IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of an application by Meridian Energy Limited for resource consents for the Mokihinui Hydro Project

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STATEMENT OF EVIDENCE OF JOHN WILLIAM HAYES ON BEHALF OF MERIDIAN ENERGY LIMITED

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1. **QUALIFICATIONS AND EXPERIENCE**

1.1 My full name is John William Hayes.

1.2 I have the following qualifications: BSc Honours and PhD in zoology from the University of Canterbury. I am a member of the New Zealand Freshwater Sciences Society and the American Fisheries Society.

1.3 I have 27 years experience as a freshwater fisheries scientist. My expertise includes instream habitat modelling, river and fish ecology, especially of trout and salmon, and recreational fisheries. After graduating with my PhD in 1984 I worked as a fisheries research scientist at the Freshwater Fisheries Centre of the Ministry of Agriculture and Fisheries until 1992. Between then and 1994 I held a similar position with the National Institute of Water and Atmospheric Research (NIWA). I have been employed as a senior fisheries scientist with the Cawthron Institute, Nelson since July 1994.

1.4 I have special expertise in recreational trout and salmon fisheries, fish bioenergetics, habitat suitability analyses, and instream habitat modelling. I also have experience with native fish ecology and distribution. My interests and research experience extend to aquatic macroinvertebrates, in respect to their importance as food for fishes, and in particular invertebrate drift.

1.5 Since the mid 1990s I have managed research programmes developing and testing bioenergetics models for predicting brown trout growth and carrying capacity (Hayes 2000; Hayes et al. 2000; Hughes et al. 2003; Kelly et al. 2005; Hayes et al. 2007). A useful application for the bioenergetics growth model that I published in 2000 is to predict the importance of migration in sustaining the large trout typically caught by anglers in New Zealand rivers (Young 2000; Hayes & Quarterman 2003).

1.6 In the late 1990s and early 2000s I managed a research programme on angler usage and satisfaction, trout age and growth, and trout catchability and behavioural response to anglers on backcountry rivers in New Zealand. Some of the research on angler usage and satisfaction included the Mokihnui River (Walrond & Hayes 1999; Walrond 2001; Hayes 2002; Young & Hayes 2004).

1.7 I have 44 years trout fishing experience, fishing throughout New Zealand and also in Australia and North America. I regularly publish articles for trout fishing magazines and have co-authored a book on trout fishing, trout habitat requirements, and trout fisheries management in New Zealand (Hayes & Hill 2005).

1.8 I have fished several backcountry rivers in Kahurangi National park, but not the Mokihinui.

1.9 I also have extensive experience providing consulting advice to regional councils, energy companies, fish and game councils and the Department of Conservation on the flow, habitat, and water quality requirements of trout and native fishes; I have written over 80 such reports for clients.

1.10 Examples of recent hearings in which I have presented freshwater fisheries and instream habitat evidence include the:

- Buller River Water Conservation Order Hearing;
- Motueka River Water Conservation Order Hearing;
- Rangitata River Water Conservation Order Hearing;
- Genesis Energy's Tongariro Power Development Resource Consents Hearing;
- Otago Water Plan Appeal Environment Court Hearing;
- Waitaki Water Allocation Board Hearing;
- Trustpower's Wairau Valley Hydro Electric Scheme Resource Consents Hearing;
- The Oreti River Water Conservation Order Hearing;
- Meridian Energy's lower Waitaki North Branch Tunnel Concept Water Resource Consents Hearing;
- Central Plains Water Scheme Resource Consents Hearing.

1.11 I have been asked by Meridian Energy to give evidence on the effects of Meridian Energy Limited's (Meridian's) Mokihinui Hydro

Proposal (MHP) on the trout fishery, specifically the effects of the dam and reservoir.

1.12 I have read the Code of Conduct for Expert Witnesses (Rule 330A, High Court Rules and Environment Court Practice Note) and have complied with it in the preparation of my statement of evidence.

1.13 In preparing my evidence I have drawn on the following work which I have undertaken in relation to the MHP:

a. An investigation of trout movement and passage in the Mokihinui River (Trout Movement and Passage Report (Hayes et. al. 2008)). Trout growth modelling and otolith microchemistry analysis were used to determine trout movement patterns and assess the effects of disruption to trout passage by the dam. The otolith microchemistry component was undertaken by Otago University and reported separately (Bickell & Closs 2007).

b. A review of the effects of dams on trout fisheries in New Zealand (Holmes & Hayes 2008).

c. The New Zealand Freshwater Fishery Database (NZFFD) to assess trout distribution in the Mokihinui River.

d. The National Angler Database (NAS) to assess the angling usage of the Mokihinui River.

1.14 I have also reviewed:

a. The following reports and statements of evidence of other experts giving evidence on behalf of Meridian relevant to my area of expertise, including:

i. Mr Greenaway (Recreation Report – (Greenaway & Associates 2007)),

ii. Dr Spigal (Lake Water Quality and Habitat report – (Floeder & Spigal 2007)),

iii. Dr Suren (Periphyton and Invertebrates Report – Suren & Kilroy 2007),

iv. Dr Jellyman (Native Freshwater Fish and Fisheries Report (Bonnett et al. 2007)),

v. Mr Jowett (Instream Habitat and Flow Regime report – (Jowett 2007).

b. Relevant submissions of others, namely by the West Coast Fish and Game Council and the NZ Federation of Freshwater Anglers.

c. Meridian's resource consent application for hydropower development on the Mokihinui River;

2. SCOPE OF EVIDENCE

2.1 I have been asked by Meridian to prepare evidence in relation to the actual and potential effects of the MHP on trout in the Mokihinui River. To do this I have included:

a. A synopsis of the nature and values of the Mokihinui trout fishery;

b. A summary of the distribution and abundance of trout in the catchment;

c. A summary of research on trout movements and recruitment patterns in the Mokihinui catchment determined by:

i. Trout otolith microchemistry analysis,

ii. Trout growth modelling;

d. A summary of the results of a review of trout fisheries outcomes of dams and impoundment in New Zealand;

e. An assessment of effects on trout, including:

i. Effects of disruption to trout movement by the dam

ii. Effects of spillway and turbine passage

iii. Effects of the reservoir

iv. Effects of the proposed flow regime downstream of the dam.

v. Options to avoid, remedy, and mitigate effects

2.2 All of the issues covered by this scope of evidence are within my area of expertise.

3. EXECUTIVE SUMMARY

Nature and values of the trout fishery

3.1 The Mokihinui catchment supports one of the best headwater trout fisheries in the upper South Island and within Kahurangi National Park its trout fishery is second only, in terms of size and importance, to the Karamea Catchment.

3.2 National angler surveys indicate that like most backcountry rivers the Mokihinui River receives comparatively low angling usage but it is ranked highly in terms of quality. Of the headwater and backcountry fisheries in New Zealand, the Mokihinui ranked very highly; only 8 % of headwater rivers received more visits and 34 % of headwater and backcountry river fisheries combined received more visits.

3.3 The North and South Branches may be of national significance for wilderness angling whereas the lower river, below the Forks, is likely to be of no more than of regional significance for angling.

Trout distribution and abundance

3.4 Electro-fishing surveys indicate that juvenile brown trout are distributed widely, throughout the Mokihinui catchment but they are not very abundant.

3.5 Drift dive surveys indicate that the abundance of medium and large trout (> 20 cm) in the Mokihinui is at least average by national standards, ranking in the top 18 – 42 % of drift dive reaches surveyed throughout New Zealand.

Trout movement and recruitment patterns

Otolith micro-chemistry

3.6 The otolith micro-chemistry analysis indicated that:

a. Large scale movement by trout in the Mokihinui catchment is common and in general, fish from the upper catchment appear to be less mobile than fish from the lower river.

b. Trout in the North Branch appear to move more frequently than those in the South Branch.

c. Sea- or estuary-run trout were relatively uncommon (14 – 16 %). This suggests that most trout in both the lower and upper reaches of the Mokihinui River do not rely on the estuary or ocean as an essential component of their life history.

d. Most of the population (94%), including fish in the lower river and estuary, appears to be sustained by spawning in the headwaters – in tributaries of the North and South Branches.

Trout growth modelling

3.7 The growth modelling results indicated that:

a. Trout from the headwaters of the Mokihinui River would not have to move downstream to the lower river, past the proposed dam site to grow to the sizes observed, assuming they attain maximum, or near maximum, invertebrate food intake.

b. The movement by trout indicated by the otolith micro-chemistry study is probably facultative, (i.e., movement occurs probably by choice or chance rather than by necessity for growth and survival) and on average confers no size advantage on migrants.

Review of trout fisheries outcomes of damming and impoundment in New Zealand

3.8 Perceptions of fisheries management staff in New Zealand indicate that dams and associated reservoirs have adversely affected trout fisheries in some catchments and benefitted them in others. Whether anglers consider effects are adverse depends on their angling preferences.

3.9 Dams and reservoirs potentially have both negative and positive effects on trout habitat and fishing opportunities. A fishery is likely to receive a net benefit from an artificial reservoir if the river is unstable, with frequent flooding and/or extreme low flows, and there is negligible seasonal migration of trout from the lower river and/or ocean. The Mokihinui River has the first of these features, unstable with frequent, large floods, but the second feature, trout migration, requires some further investigation.

3.10 It appears that the MHP is unique among hydropower developments in New Zealand in that the river below the dam has no, or very little, trout spawning habitat. In rivers below all other large dams in New Zealand spawning habitat is available in tributaries or the mainstem.

Assessment of effects

Effects of disruption of trout movement by the dam and turbine and spillway downstream passage

3.11 The proposed MHP will disrupt trout passage and increase mortality of downstream migrants. However, overall I do not expect the dam to have a major effect on the trout population throughout the catchment because most of the population will not be separated from the sources of recruitment (i.e., most trout live above the proposed dam site and these fish will continue to return to the headwaters to spawn and seed the wider catchment including the lower river below the dam).

3.12 It is important that downstream passage is maintained to sustain the lower river trout population. This will be the case with the proposed dam; trout will still be able to pass downstream (over the spillway when flow exceeds the generation flow and small trout at least will be able to pass through the turbines with low mortality.

3.13 Mortality of trout that pass downstream over the spillway is likely to be in the order of 5 – 10 % or less, particularly for small fish. Turbine passage mortality rates may be as low as 7 % for trout < 8 cm, about ~15 – 35 % for fish < 15 cm, and ~44 – 60 % for fish ≥ 25 cm. The proposed eel screen will exclude trout ≥ 25 cm, when it is in place in autumn. Most existing dams in New Zealand do not include screens for trout. Whether such mortalities result in a more than minor effect on the trout population in the lower river below the dam depends on the proportion of migrants that are small versus large and the extent of migration itself. The majority of trout attempting to migrate downstream are likely to be small and experience relatively low turbine mortality. Furthermore, most trout are likely move during high flow events when a higher proportion will pass over the spillway rather than through the turbines. If these assumptions prove correct then overall passage mortality (through turbines and over the spillway) will be low and the effect on the trout population in the lower river below the dam will be undetectable and therefore minor.

3.14 Evidence of relatively limited movement by trout and good thermal conditions for growth in the South Branch suggests the trout population and fishery in this sub-catchment will not be significantly affected by the dam.

3.15 There is a low to moderate risk that the dam will adversely affect the North Branch trout population and fishery by disrupting return of North Branch migrants from the lower river. Otolith micro-chemistry analysis showed that 53 % of a sample of North Branch trout moved out of the North Branch for part of their lives and these probably distribute throughout the mainstem below the Forks to the estuary. If trout distribute evenly between the Forks to the sea, 22% of North Branch fish (i.e., 41% of the 53% that moved) would end up below the proposed dam site – based on the relative lengths of river above and below the dam site.

3.16 However, whether the North Branch trout population and fishery is adversely affected depends on the potential mitigating influence of impoundment. Potential loss of adults and recruitment to the North Branch fishery due to the dam blocking upstream passage may be offset, or even enhanced, by potential benefits of impoundment to the trout population. In some other catchments there has been an increase in the abundance of small trout following impoundment –

both in the reservoir and rivers upstream. This is likely to occur in the proposed reservoir.

3.17 The average size of trout might decline if the abundance of small fish increases with impoundment but trout in the 2 – 3 kg range which presently comprise the bulk of the catch should remain at present levels. Water temperature regimes downstream of the Forks are currently sufficient for trout to grow in excess of 3 kg providing invertebrate food is not limiting, and the proposed reservoir will improve thermal conditions for trout growth even further. However, there is a risk that trophy trout (≥ 4.5 kg) will decline if they are sea-runners. The migratory status of these uncommon fish remains unknown.

Effects of impoundment

3.18 The proposed reservoir should provide good thermal conditions for trout growth. It is predicted to have low to moderate productivity and a small but productive littoral zone which should support moderate food resources for trout. This ought to favour trout realising their thermal growth potential although this depends on how abundant they become and therefore how much competition for food occurs.

3.19 The reservoir will also provide a refuge for trout from floods – potentially enhancing the abundance of trout, especially juveniles, through the gorge and headwaters.

Options to avoid, remedy, and mitigate effects

3.20 The proposed MHP will disrupt upstream trout passage and provision of a fish pass is not a viable option with a high dam of 77 m.

3.21 The impoundment may have a positive effect on trout abundance and growth and mitigate the small predicted losses of trout to turbine and spillway mortality in the lower river and from disruption to upstream migration of trout below the dam to the headwaters.

3.22 Overall I do not expect the dam to have major effects on the trout population and fishery throughout the catchment. However, sufficient uncertainty remains on the migratory behaviour of trout and interconnection between upper and lower river to warrant further investigation prior to the consideration of mitigation.

3.23 There are three issues that require attention. In order of decreasing uncertainty these are risk to the maintenance of: 1) large (>3kgs) and trophy (>4.5 kgs) trout in the upper catchment, 2) trout in the North Branch and 3) trout in the lower river, below the proposed dam site.

3.24 The dam could reduce recruitment to the headwater population, in particular in the North Branch and of large and trophy trout generally. Although a low risk, disruption to migration and turbine passage mortality might adversely affect trout abundance in the lower river.

3.25 It is also uncertain whether the potential positive effects of impoundment on trout abundance and growth in the gorge and headwaters will mitigate for these effects.

3.26 A range of investigations and monitoring options presented in the “Trout” section of the ”Aquatic Ecology Management Plan” addresses these uncertainties, with the investigations aimed at resolving the uncertainties prior to free passage being restricted. Mitigation options are also presented in the “Plan” in the event that research and monitoring indicates significant effects are likely or occur.

3.27 The proposed investigations will be conducted over three years before trout passage is restricted, and will most likely include the following:

a. Direct assessment of trout moving past the dam site using a DIDSON acoustic camera;

b. Further otolith microchemistry sampling and analysis, complemented by microchemistry analysis of eggs, to bolster the existing understanding of patterns of lifetime movement of trout in the catchment, including large and trophy fish;

c. A spawning survey in the lower river and tributaries, followed up by electrofishing for fry, to determine the extent of spawning habitat and opportunities for enhancement (for mitigation) below the proposed dam site.

d. An economic valuation of the Mokihinui trout fishery, and the relative contribution of its components (e.g., of large and trophy fish).

3.28 The proposed monitoring programme includes provision for the following:

a. Angler catch and satisfaction and trout abundance (by drift diving) for three years before passage is restricted. The angler surveys will continue for eight years after damming. Drift dive surveys will resume post-Scheme in the event that the angler surveys indicate a decline in the fishery.

b. DIDSON surveillance to verify free passage during construction, and to aid design, and monitor the success, of trap and transfer and spawning channel mitigation options – should they be implemented.

c. Entrainment of trout by turbines, and their mortality rates, may be monitored by trapping below the tailrace.

3.29 The process proposed in the "Aquatic Ecology Management Plan" for implementing mitigation passes this responsibility to a panel consisting of independent expert fisheries scientists and stakeholders. The panel will assess the research and monitoring results, using a weight of evidence approach, and decide whether and what mitigation options are necessary. After the three years of research and monitoring pre-Scheme the panel will decide whether mitigation should be implemented immediately, or deferred pending the results of the post-Scheme monitoring.

3.30 The proposed mitigation options for adverse effects on the upper catchment fishery include:

a. Trap and transfer;

b. Stocking, which will require construction of a hatchery.

3.31 The proposed mitigation options for adverse effects on the lower river fishery include:

a. Permanent screening of the intake;

b. Enhancement or construction of spawning areas downstream of the dam,

c. Stocking.

3.32 Which of the above options will ultimately be implemented is contingent on the opinion of the expert panel.

4. THE PROPOSAL

4.1 I confirm my evidence is based on the project proposal as described in the Assessment of Environmental Effects, brief details of which are described in Appendix 1.

5. EXISTING TROUT FISHERY AND VALUES

5.1 Mr Greenaway and Greenaway & Associates (2007) present detailed information on the nature, and recreational values, of the Mokihinui trout fishery. The following summary draws from his evidence and from other sources. Supporting information is presented in Appendix 4.

5.2 The Mokihinui catchment supports one of the best headwater trout fisheries in the upper South Island and within Kahurangi National Park its trout fishery is second only, in terms of size and importance, to the Karamea Catchment.

5.3 The 2001-2002 NAS, which did not distinguish between the upper (headwaters) and lower sections, recorded 403 angler visits for the Mokihinui River, which is relatively low usage. To put this in perspective the most frequently fished river, the Mataura, had 52,850 visits. Nevertheless, the Mokihinui ranked in the top 27 % of all rivers surveyed (i.e., 26 % of rivers received more visits). Headwater and backcountry rivers receive comparatively low angling usage but are highly valued for angling experience. Only 8 % of headwater rivers (of 129 in total) received more visits than the Mokihinui and 34 % of headwater and backcountry river fisheries combined received more visits.

5.4 The North and South Branches in particular are popular wilderness angling destinations of importance to tourist and domestic fishers. The headwater fishery provided by these branches is very popular with fishing guides and tourist anglers seeking a wilderness experience and the business it generates supports helicopter operators and accommodation houses/lodges both locally on the West Coast and to the east of Kahurangi National Park (e.g., Murchison, Motueka and Nelson). In contrast the level of trout angling in the main stem of the river where the impoundment is proposed is thought to be low (Greenaway & Associates 2007). Greenaway & Associates considered the North and South Branches may be of national significance for wilderness angling whereas the lower river, below the Forks, is likely to be of no more than of regional significance for angling.

5.5 Mr David Moate (former Nelson Fishing Guide and Fish & Game Officer) provided a useful description of the Mokihinui trout fishery in Issue 31 of Fish & Game Magazine (Moate 2000). According to Mr Moate there is excellent trout fishing in the lower river from the sea to the beginning of the gorge. He mentions sea run trout in that section but anglers often assume silvery trout are sea run when they simply may be young and living in the lower river. This is typical colouration of trout that have been living, often shoaling, in open water bodies, including the ocean, estuaries, lower river reaches and even lakes. Mr Moate described the 12 km gorge below the North and South Branch Forks as being very steep and largely inaccessible offering few angling opportunities. By contrast he rated the fishery above the Forks as exceptional and one of the best wilderness brown trout fisheries in the country. He reported that trout caught by anglers average 2 kg and that the South Branch holds plenty of fish around 3kg including some trophy trout in excess of 5 kg. This description of the Mokihinui trout fishery is consistent with the information gathered as part of Meridian's investigations on the river.

5.6 Remoteness and difficult terrain along the river are the main limitations to angling use and so access by helicopter is popular.

6. EXISTING TROUT DISTRIBUTION AND ABUNDANCE

6.1 Data on the distribution of mainly juvenile trout in the Mokihinui catchment were available from the New Zealand Freshwater Fisheries Database (NZFFD). These records were recently supplemented by data collected by NIWA for the Native Freshwater Fish and Fisheries Report (Bonnett et al. 2007). Data on the distribution and abundance of mainly older trout were available from occasional drift dive counts by Fish and Game and historical dive counts by the Ministry of Agriculture and Fisheries. Reaches have been drift dived in the main stem at the cableway, just below the proposed dam site, and in the North and South Branches.

6.2 The NZFFD records show that brown trout are distributed throughout the catchment (Figure 1). While widespread in the catchment, trout are not very abundant at most sites (mean density = 0.04 / m^2, range 0 – 0.17 / m^2 - based on single pass electro-fishing).

6.3 Most trout recorded from the Mokihinui catchment in the NZFFD were relatively small (80 - 300 mm) (i.e., most were juveniles) – mainly because the electro-fishing methods employed, and the sites fished, select for small (juvenile) trout.

6.4 Table 1 lists historical drift dive counts of trout in the Mokihinui River and its tributaries. These can be compared against a national database of trout counts in 305 river reaches collected by Teirney and Jowett (1990), for the ‘100 rivers survey’, and by MAF and NIWA divers since then (database obtained from Mr Ian Jowett, NIWA). Comparisons between rivers are best confined to medium (20 – 40 cm) and large trout (> 40 cm) combined since divers have trouble separating these size categories and they undercount small (< 20 cm) trout.

6.5 The abundance of medium and large trout recorded in the Mokihinui ranged from 32 to 64 fish / km and ranks in the top 18 – 42 % of drift dive reaches nationally. However, the drift dive estimates from the Mokihinui and in the national database are highly variable. Taking this variability into account the mean abundance estimated for the Mokihinui (43.2 fish / km (SD +10.9, -8.7)) was not significantly higher than the national mean abundance estimate (25.2 fish / km (SD +46.8, -16.4)). In other words trout abundance in the Mokihinui is at least average.

7. TROUT MOVEMENT AND RECRUITMENT PATTERNS

7.1 Understanding the life-history and migration patterns of trout populations is crucial for effective management of fisheries and effects assessments of water development projects. Brown trout display remarkable plasticity and variability in life history strategies and are known to be both migratory and resident (Klemetsen et al. 2003). In migratory populations the life history includes one or more habitat shifts which may involve: a period of juvenile freshwater residence followed by migration to the sea (anadromous fish), estuary, lower or larger river, or lake where the fish grow large and mature before migrating back upstream to spawn in natal streams (Klemetsen et al. 2003, Naslund 1993). Some of these fish may stay for varying lengths of time in the spawning tributaries and contribute to headwater fisheries.

7.2 Ideally movement of fish in rivers is best determined from direct observation by means of trapping, acoustics, and/or tagging. However, these methods are time demanding and expensive. While not as definitive, cost effective alternatives use indirect evidence from which movement is inferred. Meridian commissioned two such complementary studies to assess trout movement and recruitment patterns in the Mokihinui catchment and the importance of providing free passage to maintain the fisheries above and below the gorge. These were:

a. Trout otolith micro-chemistry analysis undertaken by Otago University (Bickel & Closs (2007) and summarised in Hayes et al. (2008)),

b. Trout growth modelling undertaken by Cawthron Institute (Hayes et al. (2008);

7.3 This was the first time these two approaches were undertaken together to address the issue of trout migration and the results demonstrated that they indeed complement each other well. The otolith microchemistry study provided information on broad scale movement patterns of trout in the catchment. The growth modelling study provided information on whether trout need to migrate in order to grow to the size fish that anglers are used to catching in the Mokihunui catchment.

7.4 The methods and results of these studies are summarised in the following sections with some additional detail given in Appendix 5 (Otolith micro-chemistry) and Appendix 6 (Trout growth modelling).

Otolith micro-chemistry

Aims and methods

7.5 Otoliths are small calcium carbonate structures found within the inner ear of fish and are useful for age estimation because they grow continuously, laying down annual and daily rings. As the otolith grows it incorporates trace elements from the environment that fish is living in and this feature can be exploited in otolith micro-chemistry analysis to determine fish migration patterns (Campana and Thorrold 2001). Importantly once material is deposited in the otolith it is not remobilised. The otolith core is formed when the fish begins to grow in the egg and the outermost layer has been deposited most recently.

7.6 Trace element concentrations differ substantially between freshwater and marine environments (especially strontium) but differences can also be detected in the water and otoliths within the freshwater parts of river catchments too (e.g., between tributaries and along rivers) as a result of varying basement geology or land use.

7.7 By analyzing levels of trace elements across layers of the otolith, patterns of movement can be inferred if the trace element signature of the different environments in which a fish may have been resident can be identified (Campana and Thorrold 2001, Wells et al. 2003). Otolith trace element signatures change in response to a change in environmental trace element concentrations within 14 days (Zimmerman 2005).

7.8 The elemental signature of trout otoliths was determined using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS). This involves firing a laser beam at predetermined locations on the thin-sectioned otolith. The ejecta are transferred via a carrier gas into a mass spectrometer which determines the trace elemental composition.

7.9 The Mokihinui otolith micro-chemistry study was aimed at determining:

a. Whether adult brown trout moved between river reaches, and more specifically between freshwater river reaches and the estuarine reaches or ocean;

b. The contribution of various tributaries to the adult stock (i.e. recruitment sources);

c. Whole-life patterns of movement of adult trout between tributaries and various reaches of the Mokihinui River.

7.10 Movement between freshwater reaches and between fresh - and saltwater (aim (a)) was examined by analysis of strontium and barium variation from the centre to the edge of the otolith. High strontium, low barium signatures indicate estuarine or ocean life history stages (Arai et al. 2002).

7.11 The contribution of various tributaries to the adult stock (aim (b)) was determined by comparing multi-element signatures from juvenile trout otoliths (sampled from the various rearing sites) and the region immediately outside the core of adult otoliths that represents the period of juvenile residency in their natal stream.

7.12 Whole-life patterns of movement (aim (c)) were determined by comparing multi-element signatures at various points from the core to the edge of adult otoliths with multi-element signatures from juvenile otoliths.

7.13 Adult trout were sampled at three sites in the main stem below the Forks (the estuary (4 fish), the lower Mokihinui (11 fish), and just below the gorge (4 fish)), and one site each in the North Branch (17 fish) and South Branch (11 fish) (Figure 2). The adult trout ranged in size from 20 to 66 cm (mean = 55 cm) and 0.2 – 3.0 kg (mean = 2 kg). No trophy trout were caught for the analysis and only one attained 3kg – from the South Branch. Juvenile trout (1 – 2 years old) were collected from the North and South branches, the lower Mokihinui main stem, and from eight sites in the major tributaries of the North and South Branches to establish multi-element habitat signatures for most of the main potential trout habitats in the catchment. A total of 106 juveniles were analysed (7 from the lower Mokihinui, 9 from the North Branch and 10 each from the South Branch and the eight tributaries). While a larger sample would be ideal from a scientific perspective in order to have a high degree of confidence in the migration patterns of Mokihinui trout, I consider this sample size adequate to allow some tentative conclusions to be drawn. The sample also allows me to recommend some further targeted research which I will discuss later in my evidence.

7.14 The juvenile trout otoliths were scanned by the laser only at their edge. This material represents the otolith material deposited most recently and hence represents the trace element signature of the location where the fish have been resident prior to capture. The lasered edge material was analysed for six elements, strontium, barium, manganese, magnesium, phosphorus and rubidium which have previously been found to be useful in distinguishing between sites within river catchments. Statistical differences in trace element signatures between main stem river reaches, branches and tributaries were determined with linear discriminant function analysis.

7.15 The adult trout otoliths were scanned by the laser across an entire radius from the core to the edge producing a trace element life history transect. The life history transects were first inspected for any areas with relatively high concentrations of strontium and low concentrations of barium which are indicative of estuarine and ocean life history stages.

7.16 Laser scans of the chemical composition within 300 μm of the core of the adult otolith provided the elemental signature of the natal stream (i.e., where the fish hatched and initially reared). This provided information on recruitment locations within the Mokihinui catchment.

7.17 In addition to the full transect life history trace element scans, annual habitat signatures for four randomly selected fish from each sampling section were also undertaken to track whole-life migration of adult fish. Comparison of multi-element signatures from the core to edge of the otolith provided an indication of the river reaches a fish may have entered over its life, when compared with the multi-element signatures obtained from resident juvenile fish, collected from various locations around the river.

Results

<u>Movement between freshwater and estuarine sections</u>

7.18 Of the four adult trout collected in the estuary, three exhibited strontium:calcium (Sr:Ca) ratios > 2 mmol/mol at the otolith edge (Figure 3) indicating a sustained period (> 2 week) in the estuary. The other fish did not show Sr:Ca levels indicating an estuarine life stage (Mk11). Presumably it had only just arrived at the estuary.

7.19 Sr:Ca ratios at the otolith edge in fish collected from other locations around the catchment were ≤ 1.5 whereas those from the estuary exceeded 2 mmol/mol. Hence ≥ 2 was adopted as an elemental signature benchmark to assess whether fish collected from upstream river reaches had spent time in the estuarine reach.

7.20 Only one of the eleven adult trout (Mk8) collected in the lower Mokihinui River reach had a Sr:Ca ratio > 2, clearly indicative of a sustained residence in the estuary (Figure 4). However, the maximum Sr:Ca ratio, close to the edge of the otolith from Mk9 was close to that (1.95), strongly suggesting that it had recently been in the estuary. There were also pronounced variations in Sr:Ca and Ba (barium):Ca ratios in the life history transects of all of the fish (particularly Mk5 & Mk7), suggesting movement by these individuals between different reaches and /or tributaries within the Mokihinui River catchment. None of the four fish collected from just below the gorge showed evidence of having spent a sustained period (> 2 weeks) in the estuary.

7.21 Of the 17 fish collected in the North Branch only one fish (Mk35) appears to have spent part of its life in the estuary (Figure 5). One other fish (Mk47 – not shown) had Sr:Ca ratios close to 2, and therefore could have spent some part of its life near the estuary. Sr:Ca and Ba:Ca ratios were quite constant along the life history transects of most of the fish (e.g. Mk31), indicating less movement through the catchment than seen in fish from the lower Mokihinui. However, some of the fish show one (e.g. Mk33) or multiple changes in Sr:Ca and Ba:Ca ratios throughout their life (e.g. Mk35).

7.22 Overall, of the 17 adult trout from the North Branch, nine (53 %) appeared to have moved out of the North Branch at some stage, four (24%) had probably remained resident in the North Branch, and four had indeterminate element signatures. Movement out of the North Branch could have been between tributaries, river branches or most probably into the Mokihinui main stem below the Forks since most early life history movements by salmonids are downstream (Olsson & Greenberg 2004).

7.23 Of the 10 adult trout collected from the South Branch, none had Sr:Ca ratios high enough to indicate estuarine residence. Three fish had probably migrated between tributaries or river branches at some stage, three others had probably remained resident in the South Branch, and element signatures of four fish were indeterminate.

7.24 In general, fish from the upper catchment appear to be less mobile than fish from the lower river.

<u>Movement between main stem, branches and tributaries, and identification of recruitment sources</u>

7.25 The discriminant function analysis showed that otolith trace element signatures of juvenile trout from the tributaries, North and South Branches and main stem Mokihinui, and adult trout from the estuary were significantly different. Overall, 73% of the juvenile trout were classified correctly to the area where they were caught. There was a perfect (100%) classification of the adult trout collected from the estuary and the elemental habitat signature for this section was clearly different to the habitat signatures obtained from the other areas within the Mokihinui River (Figure 6). Trace element signatures from the main stems of the river (i.e., the North and South Branches and the lower main stem) showed considerable overlap, and hence could not be readily separated. However, the main stem sites and the sites from the tributaries of the North and South Branches could be distinguished to a reasonable extent from each other, with a classification success of 60-90%.

Migration histories of trout from the lower Mokihinui River

7.26 The classification of trout from the various parts of the catchment according to their otolith trace element signatures presented in Figure 6 allows tracking of long term movement patterns of trout within the Mokihinui catchment. The tracking results are presented in Figures 7 – 9, for four adult trout caught in each of the following reaches: the estuary, the lower Mokihinui, and from just below the gorge.

7.27 Two of the estuary trout (Mk10, Mk11) appear to have been spawned in the South Branch tributaries (Figure 7). Another (Mk1) appears to have been spawned in the main stem, most likely upstream of the gorge in one of the two branches. However, the overlap in the elemental signatures of fish from these locations means a lower river origin cannot be ruled out. The last fish (Mk2) most likely originated from the lower Mokihinui, although there is an outside chance it might have originated from a South Branch tributary.

7.28 Adult trout collected in the lower Mokihinui River (Figure 8) appear to have originated from various locations in the catchment and either remained in the lower section throughout their lives (Mk3 & Mk4) or moved downstream from South Branch tributaries (e.g. Mk5 & Mk7). Given the relatively close overlap between South Branch tributary signatures and the lower Mokihinui signature, fish collected from just below the gorge could be interpreted as moving downstream into the lower Mokihinui River from South Branch tributaries or remaining resident within the lower Mokihinui River for their entire life (Figure 9).

Migration histories of trout from the upper Mokihinui River

7.29 The tracking results for eight adult trout caught in the upper Mokihinui (North and South Branches) are presented in Figures 10 and 11. Elemental signatures of two of the four trout caught in the North Branch suggest movement from the North Branch to the main stem downstream of the North and South Branch confluence (Mk33 & Mk39) (Figure 10). Estuarine trace element signatures were observed in the otoliths of two North Branch fish (Mk 35 & Mk47) suggesting movement downstream from the North Branch or below the Forks to the estuary and migration up into the North Branch, a pattern that corresponds with the comparatively high Sr:Ca ratios in these two fish. Based on the otolith analysis three of the four fish (Mk33, Mk39, Mk47) most likely were spawned in North Branch tributaries, and the other in the lower Mokihinui main stem downstream of the gorge (Mk35).

7.30 Element signatures of the four South Branch trout generally suggested relatively limited movement, with three of the fish (Mk 21, Mk26, Mk 29) either remaining within the South Branch or moving into the main stem downstream of the North and South Branch confluence (Figure 11). However, the similarity of the trace element signatures from these fish to the region of overlap between the signatures of the South Branch and lower Mokihinui (labelled Mokihinui R in Figure 11)) means that it is not possible to confidently distinguish movement between these locations. The fourth fish (Mk 24) probably moved between the South Branch and the main river downstream of the North and South Branch confluence, or between the South Branch and South Branch tributaries.

Recruitment sources

7.31 In this section, the most likely natal stream origin of all the adults collected for the study are predicted based on the elemental signatures close to the core of the otoliths.

7.32 Trout populations in the Mokihinui River appear strongly dependent on the recruitment of juvenile fish from the tributaries of the North and South Branches. Plots of discriminant function scores suggest that adult fish collected in the lower reaches of the Mokihinui appear to originate from a variety of locations with a large proportion recruiting from upstream sources beyond the gorge (Figure 12a-c). Adult fish sampled in the North Branch and South Branch were predominantly recruited from tributaries to the branches (Figure 12 d-e).

7.33 The predicted origins of all adult fish from the Mokihinui River based on discriminant function analysis are presented in Table 2. Overall the results indicate that the majority of the population (94%) is sustained by spawning in tributaries of the North and South branches.

Limitations of the otolith micro-chemistry study

7.34 Due to the very low number of trophy fish in the river, no trophy trout ≥ 4.5kg, and no large trout > 3 kg, were included in the analysis so the study sheds no light on the migratory status of these fish.

7.35 The analysis had limited ability to distinguish between mainstem sections especially the freshwater section from the Forks to the estuary. This limits assessment of the effect of the proposed dam on trout moving between the branches (especially the North Branch) and within the freshwater section of the Mokihinui mainstem below the Forks.

Summary of the otolith micro-chemistry study

7.36 In summary the otolith micro-chemistry results show that large scale movement by trout in the Mokihinui catchment is common and in general, fish from the upper catchment appear to be less mobile than fish from the lower river.

7.37 A high proportion (53%) of trout caught in the North Branch had moved at some time during their lives – probably downstream of the Forks. Trout caught in the South Branch displayed much less movement – only 30% showed clear evidence of movement out of the South Branch over their lives, probably between the South Branch and its tributaries or into the North Branch.

7.38 It is not possible to say where in the Mokihinui main stem below the Forks trout may move other than not many end up in the estuary or ocean. Sea- or estuary-run trout were relatively uncommon (14 – 16

% of those analysed). This suggests that most trout in both the lower and upper reaches of the Mokihinui River do not utilise the estuary or ocean. Moreover for those that do, the estuary and ocean is not necessarily an essential component of their life history but rather they may end up there by chance.

7.39 Most of the population (94%), including fish in the lower river and estuary, appears to be sustained by spawning in the headwaters – in tributaries of the North and South Branches.

Trout growth modelling

Factors affecting trout growth

7.40 Because trout are cold blooded water temperature has a strong influence on their food consumption, metabolism and growth rates. Brown trout have an optimal temperature for growth of 13.9 °C when feeding at maximum consumption rates on invertebrates, increasing to 17 °C on a fish diet (Elliott & Hurley 1998, 1999, 2000). Trout grow more slowly when the water is colder or warmer than these optimal temperatures. They grow slowly in cold headwaters and tributaries, or at high latitudes, even when invertebrate food is abundant because the rate at which they can digest their food is limited by the cold conditions. In these situations migration to warmer habitats downstream, and even to the ocean, at an early age allows trout to escape cold temperature limitations to growth.

7.41 By migrating to the lower reaches of rivers, or to the ocean, trout also have access to abundant fish prey. The abundance of native forage fish, such as bullies, smelt and whitebait, declines with distance upstream because many of these species are diadromous (sea migratory) and most only penetrate a short distance upstream in most rivers. The abundance of diadromous native fish species quickly declines with distance from the Mokihinui River mouth, and this is verified by NIWA's fish distribution survey (Bonnett et al. 2007). Juvenile trout are widespread in the Mokihinui River, including the headwaters (Figure 1), but they are not very abundant and they are difficult for large trout to capture. Probably for these reasons fish prey are rarely found in the stomachs of headwater and backcountry river trout.

7.42 Brown trout predominantly eat aquatic invertebrates in rivers, but sometimes supplement their diet with fish – even switching entirely to fish prey in some circumstances. Trout grow about three times faster eating fish prey than invertebrate prey but in the wild they usually need to attain a threshold size of about 27 cm (200 - 250 g) before they feed significantly on fish (Keeley & Grant 2001).

7.43 The main factors affecting growth and maximum size of trout in order of importance are:

a. water temperature;

b. quantity and type of food (invertebrate versus higher energy diet such as fish, mice, or artificial pellet food);

c. reproduction costs;

d. age at maturity;

e. costs associated with feeding (and other activity);

f. water clarity.

The trout growth models, study approach, and modelling options

7.44 The trout growth models used in the Mokihinui River study were developed and tested by me (Hayes 2000, Hayes et al. 2000) using bioenergetics equations developed by Elliott & Hurley (1998, 1999, 2000). They incorporate the above factors known to regulate growth. The models predict growth for both invertebrate and fish diets and for combinations of the two. Depending on the options chosen the models can show how growth is likely to be affected by differences in water temperature such as occurs between rivers, within rivers (between tributaries, and downstream) and over time and they can also predict the effect of changes in food resources.

7.45 In this case, a modelling option was chosen to determine the influence of the longitudinal water temperature gradient down the river on trout growth potential. From this analysis inferences can be made about whether trout need to migrate in order to grow to the sizes observed in anglers' catches in the headwaters (Young & Hayes 1999; Hayes & Quarterman 2005). Specifically I determined whether trout could grow to the sizes observed by anglers in the

Mokihinui, by residing for their entire lives in the headwater tributaries, or would need to migrate downstream to the lower river (i.e., below the proposed dam site) in order to do so.

7.46 The growth modelling study corroborates the otolith micro-chemistry study results and vice versa. I used the results of the two studies to infer whether disruption to trout migration by the proposed dam and resulting isolation of the headwater trout population might result in reduced growth rate and maximum size of trout in the headwaters

7.47 Whole-life-time growth (over 12 years) was predicted for trout on maximum and 90% invertebrate rations based on mean daily water temperature data collected from loggers at six sites in the catchment over the period 1 September 2006 – 20 August 2007 (Figure 13). In one modelling run, drift-foraging energy costs were applied amounting to 4% of daily energy consumption once fish reached maturity. Details of modelling assumptions and parameters are given in Appendix 6.

7.48 Predicted growth was compared with observed growth, the latter based on size at age data from 35 brown trout collected for the otolith microchemistry study from five sites distributed through the Mohikinui main stem and North and South Branches (Figure 2). Age was estimated by counting annual growth rings of thin-sectioned otoliths.

Results

Water temperature

7.49 Annual water temperature regimes for the six sites generally showed the expected pattern of increasing water temperature with distance downstream (Figure 14).

7.50 The most striking feature of the water temperature regimes was the substantially lower temperatures experienced year round at the North Branch site, compared with all the other sites, which all had relatively similar temperature regimes.

7.51 When interpreting the water temperature plots recall that the optimal temperature for growth of brown trout on maximum invertebrate rations is about 14 ºC. Sites at which seasonal water temperatures deviate the least from this optimal temperature offer best growing conditions for trout. Therefore, trout growth potential is highest at the Main Road (Highway 67) site (in the lower river) and lowest at the North Branch site (Figure 14).

Observed growth rate

7.52 Before we look at the growth predictions we first need to examine observed sizes and growth of trout in the Mokihinui catchment. Having taken this information on board we can then see whether predicted growth based on the water temperature regimes at each site can explain the observed sizes of fish. If predicted growth can explain observed growth then theoretically trout should not need to migrate to find better temperature conditions for growth, assuming they are not substantially food limited. In which case, movement between the upper and lower catchment is unlikely to be obligatory (essential to life history) but rather due to chance.

7.53 Of the trout examined for observed age and growth (34 fish), the larger and older, fish were generally collected from the upstream sites in the North and South Branches. All but one of the fish that were 7 years or older, and all but two of younger fish weighing 2,000 g or more, were caught from the upstream sites (i.e. the North and South Branches; Figure 2 and 15).

7.54 The observed size at age data suggest that for the majority of trout in the Mokihinui River growth tends to plateau at 1,500 – 2,500 g after about age 5 (Figure 15). This asymptotic growth pattern is typical of riverine trout and results largely from energy being diverted into reproduction after maturity (Hayes et al. 2000; Hayes 2002). Growth typically levels off between ages 3 – 5 in New Zealand rivers (Hayes et al. 2000; Fox et al. 2003; Hayes 2002). Increasing costs of foraging on invertebrate drift with increasing size, and food limitation, also contributes, but to a lesser extent, to the reduction in growth rate and asymptotic growth pattern after maturity (Hayes et al. 2000).

7.55 Growth rate and age at maturity (first spawning) set trout on the growth trajectory that will ultimately determine maximum size. After maturity trout on an invertebrate diet allocate most of their spare energy, additional to body maintenance costs, to reproduction. In other words, there is little scope for growth after maturity unless the fish have access to an abundant, energy rich food supply, or if they skip spawning in some years.

7.56 There were two fish in the sample that appeared to have a more rapid growth trajectory than the other fish, achieving greater than normal size (2,500 – 3,000 g) by 5.5 – and 6.5 years of age (Figure 15 – circled). One of these fast growing fish was caught in the lower Mokihinui River and the other in the South Branch.

7.57 A dichotomy of growth trajectories, with fish either falling into fast or slower growing groups, has also been recorded from other large rivers which have free access for trout through their length and to the ocean, including: the Pomahaka, Wairau, and Motueka rivers (Hayes 2002) (Figure 16). However, in these rivers the fast growing trout have generally been larger at 5 – 7 years of age (3,000 – 5,000 g). The fast growing trout from these rivers are thought to have spent time feeding either in the sea or in warmer downstream river reaches (Young & Hayes 1999; Hayes 2002). There is also evidence from tagging and spawning trap records from the Glenarriffe Stream that trout of such large size migrate to the Rakaia River estuary, or ocean (Fox et al. 2003).

7.58 Significantly, no trout older than 7 years exceeded 2,500 g or 70 cm in the sample from the Mokihinui. A similar pattern has been found in size at age plots from the Hurunui, Motueka, Pomahaka, and Wairau rivers, all of which have free access to the ocean (Hayes 2002, Hayes & Quarterman 2005) (Figure 16). This suggests that the fast growing, large trout die early as has been reported for migratory trout elsewhere (Jonsson & Jonsson 1993, Jonsson & Jonsson 2006). Hayes et al. (2000) recorded no trout larger than 2,500 g from the Maruia River above the Maruia falls – an impassable barrier to trout. Significantly, the Maruia River above the falls sustains an isolated (i.e., resident) 'A' category headwater trout population (Jellyman & Graynoth 1994)[1]. Trout in the Maruia River exhibited a similar

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[1] 'A' category rivers sustain good fishing all fishing season whereas in 'B' category rivers catch rates decline over the season.

asymptotic growth pattern as the majority of trout from the Mokihinui (Figure 15 and 16).

7.59 Corroborating results from other rivers (Hayes 2002) suggests that thermal and invertebrate feeding conditions for growth in the upper reaches of Canterbury, West Coast, and Nelson-Marlborough rivers constrain the sustainable maximum size of resident trout to between 1,500 g and 2,800 g. Migration to lower river reaches, estuary, or ocean at an early age can offer a means of exceeding this upper size threshold – especially if the diet is supplemented by fish. Alternatively some trout might exceed this weight threshold by feeding on mice, which can be temporarily abundant during beech mast (seed) years. However, such a life history involving fast growth and large size at maturity may commit these fish to repeated migration to maintain their large size and further reproduction which leads to reduced survival (Jonsson & Jonsson 1993, Jonsson & Jonsson 2006), since the rigors of recovery from spawning and migration reduce life expectancy.

Growth modelling

7.60 In the interpretations that follow a key point to understand is that if observed growth substantially exceeds predicted maximum growth (based on temperature) then this suggests trout have grown larger than expected elsewhere (i.e., under better temperature conditions for growth). Type of food (invertebrates versus fish) can also have a role to play but this will be addressed later.

7.61 Modelled lifetime growth trajectories based on water temperature records in the Mokihinui catchment generally predicted higher, or similar, weight at age than was observed in the total sample of fish caught from the entire catchment (Figure 17). The only exception was for the North Branch, which had the coolest water temperature. There were only two fish, out of the total sample of 35, that were larger for their age than the model suggested could be attained under the local temperature regime of the coldest site, the North Branch. However, neither of these fish was caught in the North Branch. One was taken from the South Branch and the other from downstream of the proposed dam site.

7.62 The fact that predicted growth for all sites exceeded observed growth of all but two of the fish in the sample is evidence that the majority of trout in the headwaters would not need to migrate downstream beyond the proposed dam site to grow to the size observed, assuming that they are able to obtain sufficient invertebrate food.

7.63 The fact that observed growth was generally substantially less than predicted by the model for all sites suggests that trout are food limited to some extent in the Mokihinui River. Alternative explanations for larger predicted than observed size at age include: 1) size selective mortality operating on large trout after maturity, resulting in only the slower growing fish attaining old age; 2) early growth retardation in juveniles, if most rear in tributaries that are colder than the North and South branches and main stem.

7.64 Figure 18 shows how the predicted growth trajectories would be affected by mild food limitation. In this case trout were assumed to be able to achieve only 90 % of their maximum daily food intake. This has the effect of reducing predicted growth rates and better matching observed growth rates – especially for fish caught in the North Branch.

7.65 Significant food limitation, and/or thermal limitation of growth in juveniles ought to drive migratory life histories – whereby trout can attain larger size and reproductive fitness by feeding in better temperature, and possibly better food, regimes for growth. Migratory life histories ought to become increasingly likely the further a site's temperature regime departs from the thermal optimum for growth – which is about 14ºC for brown trout feeding on maximum rations, but less when trout are food limited. Food limitation becomes increasingly likely as trout grow and attain maturity, because they have greater consumption and prey size requirements, but the supply and size of stream invertebrates is finite. Food limitation (on invertebrate prey) would favour headwater residence by adult trout, where the cooler temperature regimes allow conservation of energy through reduced metabolic demands and more efficient conversion of food energy.

7.66 The temperature regimes at all sites studied in the Mokihinui catchment were less than optimal (14°C) for trout growth on an invertebrate diet, even at the downstream and warmest site at the Main Road. Mean annual temperature ranged from 9.6 ºC at the coldest site (in the North Branch) to 11.2 ºC at the Main Road (lower) site. But these suboptimal temperature regimes can still support rapid growth by world standards, and theoretically allow trout to achieve observed sizes of 2 – 3 kg (58 – 67 cm). Moreover, even the temperature regime in the North Branch is sufficient to grow trout to 2.5 kg (which equals or exceeds the weight of most trout observed) provided they are not significantly food limited at the juvenile stage – in which case trout would need to migrate to find better food resources elsewhere in the catchment.

7.67 Young trout < 4.5 years in the sample, all caught in the lower river, grew much more slowly than predicted by the growth model at all sites (Figure 17, 18). This could occur because their early growth history was limited either by cold temperature and/or by food. They may have been recruited from, and reared in, cold, high elevation tributaries (e.g. of the North and South Branches) and/or experienced poor feeding conditions there or elsewhere in the catchment. However, the fact that all of these young fish caught in the lower river fell far short of their growth potential hints at invertebrate food limitation in the lower river. It is unlikely that all of them grew slowly elsewhere.

7.68 Benthic invertebrate density and taxonomic composition are similar throughout the Mokihinui catchment, except the gorge where density is lowest, and are similar to other West Coast rivers (see Periphyton and Invertebrate Report – Suren & Kilroy 2007). Overall, invertebrate densities are relatively low.

7.69 Given that temperature increases downstream, which drives higher metabolic rate (energy demand) in fish, invertebrate densities would need to increase downstream in order for growth rate of lower river trout to match that of upstream trout. The facts that invertebrate densities in the lower river are relatively low and no higher than in the upper river, and lower river trout < 4.5 years (about 1 kg or 45 cm) fall far short of their growth potential suggests significant invertebrate food limitation in the lower river. If that case there would be no advantage for trout from the upper river to migrate at an early age to the lower river in order to grow faster. In fact, under food limiting conditions it would be more beneficial for trout to remain in the cooler headwaters where metabolic rate and energy conversion of food for growth is more efficient.

7.70 The greater availability of forage fish in the lower river would offer a growth advantage, but trout generally don't become piscivorous until they reach about 27 - 30 cm. Once they attained about that size, the slow growing, young trout sampled from the lower river would have to complement their diet with fish prey, which are more energy rich than invertebrates, in order to catch up with the predicted, and even the observed, lower river growth trajectories based on an invertebrate diet in Figures 17 and 18.

7.71 Trout are able to grow up to three times faster on fish than invertebrate prey (Elliott & Hurley 2000). So on an all fish diet trout would exceed the growth rates observed in the Mokihinui by a wide margin. However, it is unlikely that fish contribute significantly to the diet of most Mokihinui River trout, except in the lower reaches of the river, estuary and ocean, because, as mentioned previously, fish prey are not very abundant in the upper reaches of New Zealand rivers, including the Mokihinui.

7.72 Regardless of the distribution of food resources for trout in the catchment, better thermal growth conditions, sufficient to explain the sizes of all trout observed, occur not only in the lower river (below the proposed dam site) but also below the Forks, in the South Branch, and Hemphill River.

7.73 It is unlikely that trout in the headwaters are substantially food limited such that downstream migration is necessary for achieving observed size at age. In fact, as I've already discussed, the available evidence suggests invertebrate food is likely to be most growth limiting in the lower river. The otolith microchemistry study showed that most trout in the South Branch are either entirely resident in the South Branch catchment or undergo restricted movement – perhaps as limited as a little downstream of the Forks. The majority of trout in the North Branch moved from that branch during their lives, possibly to the South Branch or headwater tributaries, but probably below the Forks but upstream of saltwater influence.

7.74 If migration does offer a growth advantage to migrants then we might expect to see this in those fish that were identified as migrants in the otolith micro-chemistry study. To examine this I compared the size of trout older than five years (the age at which mean size flattens off) that were classified as headwater residents with those classified as migrants to the lower river. I found no significant difference in size between these two groups indicating that migration to the lower river on average confers no size advantage, although the sample size was small (only 17 fish in total) so the statistical test had low power.

7.75 Comparative growth analysis with the Maruia River is also helpful in determining whether trout in the Mokihinui headwaters need to migrate down-river to achieve their 'large' size. The Mariua was the river in which I successfully tested the validity of my trout growth model (i.e., predicted growth matched observed whole-lifetime growth based on water temperature and invertebrate diet (Hayes et al. 2000)). Trout above the falls in the Maruia River cannot migrate downstream and return (i.e., they are resident fish). Nevertheless they attain similar sizes to trout in most backcountry rivers in the upper South Island, including the Mokihinui headwaters – about 2.0 – 2.5 kg (i.e., the food resources, mainly invertebrates, above the falls are sufficient to grow trout to that size). The Maruia's temperature regime is warmer in summer and cooler in winter than the Mokihinui (Figure 14) and its annual mean temperature (11.2 ºC) is only slightly warmer (closer to optimal) than the Mokihinui headwater sites but the same as the lower Mokihunui main stem: 9.6 ºC in the North Branch, 10.6 ºC in the Hemphill just upstream of the confluence, 10.3 ºC in the South Branch, 10.8 ºC below the Forks, 10.9 ºC in the Mokihinui main stem below the Rough and Tumble confluence and 11.2 ºC at the Main Road. Despite the slightly lower mean temperatures in the headwater sites the modelling predicts that all of the Mokihinui sites provide plenty of scope for growth for trout to attain 2.5 kg on an unlimited invertebrate diet (Figure 17). Furthermore, from the Forks downstream, the Hemphill River, and probably the lower South Branch there is sufficient scope to achieve this weight even when invertebrate food is limited by 10% (Figure 18).

Summary of trout growth modelling study

7.76 In summary the growth study showed that trout in the Mokihinui catchment attain similar sizes to those commonly found in most backcountry rivers in the top of the South Island, and in fact over most of the country (2.0 – 2.5 kg).

7.77 The growth pattern of most trout in the Mokihinui plateaus at 1.5 – 2.5 kg after about age 5 and is typical of New Zealand backcountry rivers.

7.78 Trout exhibiting a faster growth trajectory – attaining 2.5 – 3.0 kg by 5 – 7 years are uncommon in the Mokihinui (only 2 were found in a sample of 34) and trophy trout ≥ 4.5 kg are rare (none sampled).

7.79 The thermal scope for growth is sufficient for trout to attain 2.5 kg on an unlimited invertebrate diet throughout the South and North branches and from the Forks to the ocean. Furthermore, even under slight food limitation (90% invertebrate rations) the thermal scope for growth is sufficient for trout to achieve this size from the Forks downstream, the Hemphill River, and probably the lower South Branch.

7.80 Trout appear to be invertebrate food limited throughout most of the catchment, more so in the lower river such that young trout there fall far short of their growth potential.

7.81 I infer from the above results that trout from the headwaters of the Mokihinui River would not have to move downstream to the lower river, past the proposed dam site to grow to the sizes observed. In fact because invertebrate food limitation appears to be substantial in the lower river, migration at an early age to the lower river is unlikely to be advantageous.

7.82 Given the favourable temperature regimes for trout growth throughout most of the catchment, the movement by trout indicated by the otolith micro-chemistry study is probably facultative, (i.e., movement occurs probably by choice or chance rather than by necessity for growth and survival) and on average appears to confer no size advantage on migrants.

8. REVIEW OF TROUT FISHERIES OUTCOMES OF DAMS AND IMPOUNDMENTS IN NEW ZEALAND

8.1 This section of my evidence summarises Holmes & Hayes' (2008) review of the effects of dams and impoundment on trout fisheries in New Zealand. By undertaking the review it was hoped that lessons might be learnt that could help in assessing the effects of the MHP.

8.2 Because there is little quantitative information comparing fisheries before and after dam installation in New Zealand, the review was based largely on a perception survey of the professional opinions of regional fisheries management staff supplemented by opinions of a small number of prominent local anglers. Telephone interviews were conducted with, and email feedback obtained from, 21 Fisheries staff covering 11 of the 12 Fish and Game Regions, the Clutha Sports Fishery Trust, and the Department of Conservation Taupo Fisheries Area. Telephone interviews were conducted with 10 experienced anglers, from five Fish and Game regions, recommended by fisheries staff.

8.3 The National Angler Survey Database was also analysed in the review to assess the comparative usage of reservoirs versus natural lakes (Unwin & Image 2003).

8.4 Overall, ten percent of trout fishing effort in New Zealand occurs in artificially created reservoirs. This represents a high level of angling usage relative to the occurrence of reservoirs (5% of fishing water bodies in New Zealand). If ranked according to popularity, artificially created reservoirs are spread remarkably evenly among New Zealand's recognised lake fisheries. Of the 61 reservoir fisheries, 15 occur in the top 25% of the most regularly fished lakes and 15 occur in the lower 25%. The remaining 31 reservoirs are spread throughout the moderately popular lakes.

8.5 There are some exceptionally good reservoir fisheries. Benmore, Dunstan, Aniwhenua, Aviemore and Arapuni reservoirs are among the top 20 most popular fishing lakes in New Zealand. Of those, Dunstan and Benmore are among the 20 most popular fishing waters (lakes and rivers) in the country. Catch rates from Lake Dunstan compare well with those of other lakes in the Otago region (Hayes

1996). Indeed, the average catch rate of 0.31 fish per hour in Lake Dunstan is comparable to that of an average season on the Tongariro, New Zealand's most internationally famous river. From this it can be concluded that reservoir fishing is not necessarily less popular or less successful than river fishing.

8.6 Dams and associated reservoirs potentially can have both positive and negative effects on trout habitat and fishing quality throughout catchments. Dams impede trout migration from lower river reaches, lakes, estuaries and the ocean. In some systems upstream fish migrations are important for maintaining high quality angling opportunities and trout stocks. In other systems upstream migration is not important and reservoirs may actually enhance upstream trout populations.

8.7 Damming rivers with relatively stable flow regimes, such as those draining natural lakes may be detrimental to trout fisheries by increasing downstream river level fluctuations which can reduce invertebrate habitat and production, potentially decreasing trout densities and/or growth rates. Conversely, in unstable drought, flood or erosion prone catchments dams may be beneficial to trout fisheries by augmenting low flows, increasing water clarity and reducing siltation. Dams associated with significant storage can reduce the magnitude of high flow events which may exacerbate nuisance algal growths but these effects can be mitigated with appropriately designed flushing flow regimes.

8.8 A fishery is likely to receive a net benefit from an artificial reservoir if the river is unstable, with frequent flooding and/or extreme low flows, and there is negligible seasonal migration of trout from the lower river and/or ocean.

8.9 From a social perspective, factors that determine whether a new reservoir fishery in a catchment adds value to trout fishing include: the quality and uniqueness the river fishery it has replaced, the amount of people that are familiar with the former fishery, the quality, aesthetic value, and accessibility of the new reservoir fishery, and the proximity of other lake fisheries.

8.10 Overall, the experienced anglers interviewed for Holmes & Hayes' review considered that dams have adversely affected fishing quality. They considered that inundating river reaches is detrimental to a region's fishing opportunities. These anglers preferred river fishing over lake fishing and so placed a high value on the intangible properties of unmodified fishing destinations or potentially unique river fisheries. By contrast, creating artificial reservoirs that support reasonable fisheries can benefit boat owners and junior or more casual anglers. This is because reservoirs provide more consistent fishing conditions, access may be improved, technical aspects of fishing (such as casting) are easier, catch rates in reservoirs can be higher for less skilled anglers, and fishing can be more easily combined with other activities such as picnicking and boating.

8.11 The consensus among the fisheries management staff interviewed was more balanced. They considered that dams and associated reservoirs have adversely affected fisheries in some catchments and benefitted them in others.

8.12 Impoundments such as Lake Dunstan, Aniwhenua in the Bay of Plenty, and the Waitaki and Waikato hydro lakes have enhanced angling opportunities overall and benefited local communities through attracting people to the area. These lakes all have reasonable clarity and extensive shallow areas that remain submerged for prolonged periods favouring productive aquatic invertebrate communities.

8.13 Trout sometimes are more abundant and smaller in reservoirs than in river reaches they replace, probably because the reservoirs provide refuge from floods, especially for juveniles, and productive feeding habitat. However the feeding habitat can vary depending on the physical characteristics of the reservoir. These fish may move into upstream river reaches increasing abundance there. In the in-flowing rivers of Lakes' Opuha (South Canterbury) and Rotorangi (Taranki) anglers report higher catch rates of smaller sized fish compared to pre-impoundment.

8.14 It was generally perceived by most anglers and fisheries management staff interviewed that fluctuating levels created by daily and seasonal cycles of power generation, reduce fishing quality in most rivers under hydroelectric control relative to their natural state.

There are exceptions though. For example, flows vary substantially on a daily and weekly basis in the lower Waitaki River due to hydro-power generation yet it sustains an excellent trout fishery.

8.15 The review provided useful information for assessing effects of the MHP reservoir on the trout population above the dam site but was less helpful for assessing effects on the downstream fishery. In particular it appears that the MHP is unique among hydropower developments in New Zealand in that the river below the dam has very little, or no, trout spawning habitat. In rivers below all other dams in New Zealand spawning habitat is available in tributaries or the mainstem.

9. ACTUAL AND POTENTIAL EFFECTS

Effects of disruption of trout passage by the dam

9.1 The importance of upstream passage for adult trout in the lower Mokihinui River for maintaining the trout population and fishery there and upstream will be the subject of further investigation, should resource consent be granted. Clearly, presently many adult fish will migrate upstream to spawn, but whether their progeny are the juveniles that migrate downstream to repopulate the lower reaches is unknown. The growth modelling results indicated that movement of juveniles from the headwaters to the lower river most likely occurs by chance or choice rather than due to an obligatory, heritable migratory life history.

9.2 The lack of good trout spawning habitat below the proposed dam site adds to the uncertainty on whether the trout population in the lower river will be maintained at current levels after dam construction. Recruitment to the lower river will be largely dependent on trout from the upper river moving downstream as currently occurs.

9.3 The trout population in the lower river below the dam will still receive recruits from upstream and ought to suffer only a slight, probably undetectable, reduction owing to mortality due to passage through the turbines and over the spillway.

9.4 Mortality of trout that pass downstream over the spillway is likely to be in the order of 5 – 10 % or less, particularly for small fish. Turbine passage mortality rates may be as low as 7 % for trout < 8 cm, about 15 – 35 % for fish < 15 cm, and about 44 – 60 % for fish ≥ 25 cm.

9.5 Meridian has proposed to install a 25mm screen each year during autumn to prevent eels going through the turbines. The proposed eel screen will exclude trout ≥ 25 cm, but Meridian considers there would be practical difficulties and a reduction in generation efficiency (through reduced head) maintaining it permanently. As the screens may not be necessary, screening will be considered as one possible means of mitigation in the event that monitoring shows it is necessary. Most existing dams in New Zealand do not include screens for trout, yet many have good river trout fisheries downstream. However, these all have trout spawning habitat downstream. Holmes & Hayes' (2008) review found no relevant examples of rivers below dams that had little, or no, trout spawning habitat.

9.6 Whether such mortalities result in a more than minor effect on the trout population in the lower river below the dam depends on the proportion of migrants that are small versus large. The majority of trout attempting to migrate downstream are likely to be small and experience relatively low turbine mortality. Furthermore, most trout are likely to move during high flow events when a higher proportion will pass over the spillway rather than through the turbines. If these assumptions prove correct then overall passage mortality (through turbines and over the spillway) will be low and the effect on the trout population in the lower river below the dam will be undetectable and therefore minor.

9.7 Trout that pass over the dam will attempt to spawn in the lower river and/or its tributaries and this may supplement recruitment to the lower river. However, it is unlikely that spawning success in the lower river will match that upstream because if it did trout would already be spawning there.

9.8 In my opinion survival rates of downstream migrants negotiating the dam should be adequate to maintain lower river stocks at pre-impoundment levels.

9.9 Evidence of relatively limited movement by trout and good thermal conditions for growth in the South Branch suggests the trout population and fishery in this sub-catchment will not be significantly affected by the dam. At least the abundance of 2 – 3 kg trout, which comprise the bulk of the catch should not decline.

9.10 However, there is a low to moderate risk that the trout population and fishery in the North Branch may be adversely affected, but this depends on the mitigating influence of impoundment. There was evidence of migration by about 53% of North Branch trout out of the North Branch during their lives, probably downstream to the Mokihinui mainstem (below the Forks) and estuary. The dam will block the lower part of this migration route and prevent fish that end up in the lower river from returning to the North Branch to spawn. If trout distribute randomly between the Forks to the sea, 22% of North Branch fish (i.e., 41% of the 53% that moved) would end up below the proposed dam site – based on the relative lengths of river above and below the dam site (i.e., there is 29 km of river below the Forks to the sea, of which 12 km (41%) is below the proposed dam site).

9.11 If the dam is built, trout moving downstream past the Forks will enter the reservoir and their growth and survival will depend on conditions there. Whether they would continue on downstream of the reservoir, past the dam, is unclear. If they did, then the dam would reduce the number of large, adult brown trout from below the dam subsequently moving upstream to the North Branch to spawn and contributing to the headwater fishery after spawning. Thus the dam could potentially reduce recruitment to the headwater population.

9.12 However, potential loss of adults and recruitment to the North Branch fishery may be offset, or even enhanced, by potential benefits of impoundment to the trout population. Whether reduced recruitment in the North Branch affects the North Branch trout population depends on whether fry survival is strongly density dependent. In most trout populations plenty of eggs are laid to seed the available habitat and density dependent competition for space (as a surrogate for food) among juveniles limits the population. Floods are thought to be the main density independent factor periodically limiting trout density, particularly of juveniles, and large floods are frequent in the Mokihinui River. The reservoir will provide a refuge for trout displaced downstream by floods and this ought to enhance abundance, especially of juvenile trout.

9.13 There is a risk that the dam may reduce the occurrence of trophy trout (≥ 4.5 kg) in the upper river by preventing migration of these very large fish from the lower river, estuary and ocean. Because these fish are rare none were found for otolith microchemistry analysis so their migratory status (i.e., sea run or river resident) remains unknown.

Effects of impoundment

9.14 The proposed reservoir should provide good thermal conditions for trout growth. It is predicted to have low to moderate productivity and a small but productive littoral zone which should support moderate food resources for trout. This ought to favour trout realising their thermal growth potential although this depends on how abundant they become.

9.15 The reservoir will also provide a refuge for trout from floods and a good habitat for juveniles to reach maturity (especially as juvenile trout are susceptible to mortality from displacement due to flooding) – potentially enhancing trout abundance through the gorge and headwaters. This may mean there will be more small fish than at present. Although this might mean the average size will decline, there should be similar numbers of large trout in the 2 – 3 kg range.

9.16 The reservoir is not likely to provide a high quality fishery that will attract anglers from outside the region. However, it should provide reasonably good fishing for local anglers and an increased diversity of fishing opportunities for them and visitors interested in fishing the upper Mokihinui River. The reservoir will create a better fishery than is currently present in gorge, given that this section of the river is virtually inaccessible to anglers.

9.17 The reservoir will enhance access to the upper river by facilitating boat access, which is likely to result in increased angler usage of the upper river. Greater usage of the upper river may reduce its attractiveness for guided helicopter fly-in anglers, at least in the lower North and South Branches where I expect usage to increase most.

9.18 **Flow regime**

9.19 Mr Jowett has undertaken an assessment of the effects of the MHP on the flow regime and instream habitat below the dam and has presented evidence to this hearing. My comments are restricted to daily fluctuating flows associated with hydro-peaking.

9.20 In some New Zealand fisheries hydro-peaking has resulted in a perceived decline in fishing quality in rivers downstream of dams. Mr Jowett's analysis shows that in the Mohikinui River daily fluctuations in discharge will reduce invertebrate habitat in the river margins below the dam. This may have an adverse effect on the growth rate of trout less than about 1 kg (45 cm) because the growth modelling indicated that these fish in the lower river are invertebrate food limited (Figure 18). Larger trout, which are more piscivorous, may complement their diet with fish prey which are most abundant in the lower river. However, Mr Jowett expects that the adverse effect of daily flow fluctuations on invertebrates will be partly compensated by coarsening of the substrate due to the dam withholding sand and fine gravel. The effects of daily flow fluctuations on the trout population in the tidal reach below SH 67 Bridge are likely to be undetectable as the ecosystem in this area already experiences natural tidal fluctuations and trout will be more piscivorous and so rely less on invertebrate prey.

Options to avoid, remedy and mitigate effects

Uncertainties surrounding effects

9.21 Based on the available evidence I do not expect the dam will have a major effect on the Mokihinui trout fishery. However, there remain some uncertainties regarding effects, because the migratory behaviour of trout, and the level of interconnection between the upper and lower river populations, is not sufficiently understood.

9.22 There are three issues that require attention. In order of decreasing uncertainty these are risk to the maintenance of: 1) large (>3kgs) and trophy (>4.5 kgs) trout in the upper catchment, 2) trout in the North Branch and 3) trout in the lower river, below the proposed dam site.

9.23 The dam could reduce recruitment to the headwater population, in particular in the North Branch and of large and trophy trout generally. It is unlikely that the dam will result in a noticeable decline in the trout fishery in the lower river below the dam, but there is sufficient uncertainty to warrant further investigation.

9.24 The potential positive effects of impoundment on trout abundance and growth in the gorge and headwaters may mitigate for the likely small losses of trout to turbine and spillway mortality and from disruption to upstream migration of trout below the dam to the headwaters. However, there is uncertainty surrounding the numbers of trout currently migrating and their size distribution and therefore the likely losses to turbine mortality. The mitigating effects of impoundment on trout abundance and growth upstream of the dam are also uncertain (i.e., it is not clear whether this will compensate for potential reduced recruitment of fish to the North Branch and large and trophy fish to both branches).

9.25 A range of investigation and monitoring options presented in the “Trout” section of the ”Aquatic Ecology Management Plan” addresses these uncertainties, with the investigations aimed at resolving the uncertainties prior to free passage being restricted. Mitigation options are also presented in the “Plan” in the event that investigation and monitoring indicates significant effects are likely or occur. The proposed research, monitoring, and mitigation options, and process for implanting mitigation, are summarised below.

Pre-construction investigation and monitoring

9.26 Research and monitoring of trout movement and abundance, angler success, use and satisfaction, will be undertaken during the three years prior to fish passage being affected by the Scheme, in order to provide a baseline for before-and-after comparisons of fishing quality. This pre-Scheme research and monitoring will also inform a decision on whether mitigation ought to be implemented immediately, or deferred pending the results of post-Scheme monitoring. The research and monitoring will focus on six components:

a. Trout movement past the proposed dam site, including numbers, size distribution, and timing;

b. Trout abundance;

c. Lower river spawning, including surveys of existing spawning and scoping for potential spawning habitat enhancement;

d. Angler catch, including catch rates, number of fish seen and hooked, and size and condition of trout caught in the North and South Branches and in the lower river;

e. Angler satisfaction, including angler motivation and satisfaction in the upper catchment and lower river;

f. Economic value of the fishery; including large and trophy fish, and the relative contribution made by the upper and lower river and reservoir.

9.27 Trout movement will be directly assessed with a “DIDSON” acoustic camera located at the proposed dam site. Patterns and rates of movement will be assessed based on a stratified random sampling approach, with intensified sampling effort during the autumn spawning season. This monitoring will continue for three years prior to the operation of the Scheme, during which time fish passage will be maintained through the diversion channel.

9.28 Further otolith microchemistry research will be conducted, prior to operation of the Scheme, following a similar methodology to that already used, and targeting large and trophy fish. This will bolster the existing understanding of patterns of lifetime movement of trout in the catchment and will shed light on the movement patterns of large and trophy fish.

9.29 Eggs from redds (trout nests) in different areas of the catchment could be analysed for a marine or estuarine signature which will shed more light on what contribution fish from these areas make to the spawning run and recruitment in the upper catchment. This is proven methodology based on the fact that eggs contain some chemical signatures from the environment experienced by the parent during egg development.

9.30 If the otolith and egg microchemistry research, and DIDSON monitoring, confirm that there is actually little movement between the lower river, below the dam site, and the upper catchment, this will add weight to the expectation that the effect of the dam on the upper catchment should be minor or potentially positive.

9.31 Trout abundance will be monitored annually over three years by drift diving at a minimum of four sites in the upper catchment and one in the lower river. A power analysis will be undertaken on the data to determine the level of precision (ability to detect statistical change) based on the estimated variance.

9.32 A survey targeting spawning activity in the lower river and tributaries, below the proposed dam site, will be carried out in the autumn of one year prior to operation of the Scheme. An electric fishing survey targeting trout fry will be conducted early in the following summer in identified, or potential, spawning sites to verify spawning success.

9.33 Angler surveys will be undertaken to assess catch rates, number of fish sighted and hooked, fish size and condition, and angler motivations and satisfaction in the three years prior to operation of the Scheme.

9.34 The value of the Mokihinui trout fishery, and the relative contribution of different components of the fishery, will be assessed through an economic analysis to provide a baseline for comparative analysis following operation of the Scheme.

Monitoring during construction

9.35 Monitoring of angler catch and satisfaction and trout abundance will continue during the construction period on the basis of the pre-construction monitoring described above. DIDSON monitoring at the dam site will narrow its focus to verifying that free passage is maintained through the diversion channel.

9.36 As construction effects of sedimentation on trout in the lower river are expected to be temporary and minor no specific monitoring will be undertaken other than that focused on water quality in the "Aquatic Ecology Management Plan".

Monitoring during operation

9.37 There is likely to be a period of equilibration following the filling of the reservoir, as this newly created habitat possibly begins to influence trout abundance and size structure in the wider catchment. For this reason monitoring of the reservoir fishery will be delayed until the third year after filling of the reservoir. This period of equilibration needs to be taken into account in the interpretation of other monitoring data and in the triggering of mitigation options.

9.38 Post-Scheme angler creel and satisfaction surveys in the North and South branch catchments and lower river (below the dam) will commence immediately after dam operation and continue for at least eight years. If over the third to eighth year post operation, angler surveys indicate a decline in the fishery over any three year period, drift dive monitoring will be undertaken for a period of at least three years to help verify whether trout abundance has declined relative to that measured before the Scheme was commissioned.

9.39 In the event that a decision is made to mitigate by way of trap and transfer or spawning channel, DIDSON monitoring will inform location and design by showing where trout congregate below the dam.

9.40 Annual angler catch and satisfaction surveys of the reservoir fishery will commence in the third year of Scheme operation and continue for at least five years.

9.41 The numbers and size range of fish entrained by turbines, and their mortality rates, may be monitored by trapping below the tailrace. This monitoring will only be initiated if monitoring of the lower river fishery (e.g. by the angler and drift dive surveys described above) suggests a decline over any three year period, after the third year of operation.

9.42 The fishery economic valuation survey will be repeated in the eighth year following commissioning of the Scheme to determine if there has been a net change in fishery value.

9.43 If mitigation actions are triggered, then the appropriate monitoring programs will be extended to monitor their effectiveness.

9.44 In the event that trap and transfer mitigation is undertaken, trapping success will be estimated for one season by comparing DIDSON counts from below the trap with counts of fish trapped.

Mitigation options and process for implementation

9.45 It is not possible to identify meaningful quantitative effects-based triggers to action mitigation at this stage, because there is insufficient data available for power analyses required to estimate levels of statistical precision and weigh up the relative costs of monitoring versus mitigation.

9.46 Ideally, trout abundance, before and after dam construction, should be compared through an intensive drift dive programme. However, the upper catchment is very extensive and trout abundance can exhibit high spatial and temporal variability. A drift dive monitoring programme that would be sensitive enough to detect say a 30-40% change in abundance attributable to the Scheme would require considerable effort and cost substantially more than implementing all proposed mitigation options. The drift dive monitoring proposed above is a minimal effort programme, likely to have a low level of precision. Its real value is as an adjunct to the angler catch and satisfaction monitoring programme which is a more cost effective way of monitoring the fishery.

9.47 A panel will be convened to assess the research and monitoring results, using a weight of evidence approach, and decide on the implementation of mitigation options. The panel will consist of independent expert fisheries scientists and stakeholders (e.g. Fish & Game, West Coast Regional Council, and Meridian). The panel would first convene to consider the results of the life history and movement studies that will be completed before passage is restricted, and the pre-Scheme angler satisfaction and creel surveys. Based on the weight of evidence from these investigations the expert panel will decide whether mitigation should be implemented immediately, or deferred pending the results of the post-Scheme monitoring. Implementing the mitigation options, described below, should be considered by the expert panel as the default option in the absence of scientifically defensible information to suggest that such mitigation is not necessary. Further details on how the panel would operate are provided in sections 7.4.1 and 7.4.2 of the "Aquatic Ecology Management Plan". In my opinion, a weight of evidence approach by an independent expert panel will lead to more cost effective and reasoned effects assessment and mitigation decisions than hard-wired, trigger conditions for mitigation.

9.48 Mitigation options are provided below for each potential effect of the Scheme on trout and trout fisheries in the Mokihinui. Which of these options will ultimately be implemented is contingent on the opinion of the expert panel.

9.49 If a reduction in the number of large or trophy fish occurs, or is considered likely, and any consequent reduction in net value of the fishery was deemed to warrant mitigation, then a trap and transfer program would be the preferred option. A fish pass is unlikely to be a viable option with a 77m-high dam. A trap and transfer program would involve trapping trout below the dam as they attempt to migrate upstream and transferring them into the reservoir or above the Forks. A reduction in the number of large or medium trout in the upper catchment (in particular the North Branch), may also trigger a trap and transfer program.

9.50 An alternative option is to augment trout numbers in the upper catchment through release of hatchery reared trout. Stocking has some draw backs, the main one being genetic "pollution" of wild fish, which may result in reduced fitness. This effect could be reduced by sourcing brood-stock from wild Mokihinui trout. A hatchery would need to be constructed to provide fish for release since there are no alternative existing hatcheries that could reliably provide stock.

9.51 A reduction, or expected reduction, in angling quality below the dam will trigger consideration of three potential mitigation options. These are permanent screening of the intake, enhancement or construction of spawning areas downstream of the dam, and hatchery releases (as described above) downstream of the dam.

9.52 Permanent screening could simply involve implementing the 25 mm aperture screen, proposed for use during the autumn eel migration, year-round. However, depending on the results of turbine passage and mortality monitoring, a smaller aperture size may need to be considered for the screen.

9.53 Enhancement of spawning areas downstream of the dam may be possible, if spawning areas are found, and there is scope to improve them (e.g., by supplementing and cleaning gravel). An alternative would be to construct a spawning race below the dam.

9.54 Stocking with hatchery fish below the dam is another option.

10. ISSUES RAISED BY SUBMISSIONS

West Coast Fish and Game Council

Fish and Game raised several points which I address under subheadings below.

Anglers' motivations for fishing the Mokihinui River

10.1 Fish and Game requested information on the preferred angling experience sought by, and aspirations and expectations of, anglers fishing the Mokihinui River above the proposed dam site. 'For example, is it the expectation of catching large fish, lots of fish or is the back country/wilderness experience the primary attraction? *..'*

10.2 In the late 1990s and early 2000s I managed a research programme on angler usage and satisfaction on backcountry rivers in the Nelson-Marlborough and Otago Fish and Game Regions. The Nelson-Marlborough survey included rivers in Kahurangi National Park, including those in the West Coast Fish and Game Region (Walrond & Hayes 1999; Walrond 2001; Hayes 2002). The aims of the study were to determine the effect of increasing angling pressure on the backcountry river fishing experience and to determine social carrying capacity. Part of the study was directed at determining what features motivated anglers to fish backcountry rivers. With respect to this aspect of the study, no single river in the top of the South Island was singled out, but the Mokihinui River was included in the list of rivers surveyed (i.e., the study provided general information on backcountry angler motivations and angler encounter rates for the rivers in the survey). Anglers were interviewed by postal survey.

10.3 The three most important satisfaction sources that motivated anglers to fish backcountry rivers were peace and solitude, natural environment / scenery, and spotting trout (i.e., sight fishing for trout). Catching several fish and catching large fish were options presented to anglers in the survey but these were ranked less important than the three primary factors just mentioned. Clearly though, anglers are fishing backcountry rivers to catch trout.

10.4 In my experience, while some backcountry rivers provide the opportunity of catching trophy trout, or plenty of trout, this does not appear to motivate the majority of anglers to fish these rivers. These features are icing on the cake. It is the overall wilderness fishing experience that most anglers who fish rivers such as the upper Mokihinui are seeking. In addition to the scenic environment, remoteness and the hope of fishing for trout that have not received much fishing pressure are key attractions of backcountry river fishing. Increasing angling pressure in recent years has meant that the latter is a vanishing commodity.

10.5 Nevertheless, some rivers do offer high catch rates or the chance of catching trophy trout, although trophy fish are never common. This adds to the recreational opportunity spectrum in an angling region.

10.6 The backcountry river survey showed that the Mokihinui headwater fishery had a low angler encounter rate, well below the level that backcountry anglers become unhappy with (2 – 3 encounters per day) – consistent with its wilderness fishery status (Walrond 2001). In my opinion, it is unlikely that improved access as a result of the reservoir will result in the angler encounter tolerance threshold being exceeded in the medium term (10 year horizon). This view is based largely on the fact that northern Westland is off the beaten tourist track unlike Queenstown and the Nelson Lakes which are the only regions where backcountry river angler encounter rate has exceeded or approached the encounter tolerance level (e.g. in the Greenstone and Caples rivers, and the Travers River).

Trout size and abundance

10.7 Fish and Game queried that the Trout Movement & Passage report stated ' that "*trout exceeding 2.5kg are uncommon and those exceeding 3kg are rare*". There is no reference to the information that this statement is derived from. Fish & Game is unaware of any trout size distribution surveys conducted in the Mokihinui River, other than the drift dive surveys, which do not provide weight information.'

10.8 The conclusion that trout exceeding 2.5 kg are uncommon and those exceeding 3 kg are rare was based on the sample of trout taken for otolith micro-chemistry and growth analysis (48 fish in total). The conclusion is consistent with my knowledge of trout size structure in other backcountry rivers (Hayes 2002 – and see Figure 16). Most backcountry river trout caught by anglers are 2 – 3 kg. Since writing the Trout Movement and Passage report I read the Fish and Game New Zealand Magazine article on the Mokihunui trout fishery written by Mr Moate (Moate 2000) and have seen responses from 5 fishing guides experienced with the Mokihinui whom Mr Greenaway has interviewed.

10.9 Mr Moate wrote that trout caught by anglers the Mokihinui average 2 kg and that the South Branch holds plenty of fish around 3 kg including some trophy trout in excess of 5 kg.

10.10 Responses to Mr Greenaway's guide survey on trout sizes by Mr Peter Carty and Scott Murray are also constructive.

a. Mr Carty said that the Mokihinui "… fish are a good colour and have a good size range. While he has not caught a 'double figure' fish in the catchment, he has seen them and possibly had a few on the line. Generally the catch is in the 5 lb [2.3 kg] area.... "

b. Mr Murray said that "…The South Branch can have very good-sized fish (up to 10 lbs [4.5 kg]). The tributaries, such as the Johnson, has smaller fish (5 lb)." Mr Murray describes the fishery as "'fragile' considering that it has a lower number of big fish, and it is these large, well-conditioned trout (6 to 10 lb [2.7 – 4.5 kg]) in which clients are interested (although many fish are in the 4 to 8 lb [1.8 – 3.6] range, the average is around 5 lb – similar to the Karamea). … people who do not know the rivers well might think that there are very few good fish in the upper catchment – but the fact is that many excellent fish might be separated by some distance and a good hunting technique is required.".

10.11 Taking account of all the sources of information available, it would be fairer to say that trout above 3 kg are uncommon within the Mokihinui catchment overall and those above 5 kg are rare. This interpretation might appear to be at odds with Mr Moate's and Mr Murray's comments, but 'common' and 'plenty' are relative terms. Large trout might be 'more common' in one river compared with another, and guides often target big fish. The guides' comments on the average sized fish (5 lb or 2.3 kg) are consistent with the size structure of the sample of trout taken for the otolith micro-chemistry and growth study (see Trout Movement and Passage report) (i.e., most trout were less than 2.5 kg).

Trout movement and sample size

10.12 Fish and Game raised the following points on the adequacy of sampling for assessing movement patterns of trout: '…conclusions … drawn about trout migration [based on otolith micro-chemistry analysis] were based on only four fish from each tributary. It is Fish & Game's view that the sample size was inadequate to be certain about the predictions made. The Cawthron Institute report on 'Trout Movements & Passage' states "*Of the four North Branch trout analysed in detail using multiple trace elements, two had moved between the estuary and the North Branch, and a third had moved downstream of the North and South Branch confluence.*". Fish & Game believe basing the extent of movement of trout throughout the North Branch on four fish is inadequate. Especially when other analyses performed on the 17 trout collected in the North Branch shows that "*only four trout showed clear evidence of no movement out of the North Branch catchment"*. Due to the limited extent of this analysis, and others, there is no statistically sound information to ascertain if there is a seasonal influx of larger spawning migratory fish in the winter months (May – August) that require access to or from the lower Mokihinui. Another extract from the Cawthron report on 'Trout movements & Passage' states '*The growth modelling indicated that trout from the headwaters of the Mokihinui River would not have to move downstream to the lower river, past the proposed dam site to grow to the sizes observed ..*". If this is based on the same isolated sample taken for the otolith analysis, then Fish & Game believes this is insufficient to gauge the migration patterns of larger fish. More replicates are needed at differing times of the year, such as, the pre and post spawning period to effectively gauge the frequency of larger (> 2.5 kg) trout in the system.'

10.13 In respect of Fish and Game's comments on the proportion of North Branch fish that the otolith micro-chemistry analysis indicated had moved, most weight should be given to the 17 fish that were analysed for general movement (i.e., whether they had moved or not) rather than on the 4 fish analysed in detail for movement pattern). Nine (53%) of the 17 fish had moved, probably below the Forks, 4

(24%) had not moved from the North Branch and the movement status of the remaining 4 fish is unknown.

10.14 Fish and Game contends that due to the limited extent of this analysis [on the North Branch] and others (i.e., small sample size) there is no statistically sound information to ascertain if there is a seasonal influx of migratory fish that require access to or from the lower Mokihinui. This is not strictly true. The North Branch results for the 17 fish are statistically valid. A Chi-square statistical test that I conducted on the 13 of the 17 fish who's movement status was determined confirmed that there is a statistically significant degree of movement[2]; (9 of the 13 were classified as moving). However, Fish and Game is correct in pointing out that there is insufficient information to ascertain whether there is a seasonal influx of fish from the lower Mokihinui – since no seasonal sampling was conducted. It is quite likely that there is a seasonal influx of trout from the lower to upper Mokihinui in autumn and early winter associated with spawning since the otolith microchemistry analysis indicated that most spawning, including by lower river fish, occurs in the headwaters. Whether the dam will curtail such a seasonal influx is uncertain and depends on whether impoundment mitigates for the disruption to trout passage. The monitoring of fish movements by DIDSON prior to passage restriction by the dam, proposed in paragraph 9.27 will provide information on the seasonal movements of trout and the numbers of fish migrating. Pre- and post-scheme monitoring of angler catch and satisfaction will provide information on whether fishing opportunities vary seasonally and change after damming.

10.15 Fish and Game's second point asserting that the growth modelling results are similarly flawed by the small sample size of trout is only partially valid. It is true that the observed data on trout size structure was based on the same sample taken for the otolith analysis, and in that respect it would be better to have more data to better determine how big trout actually grow in the Mokihinui and the proportion of large trout ≥ 3 kg and ≥ 4.5 kg. However, the growth modelling

[2] The analysis rejected the null hypothesis that there is no movement by fish out of the North Branch - Chi-square = 1.143, $p < 0.0008$ $\alpha = 0.05$, d.f. = 1

predictions are not reliant on observed data on trout size and growth. They were made on the basis of water temperature. The growth predictions complement and bolster the results of the otolith micro-chemistry analysis. They show that water temperature regimes upstream of the proposed dam site are suitable for trout to easily grow to the average size (2.3 kg) (Figure 17, 18), and they could grow to at least 3 kg assuming they are not invertebrate food limited, or to 2.5 kg assuming slight (10%) invertebrate food limitation. All it would take is for some trout to supplement their diet in some seasons with mice or fish prey (e.g., juvenile trout) for them to exceed these weights and achieve perhaps 4 – 5 kg. Alternatively these large fish may be migratory, or at least a proportion of them.

10.16 The comments from guides contacted in Mr Greenaway survey give the impression of seasonal influxes of trout.

a. Mr Entwistle's experience is "…one of recognising the resident fish early in the season, but as the season progressed noting a whole new group of what were generally called 'sea-run' trout, although they may only have been feeding in the estuary. These fish were much fatter than the residents ('obese'), younger (without the tougher skin of the old resident fish), fitter, more light coloured, with their lower tail intact (suggesting they had not bred) and were generally of better quality. This gave the impression that the trout were running the entire river system."

b. Mr Carty's experience is "… there is an influence in the upper catchment from sea run trout – as there are in all such rivers – and he has encountered small shoals of 3 to 4 lb silvery fish which are easier to catch than the more wileful and experienced resident fish. One memorable group – almost a shoal – was in the lower North Branch below the Hemphill confluence. He identifies these as sea run fish which were either chasing whitebait upriver or moving in to spawn (or both). While he recalls seeing these in November, they can be present at any time of the year."

c. Mr Murray's opinion is that " … The large fish are generally resident. Sea run trout follow the whitebait up-river in October and November, and also to spawn. They may be seen in the upper catchment through to April, and even June, during which time they might decide to stay and 'predominate' – become resident fish – or return downriver. Large floods can displace some upriver fish, which might be replaced by the larger of the sea run trout – these are migrants who will take advantage of free territory. This behaviour is the same as for many free-running rivers, such as the Hope, Waiau, Wairau and Karamea. The sea run fish are obvious by their colouration, tending to be very silver with black spots and a dark tail. Those which become resident upriver fish slowly take on local colours. North Branch fish tend to be 'blander' in colour, with a strong green on their back. South Branch fish are more silver, with black and yellow spots and a bright yellow belly. Johnson River fish are very colourful with, also, red dots.".

10.17 These comments suggest seasonal influxes of fish, although I caution that colouration and condition of trout is naturally variable and not necessarily related to migratory or resident status. Moreover, the fish that are assumed by the guides to be sea-migratory might simply be young (bright) fish that move up from the main stem somewhere below the Forks (i.e., not necessarily as far as below the proposed dam site) or even first time spawners maturing over the fishing season within the North and South Branches. Nevertheless, given these comments and the limitations of the otolith micro-chemistry analysis, more information on trout size and sex structure and movements should be obtained to reduce the level of uncertainty over the extent and importance of migration in sustaining the trout fishery, that of large fish (≥ 3kg) and especially trophy fish (≥ 4.5kg). The limitations of the otolith micro-chemistry study include: the fairly small sample sizes (although comparable to, or better than, other such studies) and low resolution of predicted migration distances within the freshwater section of the main stem below the Forks.

10.18 Additional research that will be undertaken to better resolve these issues includes:

a. More sampling of trout from the catchment to get a better idea of size structure, and especially the relative abundance of very large trout (≥ 4.5 kg),

b. Additional otolith microchemistry analysis, with a view to increasing sample size and including big fish,

c. Angler surveys which will include analysis of seasonal patterns of catch and numbers of fish seen,

d. Monitoring of trout movement past the proposed dam site by DIDSON.

10.19 It is my view that the three years of trout and angler monitoring proposed before fish passage is restricted is sufficient time for the required information to be gathered and interpreted. This monitoring is described in Section 7.31 of the "Aquatic Ecology Management Plan" and is summarised in paragraphs 9.25 – 9.34 of my evidence.

Trout enhancement potential of the reservoir

10.20 Fish and Game expressed the following concerns about the mitigation potential of the reservoir:

a. Citing from their submission: "..Despite the limited sampling undertaken and the few trout used to draw conclusions it is stated that "*The average size of trout should not decline but there may be a reduction in larger fish that have grown large in the lower river – estuary returning to the headwaters (especially the North Branch).*" It is further stated that the lost [sic. Actually reduced] ability to migrate downstream in larger fish will be mitigated by the impoundment area. "..*Moreover, water temperature regimes downstream of the forks are currently sufficient for trout to grow in excess of 3 kg, providing food is not limiting, and the proposed reservoir will improve thermal conditions for trout even further.*" In the potential effects listed in the Cawthron Institute report "Trout Movement & Passage" the impoundment area is "*predicted to have low to moderate productivity and a small but productive littoral zone which should support moderate food resources for trout*." With this statement and predictions about the productivity of the impoundment area based on modelling with a significant number of approximated variables, Fish and Game believe there is a need for more research on the mitigating effects of the impoundment area on large trout abundance in the North Branch, accompanied by appropriate monitoring conditions. We also seek concrete mitigation options in the event that predictions regarding productivity prove to be false."

10.21 With regard to the first point, the prediction that the average size of fish should not decline was based on the growth modelling predictions so is not dependent on the sample size of trout used to assess observed sizes. Since completing the Trout Movement and Passage report I have modified my conclusion on the effects on trout average size. See paragraph 9.15 of my evidence where I say that average size may decline, owing to the reservoir enhancing abundance of small fish, but there should be similar numbers of large trout in the 2 – 3 kg range.

10.22 With regard to Fish and Game's concern that the reservoir might not provide mitigation by enhancing trout growth and abundance, trout have increased in abundance following impoundment in other reservoirs and inflowing tributaries (see paragraph 8.13 of my evidence). Furthermore, the head of the earthquake lake in the Karamea River (below the Roaring Lion confluence) provides very good trout fishing, as I have predicted for the proposed Mokihinui Reservoir. Furthermore, it is likely that the flood refuge and still-water feeding habitat that the earthquake lake provide contribute to the excellent river fishery within the Karamea system too. I expect the Mokihinui reservoir may provide similar benefits.

10.23 Fish and Game's criticism of the accuracy of the modelling predictions on the productivity of the proposed reservoir is best directed to Dr Spigel – the author of the Lake Water Quality and Habitat report.

10.24 The scope for further pre-development research on the effects of the potential mitigating effects of the reservoir on trout is very limited, other than modelling predictions and reviewing the outcome of impoundments on trout fisheries elsewhere – as has already been done.

10.25 Fish and Game's comments that appropriate monitoring should be undertaken on trout and concrete mitigation options be provided are addressed in paragraphs 9.21 – 9.54 of my evidence.

NZ Federation of Freshwater Anglers

10.26 The NZFFA's states in their submission:

a. "That the Mokihinui River is a very well known fishery that will be severely damaged by a hydro dam as highlighted by the excellent Cawthron Institute Report on 'Trout Movement and Passage'..

10.27 This misinterprets the Cawthron Report on Trout Movement and Passage – which is the subject of my evidence. The report does not conclude that the Mokihinui trout fishery will be severely damaged. Rather, the conclusion of the report is that overall the dam is unlikely to have a major effect on the trout population throughout the catchment because most of the population will not be separated from the sources of recruitment. There is a risk of adverse effect on the North Branch fishery, although that depends on the potential mitigating effect of the reservoir, and there may be a decline in very large trout (which are rare) if these fish are dependent on free passage to and from the lower river, estuary and sea (see paragraphs 11.9 – 11.18 on effects below).

The Section 42A report

10.28 The following mitigation recommendations were made in the Section 42A report:

a. Monitoring of the trout population for at least three years before dam construction

b. and seven years after.

c. Permanent screening (25 mm-bar screens) of penstock intakes to avoid turbine mortality of trout > 25 cm;

d. In the event the trout population declines by more than 30%, over at least five years, the following methods be researched, consulted on with interested parties and, if appropriate, implemented:

i. Trap and transfer of upstream migrant adult over the dam;

ii. Construction of a hatchery and stocking.

10.29 These recommendations appear to have been made based on an earlier draft of the Aquatic Ecology Management Plan and the following relevant points in the plan have been changed after further consideration:

a. Post-Scheme monitoring is now planned for eight rather than seven years;

b. Permanent screening should be deferred until further research on downstream movements (pre-Scheme) or on turbine mortality (post-Scheme) indicates effects;

c. The 30% decline in trout abundance trigger for mitigation is a cost prohibitive hurdle. The costs of achieving 30% precision with drift dive surveys exceed the cost of all mitigation measures (see paragraphs 9.45 and 9.46 of my evidence). The Aquatic Ecology Management Plan now proposes a more cost effective and reasoned approach involving a panel of independent fishery scientists, and stakeholders, assessing effects with a weight of evidence approach and making decisions on whether to implement mitigation options (see paragraph 9.47 of my evidence).

11. CONCLUSION

Trout movement

11.1 The otolith micro-chemistry analysis indicates that most trout in both the lower and upper reaches of the Mokihinui River do not rely on the estuary or ocean as an essential component of their life history.

11.2 However, dispersal and migration within the freshwater reaches of the catchment is common, although the extent of the movement may vary with river reach. Downstream populations are clearly linked to upstream river reaches through the supply of juveniles, and some adult fish migrate between the upstream and downstream (as defined by the gorge) regions of the river.

11.3 Most of the population, including fish in the lower river and estuary, is sustained by spawning in the headwaters (upstream of the gorge). Hence trout in the lower river (below the Forks) are sustained by the downstream migration of juvenile or sub-adult fish.

11.4 Trout in the North Branch appear to move more frequently than those in the South Branch.

11.5 A limitation of the otolith micro-chemistry study was that it was not possible to discriminate trace element signatures of trout between the freshwater sections of the Mokihinui mainstem (below the Forks) upstream and downstream of the proposed dam site. However, given that some North Branch migrants end up in the estuary it is likely that others distribute throughout the mainstem.

11.6 The otolith micro-chemistry study in the Mokihinui catchment adds to a growing body of evidence that the life history of brown trout in moderate to large New Zealand rivers is variable often involving movements over a variety of scales for a significant proportion of the population. Some juvenile and adult fish may undertake migrations over large distances, sometimes spanning the entire catchment, while a proportion of the population may also remain resident in some river reaches.

11.7 However, the growth modelling study indicated that movement by trout in the Mokihinui catchment is probably facultative, (i.e., movement occurs probably by choice or chance rather than by necessity for growth and survival) and on average confers no size advantage on migrants.

11.8 In my opinion, a key point that can be inferred from the growth modelling study is that trout from the headwaters would not have to move downstream to the lower river, past the proposed dam site, to grow to the sizes observed, assuming they attain maximum, or near maximum, invertebrate food intake.

Effects

11.9 The dam will block upstream passage of trout from the lower river to the headwaters, where most spawning occurs. Recruitment to the lower river will be largely dependent on trout from the upper river moving downstream as it is currently.

11.10 In my opinion adequate numbers of trout should survive passage through and over the dam to maintain lower river stocks similar to existing levels.

11.11 In my opinion the South Branch trout population and fishery should not be adversely affected by the dam (at least the abundance of 2 – 3 kg trout, which comprise the bulk of the catch).

11.12 There is a low to moderate risk that the population and fishery in the North Branch may be adversely affected by the dam blocking movement to and from the lower river, but this depends on the mitigating influence of impoundment. To help put the potential effect in perspective, the otolith micro-chemistry results suggest that 22% of North Branch fish might end up below the proposed dam site, assuming that those that move distribute evenly between the Forks and the sea.

11.13 There is a risk that the dam may reduce the occurrence of trophy trout (≥ 4.5 kg) in the upper catchment by preventing migration of large fish from the lower river, estuary and ocean.

11.14 The proposed reservoir should provide good thermal conditions for trout growth and moderate food resources for trout. The latter ought to favour trout realising their thermal growth potential in the reservoir although this depends on how abundant they become.

11.15 The reservoir will provide a refuge for trout from floods and a good habitat for juveniles to reach maturity which may result in more small fish than at present. The numbers of large trout in the 2 – 3 kg range should remain about the same as present.

11.16 The reservoir should provide reasonably good fishing and an increased diversity of fishing opportunities. It will be a more popular fishery than is currently present in the gorge, because the reservoir will enhance angler access.

11.17 The reservoir will allow access to the upper river by boat, which is likely to increase angler usage of the upper river.

11.18 Daily fluctuating flows due to hydro-peaking will reduce invertebrate habitat in the lower river below the dam down to the limit of tidal influence (Highway 67 Bridge). This may have an adverse effect on the growth rate of trout less than about 1 kg (45 cm) because these fish presently appear to be invertebrate food limited. However, this effect may be partly compensated by coarsening of the substrate due to the dam withholding sand and fine gravel.

Options to avoid, remedy and mitigate effects

11.19 The main effect of the Scheme on trout is that the dam will disrupt passage. The potential positive effects of impoundment on trout abundance and growth in the gorge and headwaters may mitigate the small predicted losses of trout to turbine and spillway mortality and from disruption to upstream migration of trout below the dam to the headwaters.

11.20 While overall I do not expect the dam to have major effects on the trout population and fishery throughout the catchment, sufficient uncertainty remains to warrant further investigation and monitoring. In the event that effects are clearly identified prior to damming or after, I consider that the mitigation options presented in the "Aquatic Ecology Management Plan" are adequate to maintain the fishery.

11.21 I also support the process of effects assessment, based on additional investigation and monitoring, and implementation of mitigation options presented in the "Aquatic Ecology Management Plan". In my opinion that process, involving an expert panel of fisheries scientists with stakeholder inclusion, will provide a cost effective means of making reasoned effects assessment and mitigation decisions.

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