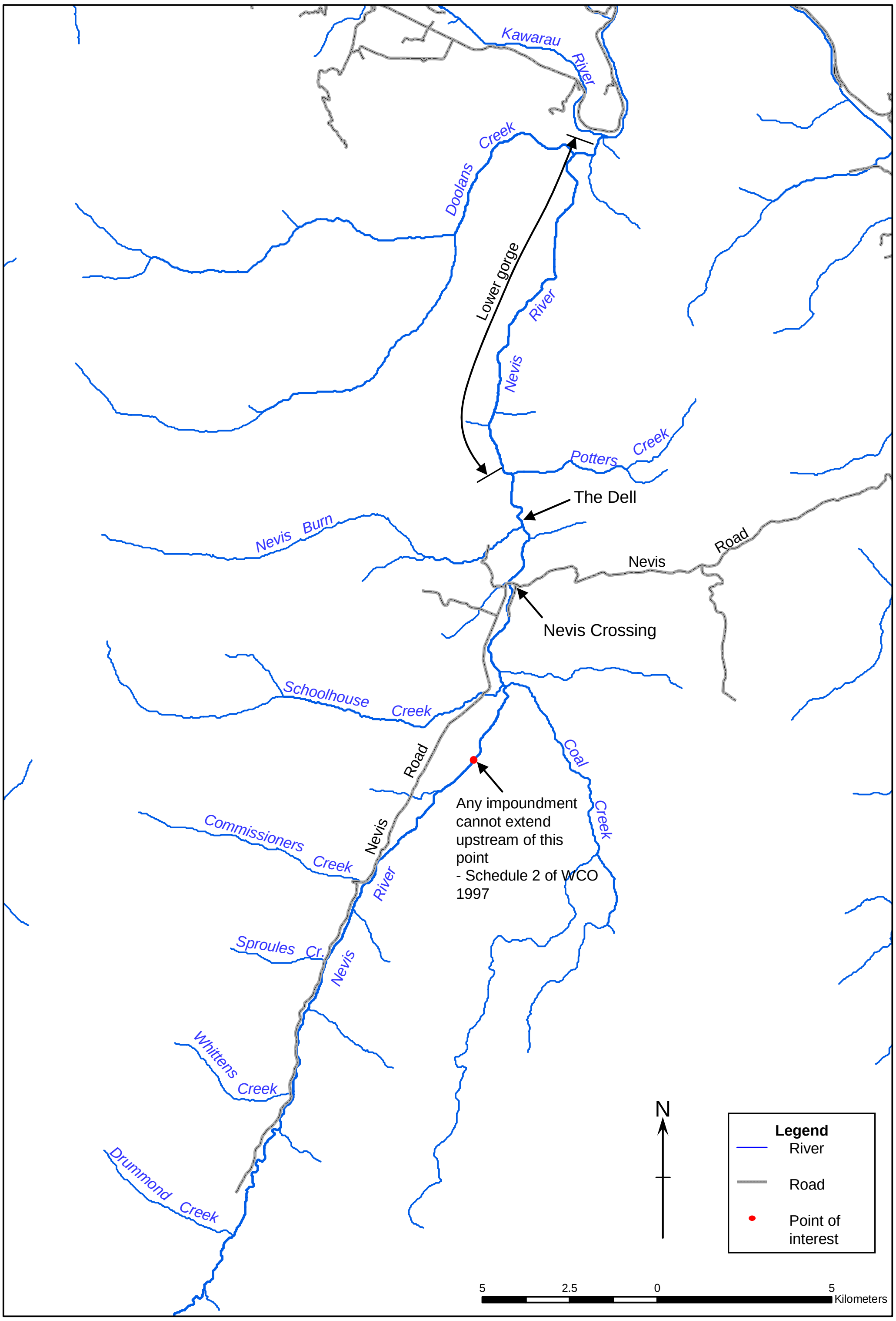

Figure 1 Map of the Nevis River Catchment.

2. THE NEVIS FISHERY

2.1 Angling regulations

The Nevis River is open for angling from the 1st of October until the 30th of April. Only fly fishing is allowed and the bag limit is one fish per angler per day.

2.2 Natural character

The natural environment and scenery is a major factor drawing anglers and others to the Nevis catchment (see Section 2.7 – Angler motivation). These values are recognised in Schedule 1A of the Otago Regional Council Regional Water Plan (ORC 2004) with the whole of the Nevis catchment being identified as having outstanding natural feature or landscape values particularly with regard to scenery and recreation (Table 2).

Table 2 Natural and human use values of the Nevis River, as identified in Schedule 1A of the Otago Regional Water Plan (2004).

Water body	Ecosystem values	Outstanding natural feature or landscape
Nevis	- Large water body - No artificial barriers - Bed of sand, gravel & bedrock - Trout spawning habitat - Trout juvenile raring habitat - Free of aquatic pest plants - Significant presence of trout - Waterfowl diversity - Significant presence of rare waterfowl - Indigenous invertebrate diversity (upstream of Nevis Crossing)	Main stem gorge from Nevis Crossing to Kawarau River confluence: Outstanding (a) for its wild characteristics; (b) for recreational purposes, in particular fishing and kayaking Main stem above Nevis Crossing to source: Outstanding (a) for its scenic characteristics (b) for recreational purposes, in particular fishing High level of naturalness above Nevis Crossing to its source Spectacular river gorge, white water and rapids in main stem from Nevis Crossing to confluence with Kawarau River

The high scenery and landscape values of the valley relate to the geological character of the area and the lack of development apparent in the valley. The valley is dominated by unmodified tussock grassland and scrubland and is treeless, apart from some trees surrounding homesteads in the vicinity of Nevis Crossing.

The unmodified nature of the landscape is also apparent in the river and the river has a largely natural geomorphology. Any effects of historic gold mining are no longer apparent in the river today due to natural riverine processes. Water quality is high with levels of dissolved oxygen, very low nutrient concentrations, low counts of faecal coliforms and high water clarity (Otago Regional Council, unpublished data).

The river is classified as a nationally important backcountry trout fishery in the Sports Fish and Game Management Plan for Otago (Otago Fish and Game Council 2003).

2.3 Fish species

Brown trout are the primary sports fish in the Nevis and are found throughout the mainstem, with juveniles in many of the tributaries. Some rainbow trout are caught in the lower gorge close to the confluence with the Kawarau and some small brook trout are found in the headwaters and in some tributaries (Jellyman & Bonnett 1992; Jellyman & Graynoth 1994; Jowett 2004; National Freshwater Fish Database). The upstream distribution of rainbow trout appears to be limited by waterfalls in the lower gorge (Figure 2) (Trotter 2006). These same barriers are expected to prevent the upstream movement of brown trout from the lower Nevis and Kawarau Rivers.

The native fish, *Galaxias gollumoides* is also found in the mainstem and tributaries of the Nevis River (Wallis & Waters 2003; National Freshwater Fish Database). Interestingly, the Nevis population is the only *G. gollumoides* population in the Clutha catchment. This is because the Nevis used to flow south into the Mataura catchment, where *G. gollumoides* is common (Wallis & Waters 2003). The Nevis population of *G. gollumoides* was separated from Southland populations of *G. gollumoides* about 1-2 million years ago, when geological uplift resulted in the Nevis changing course to flow northwards into the Kawarau (Wallis & Waters 2003).

Figure 2 Photograph of a waterfall in the lower Nevis River (NZMS: F42 954 589) which is likely to prevent upstream migration of trout. Flow was approximately 12 m^3s^{-1} when this photo was taken.

2.4 Access

The Nevis Road, a dry-weather four wheel drive track which runs from Bannockburn (near Cromwell) to Garston in the Upper Mataura catchment, provides easy access to most of the Nevis upstream of, and immediately below Nevis Crossing. The lower gorge, however, from Nevis crossing to the confluence with the Kawarau, is relatively inaccessible due to the steep terrain and limited vehicular access points.

2.5 Fishable water

There are approximately 12 km, or three angler days of prime fishable water in the Nevis, which represents almost 5% of the total length of fishable backcountry rivers in Otago (Walrond & Hayes 1999). However, this is likely to be an underestimate of the amount of fishable water in the Nevis, since it does not include fishable water upstream of Sproules Creek (approximately 5-7 km), or the 12.5 km of water present in the lower gorge (including The Dell), downstream of Nevis Crossing, probably because access to this reach is limited due to the rugged terrain and lack of roads.

2.6 Fishery use

It is estimated that the Nevis River supports 250 angler days per year (standard error = 80 angler days y^{-1}), with peak usage occurring in December and January (Unwin & Brown 1998; Unwin & Image 2003). This ranks the Nevis as the 10th most fished river of 15 the backcountry rivers in Otago identified by Walrond & Hayes (1999) (Table 3). The Makarora, Manuhurekia, Pomahaka and Taieri Rivers were not included in this analysis, as the National Angler Survey, on which this analysis was based, did not differentiate the backcountry sections of these rivers from other reaches. The national angler survey may have underestimated the amount of usage of the Nevis given the large proportion of visiting anglers (32% overseas anglers), as day licence holders were not surveyed.

However, this analysis is somewhat simplistic, as the most heavily fished rivers were also generally those with the most fishable water (Table 3). To overcome this, we estimated the maximum capacity of each river: the amount of fishable water available in each river (angler days – based on Walrond & Hayes 1999) multiplied by the length of the fishing season for each river (Table 3). This information should be interpreted cautiously as it relies on the estimates of fishable water and angler usage. Based on this approach, the Nevis is currently fished between a quarter and half of its maximum potential usage. This ratio is an average, and there will be times when there are more anglers on the water than the three angler-days identified in Table 3, and there will be days when the river is not fished. Also, this ratio does not take fish behaviour into account, and a higher rate of usage may not allow fish adequate recovery time after disturbance by previous anglers, so the potential maximum usage may not be sustainable in the long term. Usage of the Nevis as a proportion of the maximum potential usage falls in the middle of the range estimated for other Otago backcountry rivers (Table 3).

The level of usage based on information from the national angler survey (NAS) may not be a reliable measure of the value of a particular river either, since those close to urban centres are likely to be heavily fished, simply because of their proximity to population centres. Unwin & Deans (2003) propose using estimates of travel distance in addition to estimated usage to gauge how valued a fishery is, since if anglers value a river highly, then, presumably, they will be prepared to travel further to fish it. On the basis of the mean distance travelled, the Nevis ranked 3rd out of the 175 rivers that received more than 100 angler days within a season, with anglers travelling a mean distance of almost 150 km (back-calculated from log-transformed data - Unwin & Deans 2003). Unwin & Deans (2003) also calculated an importance score based on usage and travel distance (p. 18, Unwin & Deans 2003) which ranged from 1.48 (Maitai River) to 3.59 (Tekapo River). The Nevis ranks in the top 16% of the 175 rivers considered by Unwin & Deans (2003), with a score of between 2.9 and 3.0. This indicates that, whilst the Nevis receives a comparatively low amount of angling effort (Table 3), the anglers who fish there value it highly enough to make a considerable effort to access it. Other back country rivers in Otago such as the Hunter (3.2), Makarora (3.1), Shotover (2.9) and Taieri (2.9) also score highly, indicating that many anglers travel considerable distances to fish Otago rivers.

Table 3 Fishable water (from Walrond & Hayes 1999) and estimated usage (angler days) for Otago backcountry rivers recorded in the 2001/2002 National Angler Surveys (from Unwin & Image 2003).

River	Fishable water Angler days	Fishable water km	Usage 2001-2002 (Angler days)	Potential usage (angler days per season)*	Usage: potential usage ratio Mean (±1SE)
Routeburn	1	3	420 (±340)	211	1.99 (±1.61)
Hunter	7	27	1630 (±580)	1477	1.10 (±0.39)
Matukituki	4	15	530 (±280)	844	0.63 (±0.33)
Von	4	19	520 (±190)	844	0.62 (±0.23)
Fraser	4†	20.5†	530 (±390)	844	0.62 (±0.46)
Timaru	4	8.75	480 (±150)	844	0.57 (±0.18)
Nevis	3	12	250 (±80)	633	0.40 (±0.13)
Caples	3	16	230 (±120)	633	0.36 (±0.19)
Greenstone	5	28	370 (±170)	1055	0.35 (±0.16)
Rees	2	11	130 (±90)	422	0.31 (±0.21)
Lochy	5	20	260 (±170)	1055	0.25 (±0.16)
Young	3	9.25	120 (±100)	633	0.19 (±0.16)
Wilkin	4	7.5	140 (±90)	844	0.17 (±0.11)
Dingleburn	4	10.75	100 (±80)	844	0.12 (±0.09)
Motatapu	2	5	20 (±20)	422	0.05 (±0.05)

* Fishable water (angler days) multiplied by the length of the 2001-2002 fishing season (211 days in the Fraser & Nevis rivers, 180 days in all others)
† Estimated fishable water for the whole river.

2.7 Encounter rates

Anglers on the Nevis encounter relatively few other anglers (median=0; Walrond & Hayes 1999) and usually have long stretches of river to themselves (0.08-0.22 anglers km^{-1} d^{-1}; Scott & Wright 2005). This is related to the relatively low angler usage (250 angler days per year versus 211 days in the fishing season).

In a survey of anglers on the Nevis conducted between 2000 and 2002, 39% were from Otago, 29% from elsewhere in New Zealand, 19% were guided tourists and 13% were unguided tourists (Trotter 2005). The proportion of New Zealand-resident anglers (68%) is higher than that observed in the Upper Oreti (41%; Sutherland 2002) and Caples Rivers (43%; Walrond 1997).

2.8 Angler motivation

The natural environment and scenery were primary motivations for anglers fishing the Nevis, with 98.4% of anglers interviewed in the Nevis River angler survey saying that it was essential (61.9%) or important (36.5%) to their fishing experience (Trotter 2005). Anglers surveyed on the Nevis also valued the peace, solitude, and opportunity to spot trout (Trotter 2005).

The Nevis has a reputation for providing the opportunity to fish for trophy trout, being ranked 3rd out of 256 New Zealand rivers for its ability to produce trophy trout (Unwin *circa* 1993). These trophy fish are the exceptional characteristic of the Nevis, and it is important to establish the basis for this reputation and the characteristics of the Nevis that result in such fish through further research (see Section 4).

3. LIKELY CONSEQUENCES OF HYDRO-ELECTRIC DEVELOPMENT

3.1 Proposed hydro-electric development

A report prepared for the Ministry of Economic Development (East Harbour Management Services 2004) provides an indication of the likely nature of hydro-electric development in the Nevis Valley. This report describes a two-dam scheme, with a large-volume storage lake (with a surface area of up to 400 ha) being formed by the upper dam, just downstream of the Nevis Crossing bridge, supplying another dam constructed approximately 2 km downstream (Figure 3). The lower dam will capture flow from the Nevis Burn and divert it, along with water from the upper dam, into a 6.5 km tunnel which will carry water to penstocks that will supply the power station on, or about, the 300 m contour line (Figure 3). Minimum and maximum likely footprints of the reservoirs formed by such a scheme are presented in Figure 4.

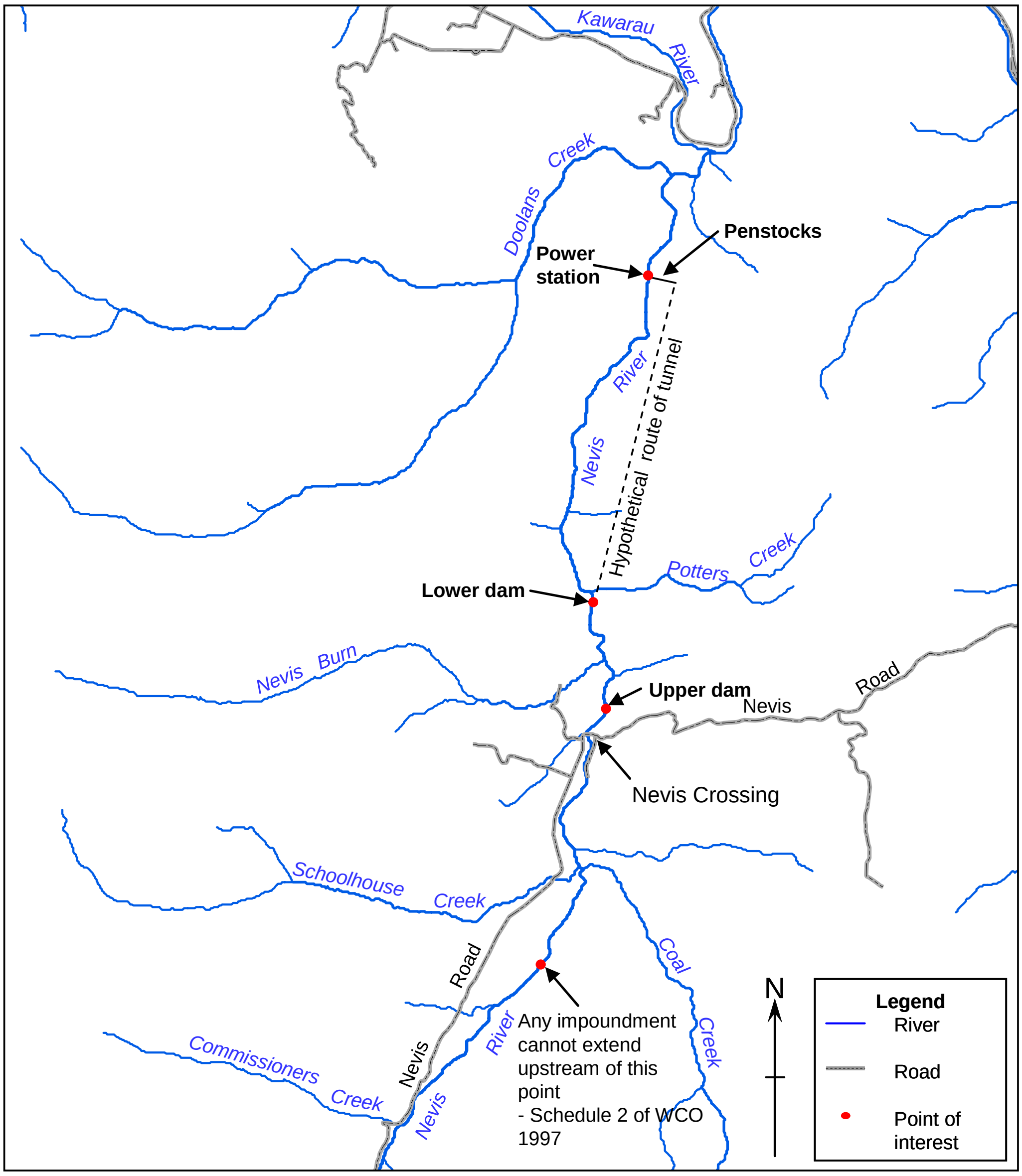

Figure 3 Map of the Nevis River (NZMS: F42 954 589) showing possible hydroelectric development (based on description in East Harbour Management Services 2004). Location of structures is approximate.

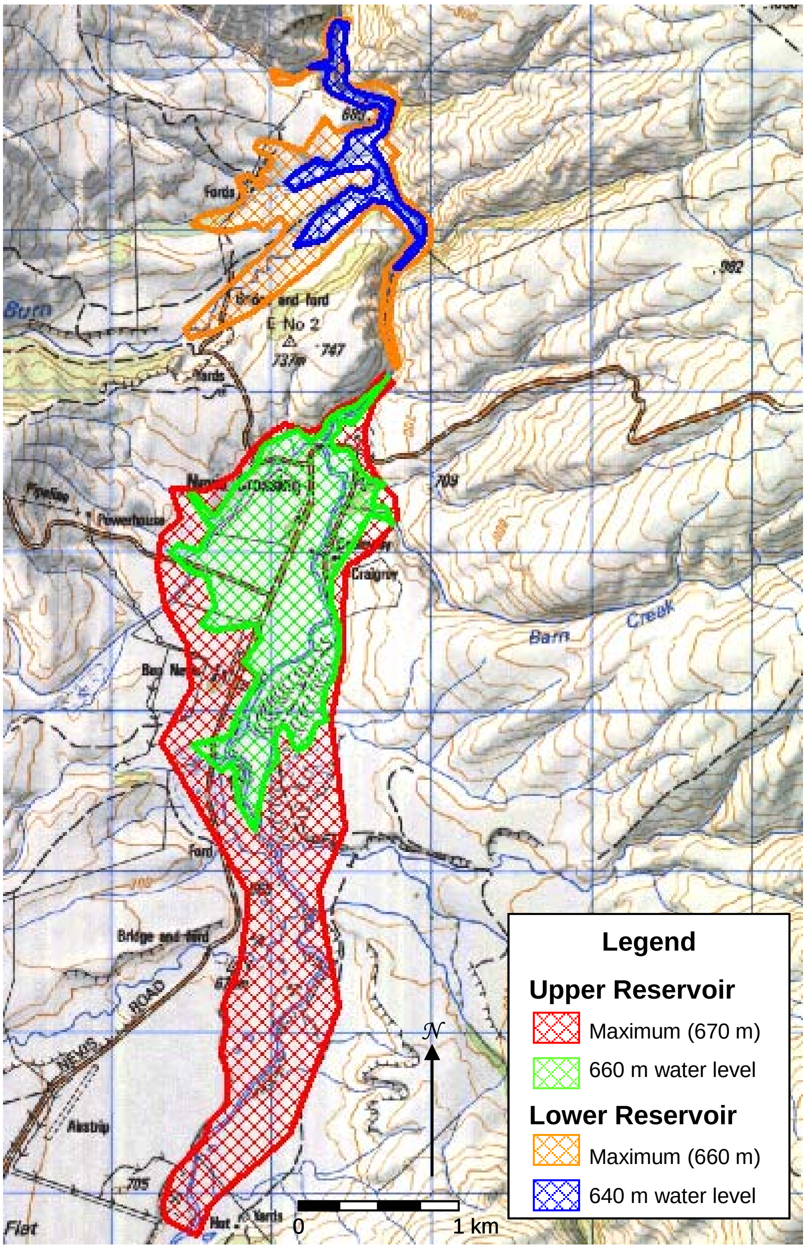

Figure 4 Map showing the likely extent of reservoirs formed on the Nevis River by a scheme as that outlined in Section 3.1. Water surface levels are given for each area.

3.2 Environmental effects of hydro-electric development

The impoundments formed by a hydroelectric scheme such as that described above will result in the inundation of up to 6 km of the best, and most popular, trout fishing water in the Nevis (Section 3.2.1). The dams constructed to form the impoundments are likely to present a significant barrier to the upstream migration of fish from the lower gorge (Section 3.2.1). Diversion of water from the lower dam to the powerhouse will also result in residual flows remaining in a section of river of approximately 8.2 river kilometres and fluctuating flows in the 3.6 km from the power house to the Kawarau confluence (see Section 3.2.2).

3.2.1 Inundation of existing habitat

The primary effect of a scheme such as that outlined above will be the flooding of the reach between the upper dam (just downstream of the Nevis Crossing bridge) and the point approximately 6 km upstream of Nevis Crossing (F42:943 468, Figure 3) established in Schedule 2 of the Water Conservation (Kawarau) Order (1997) as being the upper limit of any impoundment (Appendix 1). This is approximately half of the low-gradient reach upstream of Nevis Crossing that is predicted to support highest biomass of trout (see Section 4.1.1). Furthermore, the lower dam will also result in an impoundment from below the Nevis Burn confluence upstream towards the upper dam, including the low-gradient area known as The Dell.

These reservoirs will, undoubtedly, have some fisheries value. However, the quality of such fisheries remains uncertain, as this will be highly reliant on the stability of water levels, which will depend on the operating regime of the power scheme. Fluctuating lake levels have the potential to significantly affect the productivity of the littoral zone, which will affect the productivity of any lake fishery (Stark 1990; Hayes 1995; James *et al.* 1995; Young *et al.* 2000). Moreover, lake and reservoir fisheries are already common in Otago whereas river fisheries, especially high quality backcountry river fisheries are uncommon in comparison with other regions (e.g. Nelson-Marlborough; Walrond & Hayes 1999).

3.2.2 Fish passage

Construction of dams below Nevis Crossing and The Dell will prevent upstream migration of adult trout from the lower gorge; although it is currently unclear whether there is significant movement of fish from the gorge (see Section 4.2). Passage is likely to be most important during spawning movements, since the steep and boulder-strewn gorge is unlikely to have significant deposits of gravels suitable for spawning. It is possible that fish move upstream from these areas to lower gradient mainstem spawning areas (upstream of Nevis Crossing, and The Dell), and tributaries (such as the Nevis Burn, Schoolhouse and Coal Creeks). Under the Water Conservation (Kawarau) Order, fish passage within the Nevis must be maintained (Schedule 2, Water Conservation (Kawarau) Order, 1997). While fish passage past dams can be facilitated by fish passes, such structures have enjoyed mixed success and have sometimes failed completely.

3.2.3 Flow requirements

An Instream Flow Incremental Methodology (IFIM) study conducted in the Nevis upstream of Nevis Crossing found that a flow of approximately 5 m^3s^{-1} at Nevis Crossing (7.7 m^3s^{-1} at Wentworth Station) provided maximum habitat for adult brown trout, whilst peak aquatic invertebrate food producing habitat occurred at a flow of approximately 6.2 m^3s^{-1} (9.5 m^3s^{-1} at Wentworth Station- Figure 5). Habitat for juvenile trout and spawning declined rapidly as flow fell below 1 m^3s^{-1} (1.5 m^3s^{-1} at Wentworth Station - Jowett 2004).

These results suggest that any water takes that result in flows below the mean annual low flow (3.3 m^3s^{-1}at Nevis Crossing, 5.1 m^3s^{-1} at Wentworth Station) will result in steep reduction of habitat for adult brown trout and aquatic invertebrates. Based on the IFIM model, existing levels of water abstraction from the Nevis above Nevis Crossing (approximately 1 m^3s^{-1}) are likely to reduce available habitat for adult brown trout by approximately 20% and the benthic invertebrate food producing habitat by 25% if fully exercised at the MALF. In such a situation, it is necessary to identify an acceptable level of habitat retention and to formulate acceptable flow management rules. In defining possible flow management rules for the Environment Southland Regional Water Plan Jowett and Hayes (2004) suggested that an appropriate habitat retention level for a highly valued trout fishery might be 90% of habitat pertaining at the MALF. The same habitat retention level has been accepted by other regional councils (e.g. Horizons). More stringent flow rules have been incorporated in National Water Conservation Orders for outstanding trout fisheries. For example, under the Buller and Motueka River National Water Conservation Orders instantaneous mainstem flows cannot be changed by more than 5% and 12%, respectively. Note that these rules are not habitat based whereas the 90% habitat retention rule discussed above is – and therefore is more prescriptive.

Applying a 90% habitat retention rule in the Nevis River would mean that the minimum flow would be set at 2.8 m^3s^{-1} at Nevis Crossing (4.3 m^3s^{-1} at Wentworth) (i.e., 2.8 m^3s^{-1} would retain 90% of the habitat available for adult brown trout at the MALF). Under such a rule, current takes would be limited at flows of less than 3.8 m^3s^{-1} at Nevis Crossing (5.9 m^3s^{-1} at Wentworth Station) (i.e., the full 1 m^3s^{-1} allocation could not be abstracted) but additional allocation may be possible at flows of more than 3.8 m^3s^{-1} given appropriate restrictions (e.g. a minimum flow of 2.8 m^3s^{-1} at Nevis Crossing). The approval of further takes would require analysis of flow duration curves to assess the extent of “flat-lining”, where flows are reduced to stable, low flows for extended periods of time (4.3 m^3s^{-1} at the Wentworth Station recorder). However, the results of the existing flow-modelling are largely irrelevant when considering the effects of the proposed hydro-electric development, since the reach modelled is upstream of Nevis Crossing and will either be flooded by the impoundment, or will be upstream of, and not affected by, hydroelectric development.

The lower gorge, the reach that will be subject to residual flows under a scheme as outlined in Section 3.1, contrasts markedly with the section of river where the IFIM study was conducted. This is evident in Figures 6 and 7, where the lower gorge is much steeper (mean gradient 3.8% over 300 – 600 m contours) than the modelled reach above Nevis Crossing (mean gradient 0.43% over 640 – 680 m contours). The lower gorge is best classified as a step-pool reach using the classification of Montgomery & Buffington (1993). Step-pools are typically dominated by cobbles and boulders (see Figure 7b), as finer sediment is quickly transported downstream during high flows. The reach upstream of Nevis Crossing is a free-formed pool-riffle reach and is dominated by gravel and cobble substrate (Jowett 2004). Upstream of Nevis Crossing, instream habitat is dominated by runs (48%) and riffles (40%), with pools making up about 12% of instream habitat (Jowett 2004).

The above estimates of flow requirements are likely to overestimate flow needs of trout and invertebrates in the steeper gorge sections – where flow is faster, however, there are no IFIM data available for these reaches. Habitat modelling of such habitats is likely to be difficult (if not impossible) due to turbulent flow in these sections, resulting from the high bed gradient and the predominance of boulders and bedrock (Figure 7b). Flows in the residual river under a scheme such as that described above are expected to be low and stable for considerable periods of time, particularly in late summer, autumn and late winter (when most precipitation will be stored as snow). The operating regime of the scheme proposed is unclear at this time, however, it is likely that high-flow events in late summer and autumn will be captured by the storage lakes, rather than discharged into the residual river. However, given the lack of spawning habitat in this reach and the downstream barrier (NZMS: F42 954 589), the proposed development may reduce recruitment to this reach markedly.

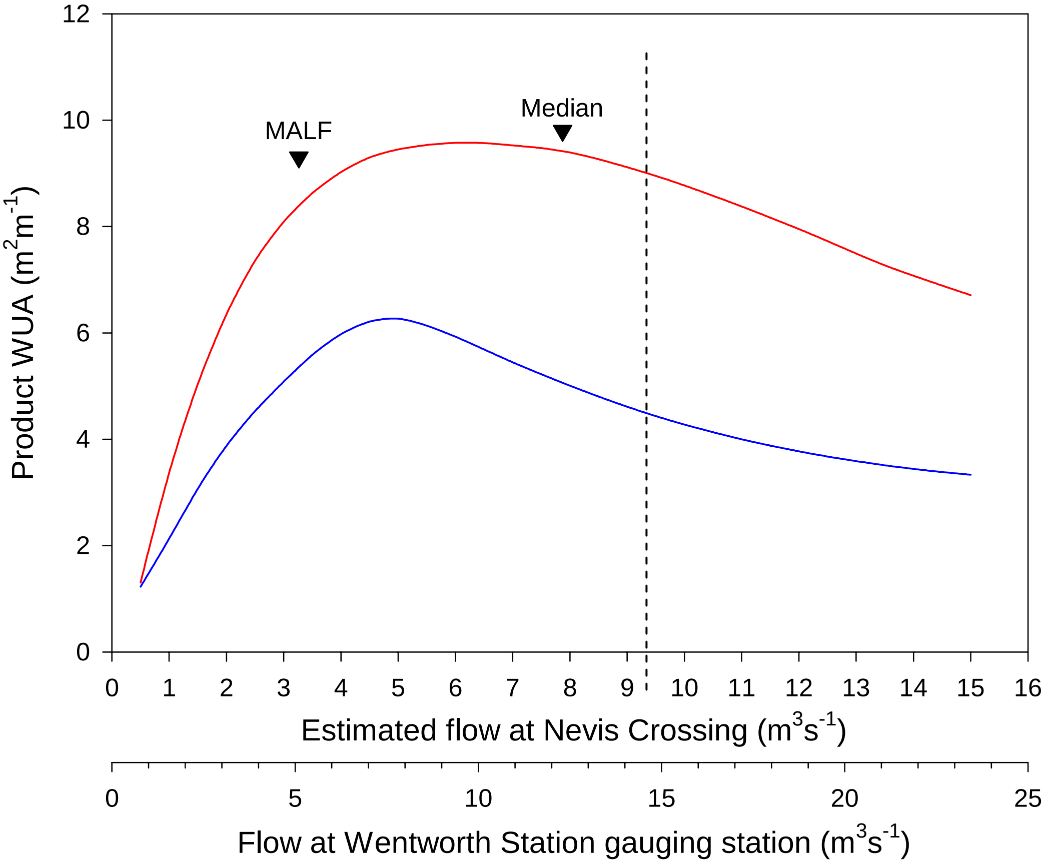

Figure 5 Availability of instream habitat (weighted usable area) for adult brown trout (blue line – Hayes & Jowett 1994 habitat suitability curves) and food producing (red line – Waters 1976 habitat suitability curves) at different flows in the Nevis River (Jowett, 2004). Confidence in the WUA values declines above 9.4 m^3s^{-1} (dotted line) owing to likely error associated with extrapolation of cross-section rating curves.

Fluctuating flows are expected to be most pronounced in the 3.6 km reach between the power house and the confluence with the Kawarau River. Much of this reach is deeply incised and constrained (Figure 7b), and variations in flow will result in pronounced changes in the water surface level and velocity and smaller changes in the wetted area than would be expected in unconstrained reaches, such as above Nevis Crossing (Figure 7a). Transport reaches such as the lower gorge have considerable capacity to move water and sediment downstream because of their high gradient and lateral constraint. This means that the energy of water is conserved rather than dissipated, as it would as water spreads out in low-gradient reaches (Figure 7a). Consequently, fluctuating flows are likely to have more pronounced effects on the flow velocity and water depth experienced by organisms in constrained reaches, whilst in unconstrained reaches there will be a proportionally larger varial zone (the area of bed that is periodically wetted and dewatered by fluctuating flows).

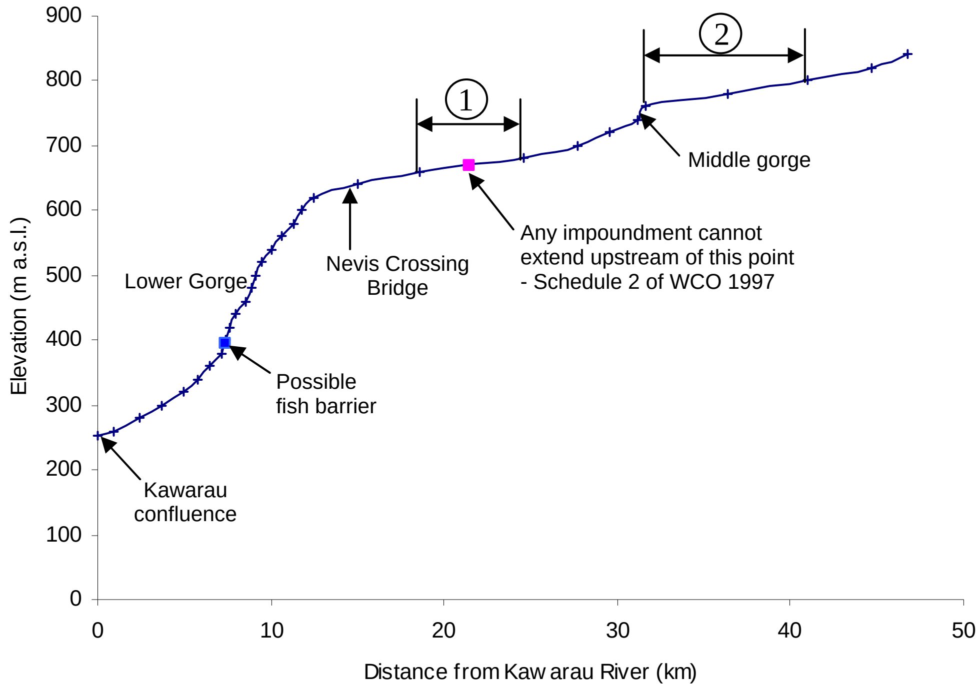

Figure 6 Elevation profile of the Nevis River with the two low-gradient reaches marked and numbered.

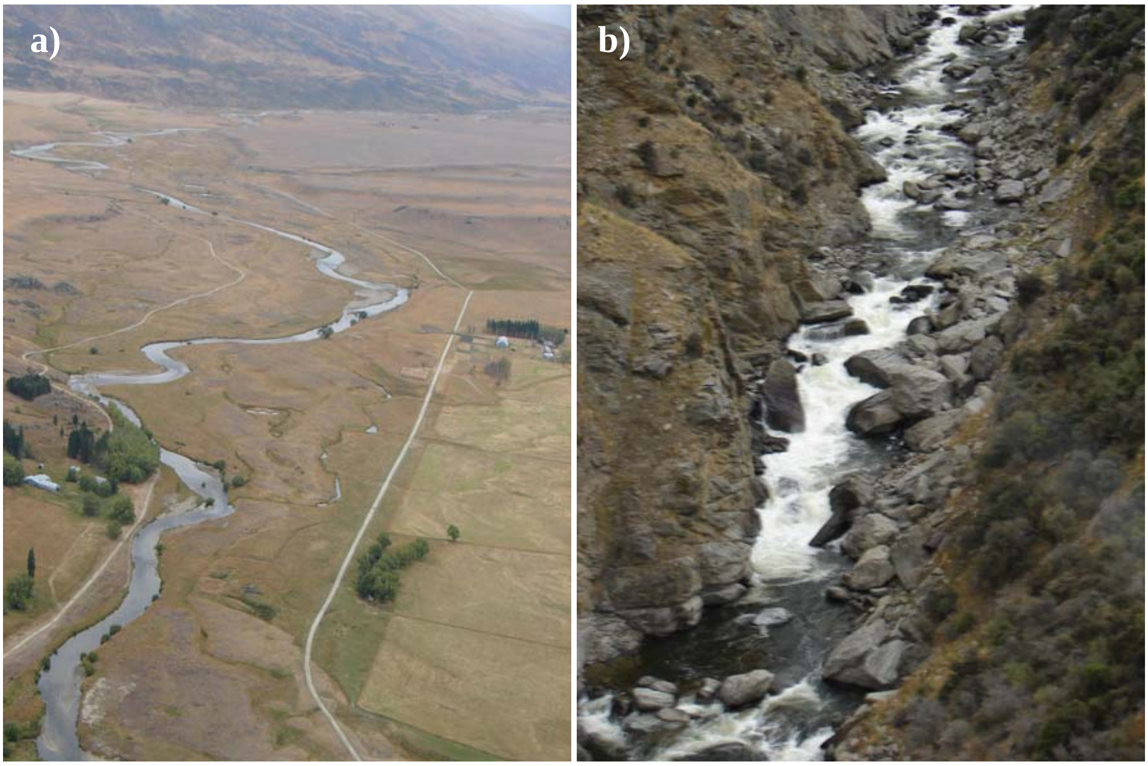

Figure 7 Photographs of the Nevis River a) above Nevis Crossing and b) in the lower gorge showing the marked difference in slope and geomorphology between these reaches. Both photographs were taken looking in a upstream direction

3.2.4 Construction activities

Road construction, necessary during construction and maintenance of the proposed schemes, and increased traffic on existing roads, may lead to increased sediment inputs to the Nevis River. These are likely to cause significant degradation in habitat for fish and macroinvertebrates in low gradient sections. However, it is unlikely that sedimentation will be an issue in the high gradient and tightly constrained lower gorge, since the river's capacity to transport sediment in this reach is likely to exceed any sediment inputs.

4. RESEARCH REQUIREMENTS

4.1 Population distribution and size structure

4.1.1 Fish distribution

To understand the nature of the Nevis fishery, and any potential effects of hydro-power development, it is important to understand the distribution of fish within the catchment and the role of their unimpeded movement in sustaining the population. Since the number of trophy fish is the outstanding characteristic of the Nevis fishery, it is particularly important to understand how the Nevis produces and supports such large fish and to verify which areas are important for maintaining them.

Reach gradient is expected to be an important factor affecting the biomass of trout a reach can support, and the biomass of brown trout is negatively correlated with the stream gradient (Jowett 1990). Rivers with low biomass brown trout populations have an average gradient of 0.55% (Jowett 1990). Reach gradient is of particular interest in the Nevis because it varies greatly between reaches (Figures 6, 7). Only two reaches have gradients of less than 0.55% (Figure 6). The first of these is between the 660 m and 680 m contour lines, immediately upstream of Nevis Crossing (Figure 6), which has a gradient of 0.33%, and is close to the gradients associated with moderate to high biomass populations of brown trout (0.30-0.32%; Jowett 1990). An interesting point to note is that the current conditions of the Kawarau WCO prohibit any impounded water resulting from damming in the Nevis extending past the point F42: 943468, which is in the centre of this low-gradient reach (Figure 1). The second low gradient reach is from the top of the middle gorge to where Drummond Creek enters the Nevis and has an average gradient of 0.43% (Figure 6).

These two low-gradient reaches are expected to support the highest biomass of fish in the Nevis. This is not to say that high gradient reaches (such as the lower gorge) will not support large fish, but that these reaches are expected to support a lower biomass of adult trout, including large fish, on a per kilometre basis compared to the low gradient reaches. It is likely that within these reaches fish are mainly limited to localised low-gradient areas and deep, low-velocity pockets.

4.1.2 Size structure

The outstanding characteristic of the Nevis is its reputation for producing large trout yet, at present, there is little information on the overall structure of the brown trout population in the river. While Trotter's drift dive results (2006) corroborate the perceptions of anglers in respect of trophy trout, it is particularly important to establish the exceptional features of this fishery relative to similar fisheries and to determine how the presence of large fish has come about. It is also important to establish the population characteristics in different reaches of the Nevis to identify the most important reaches for supporting these large trout. Drift-diving surveys of different reaches, with an effort to distinguish and count trophy-class fish (3 kg+) from other 'large' (>45 cm) fish, should address this information gap (e.g. such as the initiative that was undertaken this year (Trotter 2006)). To make the most of this information, equivalent data should be collected from other fisheries from Otago and nationally, especially from fisheries with reputations for producing large trout.

4.2 Fish movements

It was believed, until recently, that the movement of adult stream salmonids was largely restricted to small feeding-related excursions within their home range. However, there is now considerable evidence that conflicts with this paradigm. Studies on Colorado mountain streams found that a significant component of stream trout populations were mobile and colonise vacant adult habitat when they come across it (Riley *et al.* 1992; Gowan *et al.* 1995; Gowan & Fausch 1996).

Several studies have shown large-scale movements of adult trout within New Zealand rivers. Radio-tracking studies of brown trout in the New Zealand rivers indicate that some trout make substantial movements within a catchment, most likely in response to changes in physical habitat and food availability, resulting from variation in flows, and temperature (Wilson & Boubée 1996; Strickland *et al.* 1999; Fish & Game – Southland Region 2002; Young 2006). Understanding the magnitude and significance of such movements in the Nevis catchment is important when considering the effects of dam construction, since a dam may affect access to spawning areas and population dynamics by restricting movement of fish within the catchment.

The extent and importance of movement of trout within the Nevis catchment can be addressed by either radio tracking or fish tagging. Tagging fish in different reaches of the river (with tag colour coding for the reach in which they were tagged – Figure 8) and then drift-diving to see if any tagged fish have moved has potential to track fish movements except for the difficulty of carrying out follow up surveys in the lower gorge. It may be possible to catch fish by hand- or drift-netting when drift-diving, or by angling. Petersen tags (small discs attached to the front of the dorsal by a wire ring) or double T-Bar Anchor tags (one on each side of the dorsal fin for visibility) could be used.

A program breaking the river up into six reaches (Table 4, Figure 8) and using different colours of tags in each of these reaches, would allow for the detailed measurement of fish movement. However, given time and money constraints, the most important reaches to consider are those labelled 4, 4a and 5, since these are likely to be the most severely affected by dams below Nevis Crossing preventing the passage of adult fish moving to areas with suitable spawning gravels.

Table 4 Possible reaches for a tagging program to assess the movement of adult brown trout in the Nevis River as outlined in Figure 8.

Reach	Location
1	Upstream of Whittens Creek confluence
2	Middle gorge between Commissioners Creek and Whittens Creek
3	Nevis Crossing to Commissioners Creek
4	The low gradient section downstream of Nevis Crossing known as “the Dell”.
4a	Short gorge section between “the Dell” and Nevis Crossing
5	Lower gorge downstream as far as the waterfall located at NZMS: F42 954 589.

Radio-tracking would provide more detailed information on the nature of any movements of fish within the Nevis catchment although these studies are expensive and, when costs are an issue they suffer from low sample size. However, the Petersen/T-Bar Anchor tagging study outlined above is adequate for quantifying fish movements and the likely effects of damming.

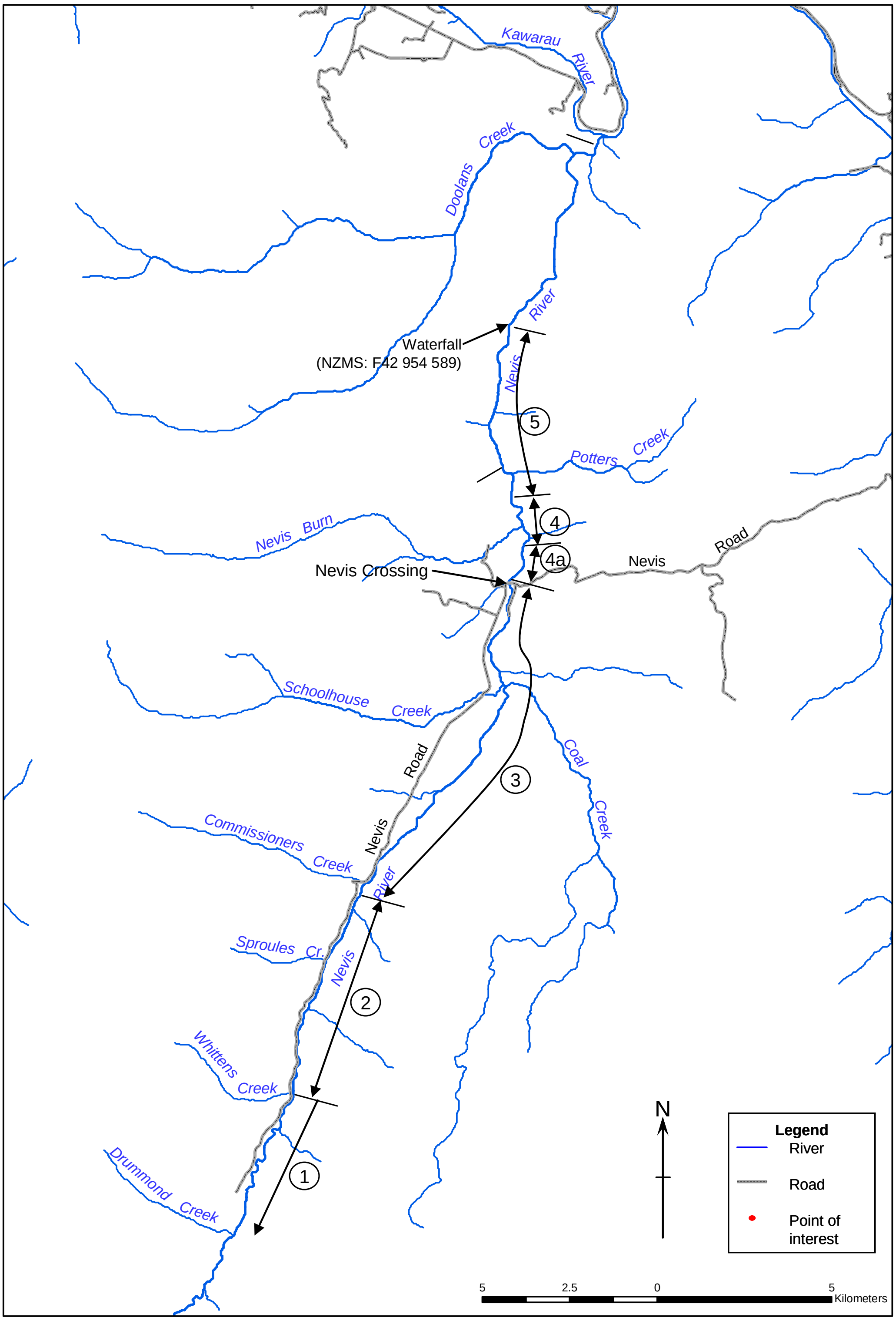

Figure 8 Map of the Nevis River showing possible reaches for a tagging study of fish movements within the catchment. Fish would be tagged with different tag colours depending on which reach (identified by a circled number) they were first caught in.

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Appendix 1 Water Conservation (Kawarau) Order

The following is the full text of the Water Conservation (Kawarau) Order 1997.

1. Title and Commencement -
(1) This Order may be cited as the Water Conservation (Kawarau) Order 1997.
(2) This Order shall come into force on the 28th day after the date of its notification in the *Gazette*.

2. Interpretation -
In this order, unless the context otherwise requires, -
"Act" means the Resource Management Act 1991:
"Preserved waters" means the waters set out in Schedule 1 of this order:
"Protected waters" means the waters set out in Schedule 2 of this order.

3. Preservation in natural state
(1) It is declared that the waters described in Schedule 1 contain one or more of the following outstanding amenity and intrinsic values which are afforded by waters in their natural state:
(a) Natural and physical qualities and characteristics that contribute to -
(i) People's appreciation of pleasantness of waters:
(ii) Aesthetic coherence:
(iii) Cultural and recreational attributes:
(b) Biological and genetic diversity of ecosystems:
(c) Essential characteristics that determine the ecosystem's integrity, form, functioning, and resilience.

(2) Because of the outstanding amenity and intrinsic values recognised in subclause (1), these outstanding values shall be sustained.

(3) Because of the outstanding amenity and intrinsic values recognised in subclause (1), it is hereby further declared that the water bodies set out in Schedule 1 are outstanding in their natural state.

(4) Because the water bodies set out in Schedule 1 are recognised to be outstanding in their natural state, they must be preserved as far as possible in their natural state.

(5) Except as provided in clauses 5 and 6 of this order, the exercise of a regional council of its functions and powers under Section 30(1)(e) and (f) of the Act (as they relate to water) are restricted or prohibited so as to retain the preserved waters as far as possible in their natural state.

4. Protection of characteristics
(1) It is declared that the waters set out in Schedule 2 which are no longer in their natural state contain one or more amenity and intrinsic values which warrant protection because they are considered outstanding.

(2) Because of the outstanding amenity and intrinsic values recognised in subclause (1), these outstanding values shall be sustained.

(3) Because of the outstanding amenity and intrinsic values recognised in subclause (1), it is declared that the water bodies described in Schedule 2 contain one or more of the following outstanding characteristics, as set out in Schedule 2 -
(a) As a habitat for terrestrial and aquatic organisms:
(b) As a fishery:
(c) For its wild, scenic and other natural characteristics:
(d) For scientific values:
(e) For recreational, or historical purposes:
(f) For significance in accordance with tikanga Maori.

(4) Because of the outstanding characteristics specified in subclause (3), the characteristics of the waters, as set out in Schedule 2, are protected.

(5) Except as provided in this order the exercise by a regional council of its functions and powers under Section 30(1)(e) and (f) of the Act (as they relate to water) are restricted or prohibited as set out in Schedule 2.

5. Exemptions -
The restrictions and prohibitions in clauses 3(5) and 4(5) and Schedule 2 do not limit the regional council's functions or powers to grant a resource consent or to make a rule for any part of the preserved waters or protected waters for all or any of the following purposes -
(a) Maintenance or protection of any network utility operation (as defined in Section 166 of the Act) or any public or private road or any bridge:
(b) Maintenance of soil conservation and river protection works:
(c) Research into, protection of, enhancement of, or restoration of, values and characteristics for which the water bodies are being preserved or protected, as the case may be:
(d) On the same or similar conditions for any lawful use of water being undertaken immediately before the date on which this order came into force.

6. Further exemptions-
(1) This clause applies to:
(a) the Dart River mainstem from Lake Wakatipu to its confluence with the Beans Burn; and
(b) the Rees River mainstem from Lake Wakatipu to its confluence with Hunter Stream.

(2) The restrictions and prohibitions in clause 4(5) and Schedule 2 do not limit the regional council's functions and powers to grant a resource consent or to make a rule for the waters referred to in subclause (1) for all or any of the following purposes:
(a) the construction, maintenance and protection of roads and bridges:
(b) any exercise of the powers of a Catchment Board under the Soil Conservation and Rivers Control Act 1941:
(c) any exercise of the powers of a River Board or local authority under the River Boards Act 1908:

(3) any exercise of the powers of a Land Drainage Board or local authority under the Land Drainage Act 1908.

(4) The purposes in subclause (2) include -

a) The undertaking of work necessary to prevent or control soil erosion and flooding affecting properties adjacent to the above water bodies including work in the river bed such as (but not by way of limitation) the diversion of water and damming of water to construct river training works, groynes and other flood protection works:
b) The maintenance of existing flood protection and erosion control works both in and adjacent to the above water bodies:
c) Action taken in accordance with section 330 of the Resource Management Act 1991 to carry out any of the works referred to in paragraphs (a) and (b).

7. Provisions for the Nevis River -
The regional council may grant a resource consent or make a rule in a plan for hydro electric development in respect of the Nevis River if that resource consent or rule complies with the restrictions and prohibitions set out in Schedule 2.

8. Existing permits may be replaced -
The restrictions and prohibitions in clauses 3(5) and 4(5) and Schedule 2 do not limit the regional council's functions in respect of any part of the preserved or protected waters to replace any existing resource consent or grant any resource consent in substitution for an expiring resource consent if the new resource consent is granted on substantially the same terms and conditions as the existing or expiring resource consent.

9. Lake Dunstan not affected -
Nothing in this order affects the levels of Lake Dunstan or the operation of the Clyde power station.

10. Scope -
Nothing in this order limits the effect of sections 14(3)(b) and 14(3)(e) of the Act relating to use of water for an individual's reasonable domestic needs, the reasonable needs of an individual's animals for drinking water, and for fire-fighting purposes.

Schedule 1
Waters to be preserved

All map references NZMS 260

Waters	Outstanding amenity and intrinsic values
Dart River mainstem above the Beans Burn confluence to source (E40:375077 to E39:590261):	a, b, c, e, f
All tributaries of the Dart River within the boundaries of the Mount Aspiring National Park, excluding Route Burn, but including the sections of the Rock Burn and Beans Burn within the boundary of the Mount Aspiring National Park:	a, b, c, e, f
Parts of tributaries of the Dart River not within the Mount Aspiring National Park Rock Burn (E40:386048 to E40:383047); Beans Burn (E40:375077 to E40:370084).	a, b, c ,e, f
Route Burn from confluence with Dart River to source, and all its tributaries, including Left Branch and North Branch (E40:394982 to D40:284012 and D40:292060)	a, b, c, d, e, f
Rees River mainstem above Hunter Stream confluence to source (E40:499117 to E40:579149):	a, b
All tributaries of the Rees River within the boundaries of the Mount Aspiring National Park:	a, b
Greenstone River mainstem from Lake Wakatipu to source, including Lake McKellar and its tributaries (E41:441758 to D41:275860 and D41:249861)	a, d, f
Caples River mainstem from Greenstone River confluence to source (E41:412757 to D41:289890 and D41:296-837):	a, d, f
Lochnagar and Lake Creek (at or about E40:615143; and E40:649110 to E40:627143):	f
Nevis wetland (all water bodies upstream of F43:885-243 on a tributary of Roaring Lion Creek)	f

Key:

Amenity values:

(a) Natural and physical qualities and characteristics that contribute to people’s appreciation of pleasantness of waters:

(b) Natural and physical qualities and characteristics that contribute to aesthetic coherence:

(c) Natural and physical qualities and characteristics that contribute to cultural attributes:

(d) Natural and physical qualities and characteristics that contribute to recreational attributes

Intrinsic values:

(e) Biological and genetic diversity of ecosystems:

(f) Essential characteristics that determine the ecosystem’s integrity, form, functioning and resilience.

Schedule 2
Waters to be protected

All map references NZMS 260

Waters	Outstanding Characteristics	Restrictions and Prohibitions
Kawarau River mainstem from Scrubby Stream to Lake Wakatipu control gates (F41:035680 to F41:738667)	(c) wild and scenic characteristics (c) natural characteristics, in particular the return flow in the upper section when the Shotover River is in high flood; (d) scientific values, in particular the return flow in the upper section when the Shotover River is in high flood; (e) recreational purposes, in particular rafting, jetboating and kayaking	(i) no damming allowed; (ii) water quality to be managed to Class CR standard
Nevis River mainstem gorge from Nevis Crossing to Kawarau River confluence (F41:978644 to F42:952516)	(c) wild characteristics (e) recreational purposes, in particular fishing and kayaking	(i) no damming allowed unless a rule in a plan or condition in any water permit granted makes provision for river flows to be provided at sufficient levels to enable kayaking to be undertaken in the gorge at times stated in the plan or permit, and the extent of any impounded water is not beyond F42:943468; (ii) fish passage to be maintained; (iii) water quality to be managed to Class CR, Class F and Class FS standards.

Waters	Outstanding Characteristics	Restrictions and Prohibitions
Nevis River mainstem above Nevis Crossing to source (F42:952516 to F43:799217)	(c) scenic characteristics (e) recreational purposes, in particular fishing	(i) no damming allowed unless a rule in a plan or condition in any water permit granted makes provision for river flows to be provided at sufficient levels to enable kayaking to be undertaken in the gorge at times stated in the plan or permit, and the extent of any impounded water is not beyond F42:943468; (ii) fish passage to be maintained; (iii) water quality to be managed to Class F and Class FS standards.
Shotover River mainstem (at or about F41:765680 to E40:662173)	(c) wild and scenic characteristics; (c) natural characteristics, in particular the high natural sediment load and active delta at confluence with Kawarau River; (d) scientific value, in particular the high natural sediment load and active delta at confluence with Kawarau River; (e) recreational purposes, in particular rafting, kayaking and jetboating; (f) historical purposes, in particular goldmining.	(i) no damming allowed; (ii) water quality to be managed to Class CR standard.
Dart River mainstem from Lake Wakatipu to confluence with Beans Burn (at or about E41:438-853 to E40:375-077)	(a) habitat for wildlife; (c) scenic characteristics; (c) natural characteristics, in particular natural turbidity; (d) scientific value, in particular natural turbidity; (g) significance in accordance with tikanga Maori, in particular sites at the mouth of the river.	(i) no damming allowed; (ii) braiding of water to be maintained.
Rees River mainstem from lake Wakatipu to confluence with Hunter (at or about E41:448-852 to E40:499-117)	(a) habitat for wildlife; (c) scenic characteristics; (g) significance in accordance with tikanga Maori, in particular sites at the mouth of the river.	(i) no damming allowed; (ii) braiding of water to be maintained.

Waters	Outstanding Characteristics	Restrictions and Prohibitions
Diamond Lake, Diamond Creek and Reid Lake (at or about E40:435-975; E40:444-963 to E40:450-918)	(a) habitat for wildlife and quinnat salmon; (b) fishery	(i) no damming allowed; (ii) fish passage to be maintained (iii) water quality to be managed to Class F and Class FS standards
Lake Wakatipu (from outlet at control gates (F41:738-667) to confluences of Dart River (at or about E41:438-853) and Rees River (at or about E41:448-852) and including whole lake)	(b) fishery; (c) scenic characteristics; (d) scientific value, in particular water clarity, and bryophyte community; (e) recreational purposes, in particular boating; (g) significance in accordance with tikanga Maori, in particular sites at the head of the lake, and the legend of the lake itself.	(i) fish passage to be maintained; (ii) water quality to be managed to Class AE, Class CR, Class F and Class FS standards.
Lochy River mainstem (F42:720-488 to E42:480-390 and E42:462-364)	(b) fishery; (e) recreational purposes, in particular fishing.	(i) fish passage to be maintained; (ii) water quality to be managed to Class F and Class FS standards.
Von River mainstem (E42:500592 to E42:444363 and E42:375581)	(b) fishery (e) recreational purposes, in particular fishing.	(i) fish passage to be maintained; (ii) water quality to be managed to Class F and Class FS standards.

Key:
Outstanding characteristics (Section 199(2)(b) and (c) of the Act):
(a) as habitat for terrestrial or aquatic organisms;
(b) as a fishery;
(c) for its wild, scenic or other natural characteristics;
(d) for scientific and ecological values
(e) for recreational purposes;
(f) for historical purposes;
(g) for significance in accordance with tikanga Maori.

Restrictions and Prohibitions:
References to Classes are Water Quality Classes as in the Third Schedule of the Act.