**BEFORE THE ENVIRONMENT COURT**
**AT CHRISTCHURCH**

**ENV-2010-CHC-115, 123, 124 AND 135**

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| **IN THE MATTER** | **of Appeals pursuant to Section 120 of the Resource Management Act 1991** |
| **BETWEEN** | **WEST COAST ENT INC**<br>**Appellant** |
| **AND** | **ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NEW ZEALAND INC**<br>**Appellant** |
| **AND** | **WHITE WATER NEW ZEALAND INC**<br>**Appellant** |
| **AND** | **DIRECTOR GENERAL OF CONSERVATION**<br>**Appellant** |
| **AND** | **WEST COAST REGIONAL COUNCIL AND BULLER DISTRICT COUNCIL**<br>**Respondents** |

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STATEMENT OF EVIDENCE OF
**JOHN RALPH LEATHWICK**
FOR DIRECTOR GENERAL OF CONSERVATION
Dated: 14th May 2012

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| **AND** | **MERIDIAN ENERGY LIMITED**<br>**Applicant** |
| **AND** | **FRIDA INTA**<br>**Section 274 Party** |
| **AND** | **WHANAU PIHAWAI WEST – RICHARD WAYNE BARBER AND IRI MAY BARBER MILNER**<br>**Section 274 Party** |
| **AND** | **J MacTAGGART**<br>**Section 274 Party** |
| **AND** | **ORION ENERGY NZ LTD, ALPINE ENERGY LTD, MAIN POWER NZ LTD AND ELECTRICITY ASHBURTON LTD**<br>**Section 274 Party** |
| **AND** | **NZ RAFTING INC**<br>**Section 274 Party** |
| **AND** | **ANN SHERIDAN**<br>**Section 274 Party** |
| **AND** | **BULLER ELECTRICITY**<br>**Section 274 Party** |

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# 1. QUALIFICATIONS AND EXPERIENCE

1.1. My full name is John Ralph Leathwick. I am an ecologist holding degrees in forestry science (BForSc) and science (DSc), both from the University of Canterbury.

1.2. I have 34 years experience in the study of New Zealand's natural ecosystems. Over this period I have published 64 papers in refereed journals, and written two books and four book chapters.

1.3. During the course of my career my work has focused on the analysis and description of spatial patterns in New Zealand's species, communities and ecosystems, and the application of these results to conservation and resource management. I have extensive experience in the analysis of large and complex ecological datasets, with skills in statistical and environmental modeling, geographic information systems, spatial analysis and optimization. A particular feature of my career has been the range of environments I have worked in, which span terrestrial, freshwater and marine ecosystems.

1.4. During the first 20 years of my career, I worked as a forest ecologist, initially at the Forest Research Institute in Rotorua, and then for Landcare Research at Rotorua and Hamilton. During this period I carried out extensive numerical analyses of spatial patterns in New Zealand's indigenous forests and their relationships with environment. This work culminated in my leading a project that resulted in the production of the Land Environments of New Zealand classification (LENZ – Leathwick et al. 2003). In 2004 I was awarded the degree of Doctor of Science from the University of Canterbury for this body of work.

1.5. After moving to NIWA in 2003 I worked on a range of similar studies in freshwater and marine environments, including the production of marine and riverine classifications, the analysis and prediction of species distributions in aquatic environments, and the development of methods for identifying optimal sets of sites to maximize conservation benefits. Work carried out during this period and of particular relevance to this case include the development of predictive models of the distributions of New Zealand's freshwater fish and macro-invertebrate species (Leathwick et al. 2005, Leathwick et al. 2008, Leathwick et al. 2009), the production of a biologically-tuned classification of New Zealand's rivers (Leathwick et al. 2011), and the development of robust methods for calculating conservation values (Leathwick et al. 2010a) and identifying priority sites for conservation management (Leathwick et al. 2012) in riverine ecosystems.

1.6. In 2010 I moved to the Department of Conservation where I am involved in a range of terrestrial and freshwater projects. Several of these projects have involved work that is now widely referred to as systematic conservation planning (SCP), and include work designed to deliver a consistent set of environmental and biological spatial data for freshwater management (Freshwater Environments of New Zealand or FENZ – Leathwick et al. 2010b), and a national project to prioritise the Department's terrestrial ecosystem management activities.

1.7. In preparing this evidence I have reviewed:

(a) The reports and statements of evidence of other experts giving evidence on behalf of the applicant in relation to matters relevant to my experience, including: Dr M. James, Mr I.

Jowett, Mr N. Norton, Mr M. Bonnett, Dr D. Jellyman, Dr I. Payton, Mr J. Parkes, Dr D. Norton and Dr G. Ussher;

(b) The reports and statements of evidence of other witnesses giving evidence on behalf of the Department of Conservation, including Drs Allibone, Kelly, Lloyd, O'Donnell, Schallenberg and Shaw.

1.8. As part of this work I carried out a field visit in November 2011 to the Mokihinui River, walking from Anderson's Flat to the Mokihinui Forks Hut, and flying out via the gorge[1] . I also flew over much of the proposed transmission line route, stopping at various points for ground inspections. During a more recent visit in February 2012 I inspected the Waimangaroa Bush site proposed by the applicant as an additional offset.

1.9. I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts and opinions known to me that might alter or detract from the opinions expressed.

## 2. SCOPE OF EVIDENCE

2.1. I have been asked by the Department of Conservation to present a Systematic Conservation Planning perspective on

[1] In this evidence I use the term ‘gorge’ to describe the Mokihinui gorge from the proposed dam site upstream to the forks.

(i) the conservation significance of the freshwater and terrestrial ecological values affected by the MHP, and (ii) the mitigation and offsetting proposal presented by the applicant. To this end, my evidence relies on parts of the evidence provided by several other experts including Dr Allibone, Dr Lloyd, Dr O'Donnell, Dr Schallenberg and Dr Kelly.

## 3. KEY FACTS AND OPINIONS

*Systematic conservation planning and the management of New Zealand's biodiversity and natural resources*

3.1. Systematic conservation planning is a recently emerged sub-discipline of ecology that seeks to achieve the efficient use of limited resources to ensure the persistence of a representative range of biodiversity. In this context, biodiversity is understood to include not just species in a narrow sense, but also variability across multiple levels of organization up to and including ecosystems. Ecosystems are generally understood to include not only species and the communities they form, but also the environments they occupy, and the emergent relationships between these different components as typified by the transfer and circulation of energy and matter.

3.2. The concept of representativeness is central to current approaches to the protection of biodiversity, and refers to the ability of a set of protected areas to collectively represent the full range of biodiversity values of a landscape or region. Concepts of irreplaceability and integrity are also important in considering the protection of biodiversity.

3.3. Together, these approaches and concepts are embedded deeply in a range of New Zealand’s environmental legislation and policies related to the protection and management of New Zealand’s biodiversity and natural resources. For example, the intrinsic values of ecosystems are widely recognized in statements regarding the desirability of protecting a representative range of New Zealand’s biodiversity, and the need to control developments that otherwise would cause avoidable degradation of ecosystem functioning and health.

3.4. A variety of tools have been developed to support assessment of the conservation value and ecological integrity of New Zealand’s riverine and terrestrial ecosystems, and these are directly relevant to any assessment of the values of the landscapes and associated riverine features that would be affected by the MHP. These tools include (i) a comprehensive collection of spatial data describing ecosystem patterns, ecological integrity and conservation values in New Zealand’s rivers and streams, generally referred to as ‘Freshwater Ecosystems of New Zealand’ or FENZ (Leathwick et al. 2010b), and (ii) a systematic approach to the prioritization of ecosystem management developed by the Department of Conservation to insure the protection of a representative range of New Zealand’s ecosystems; this includes the identification of four ecosystem management units within the landscapes that would be affected by the MHP.

*The conservation significance of the Mokihinui River*

3.5. A classification analysis of environmental data for rivers at a whole of catchment scale indicates that the Mokihinui sits among a group of mid- to large-sized rivers of the north-western South Island, including the Karamea, Aorere, Takaka, and Paturau Rivers. Other closely related rivers include the Grey, Buller, Motueka and Waimea Rivers.

3.6. Conservation rankings from the Freshwater Ecosystems of New Zealand (FENZ) database, calculated using a spatial approach that takes account of environmental representation, ecological integrity, and the desirability of maintaining upstream-downstream connectivity, places the Mokihinui within the top 20% of New Zealand's large rivers (14th out of 77 rivers with catchment areas > 50,000 ha), and ranks it third within a smaller group of nine closely related rivers from the north-western South Island.

3.7. The Mokihinui has the eighth highest ecological integrity score out of New Zealand's 77 rivers with catchments of 50,000 ha or more, and has the second highest integrity score within the smaller group of nine rivers to which it is closely related. Main reductions in the integrity score for the Mokihinui catchment are from historic mine sites that are located mostly downstream of the proposed dam site. Integrity scores above the proposed dam site are generally very high, being penalized mostly by the widespread presence of introduced fish.

3.8. In my view, this combination of high conservation ranking and high ecological integrity results in the Mokihinui River having highly significant conservation values nationally; this is reflected in the very high levels of intactness and naturalness of both its species assemblages and its ecosystem functions and processes.

*Impacts of the MHP on aquatic values of the Mokihinui River*

3.9. The artificial reservoir to be created by the MHP will result in the inundation of approximately 22.9 km of river and stream courses, of which 14.5 km consists of the main stem, and the balance of tributary streams. These river and stream sections will be replaced by a reservoir that will differ significantly from natural earthquake lakes, both in the large and relatively impermeable barrier formed by the dam at its downstream end and its unstable water levels.

3.10. The MHP will result in the construction of a significant obstacle to both the upstream and downstream movement of native migratory fish species. In my opinion the mitigation proposed by the applicant to reduce these effects is likely to be only partially effective and will almost inevitably result in significant changes in both the distributions and abundances of migratory fish species above the reservoir. Based on a statistical model that predicts the occurrence of these species throughout the catchment, I estimate that these residual negative impacts will extend up to approximately 40 km upstream of the dam, and will affect approximately 69.2% of the river and stream segments upstream of the dam (629.4 out of 908.9 km total segment length). Evidence concerning the survival of larval fish while migrating downstream through the turbines or over the spillway indicates considerable potential for adverse effects. Overseas studies summarized by Larinier (2001) indicate that the combination of Francis turbines and an 85 m spillway as planned for the MHP is likely to cause significant mortality.

*Downstream impacts of the MHP on aquatic values of the Mokihinui River*

3.11. Evidence presented by the applicant indicates that, except during the white-baiting season and during flood events, the MHP will result in a 10-fold increase in daily flow variability, with once- or twice-daily peaks in flow of greater than 120 cumecs. While I lack the data required to develop a statistical model to predict directly the likely impacts of this change on native biota, in my opinion published evidence from both New Zealand and internationally indicates that (i) in general, flow variability strongly influences natural patterns of variation in native fish and macro-invertebrate community structure in riverine ecosystems, and (ii) the dramatic, artificial alteration of flow variability as proposed for the Mokihinui is highly likely to significantly alter biological communities below the dam. In my view, a statistical model used by one of the applicant's witnesses (Mr Jowett) to support the contrary view that impacts below the dam will be negligible contains critical shortcomings that invalidate its use in this setting.

3.12. When riverine conservation rankings are recalculated, assuming that the MHP has been implemented as described in the applicant's evidence and taking into account the residual negative impacts just described, the conservation ranking of the Mokihinui River is predicted to decline by 30 places to 44th out of 77 large rivers.

*Impacts of the MHP on terrestrial values*

3.13. The forests of the Mokihinui catchment have complex patterns, showing both broad variation reflecting the influence of climate (coastal to inland, low to high elevation), and more local variation associated with changes in geology, landform and disturbance history. Dominant tree species in the gorge include kamahi[2], rimu, hard beech, northern rata, quintinia and mahoe. Locally dense rimu forests on low altitude terraces and benches along the valley floor, mostly in the lower two-thirds of the

[2] Scientific names for species referred to in the text by common name are contained in Appendix III or are provided in brackets after their first use.

Mokihinui gorge, are ecologically significant, given the widespread destruction of such lowland forests through much of the Buller region. The local dominance of northern rata in the lower part of the gorge is notable, as this species is approaching the southern limit of its geographic range. With progression upstream, forest communities become increasingly different to those associated with the dam site, reflecting the gradual increase in elevation and reduced coastal influence; forests upstream of the forks are generally dominated by red, silver and/or mountain beech.

3.14. Construction of the MHP will result in the destruction of approximately 300 ha of vegetation with significant ecological values, i.e., the area of the proposed reservoir (337 ha), less the area currently occupied by open riverbed. Most of this vegetation is tall forest, although lower statured, early successional vegetation occurs on recent slip sites, and specialized shrub and turf communities occur close to the river margins on sites subject to frequent inundation.

3.15. Diverse ecosystems along the proposed transmission line reflect the combined effects of low fertility, variation in elevation and human disturbance. They include rock pavements formed on infertile sandstones with scanty vegetation cover, possibly modified through burning; fire-induced sedge-fernlands and scrub dominated by manuka, yellow-silver pine and rimu; and intact primary forest dominated by various mixtures of rimu, silver pine, yellow-silver pine, mountain toatoa, hard beech, southern rata, kamahi, pahautea, and mountain beech.

3.16. Impacts of the MHP along the transmission line, while less severe and extensive than those in the gorge, will result in disruption of vegetation cover at a large number of pylon sites; recovery at these cleared sites is likely to be slow because of the infertile soils that prevail here, and risks of weed invasion are high. The highly distinctive and irreplaceable nature of these ecosystems is reflected in the designation and gazettal of much of this area as an Ecological Area by the former New Zealand Forest Service, and it's very high values are also acknowledged by the applicant's witnesses. Elsewhere these ecosystems are under major threat from current and proposed coal mining.

3.17. In my view the offsetting proposal presented by the applicant contains significant shortcomings in that it (i) ignores entirely the major adverse impacts of the MHP on the high conservation values of freshwater ecosystems both upstream and downstream of the dam, (ii) ignores damage that will be caused to the highly distinctive and irreplaceable vegetation communities along the proposed transmission line, and (iii) relies on an inappropriately coarse-scale comparison of ecological similarities between forests in the impacted and 'offset' areas, and a relatively simplistic management regime within the 'offset' area.

3.18. The more recent proposal to offer a 'trade-up' site (Waimangaroa Bush) centres on a small area of forest that is of undoubtedly high conservation value, but is of a fundamentally different ecological character to forests affected by the MHP. This block is already well fenced and is receiving both browser and predator control through Animal Health Board and landowner operations respectively; management proposed for this block does not address what is arguably the most significant threat to this block, i.e., coastal erosion at its south-western end.

3.19. Accordingly, while the offset plan proposed by the applicant will deliver some gains in forest condition and for some threatened species, in my view it neither acknowledges nor adequately compensates for the significant residual biodiversity losses that will result from the MHP, particularly in relation to aquatic ecosystems.

## 4. SYSTEMATIC CONSERVATION PLANNING – CONCEPTS AND DEFINITIONS

4.1. **Systematic conservation planning** (SCP) takes its name as a discipline from a seminal review paper published in the journal Nature by Margules & Pressey in 2000. They identify the primary goal of SCP as the efficient use of limited resources to insure the persistence of a representative range of biodiversity (i.e., ‘biological diversity). Key components of SCP include the identification of surrogates or frameworks that can be used to document biodiversity values and map their geographic distributions; the setting of explicit goals for biodiversity protection; the identification and protection of representative sites requiring protection to achieve those goals; and the identification of management actions (including monitoring) to maintain biodiversity within protected sites.

4.2. A robust understanding of the term **biodiversity** (or biological diversity) is central both to understanding the intent of SCP and to any assessment of the impacts of the MHP. The United Nations Convention on Biological Diversity provides one of the most widely used definitions, defining biological diversity as *"the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes* *diversity within species, between species and of ecosystems"*. That is, biodiversity refers not just to species, but to variability across multiple levels of organization up to and including ecosystems.

4.3. This in turn highlights the need for a robust understanding of the concept of an **ecosystem**. Accepted definitions focus on the combination of a biological community and its environment, treated together as a functional system of complementary relationships, and transfer and circulation of energy and matter (e.g., Whittaker 1975). Although such a definition is intuitively attractive, it can be problematic when attempts are made to translate it into management practice (Noss 1996). This is because there is no inherently ‘correct’ scale for defining ecosystems (Christensen et al. 1996), with current conceptual understanding emphasizing their open, hierarchical nature (e.g., O’Neill et al. 1986). That is, ecosystems that are defined at a particular scale can be seen as both containing finer-scale ecosystems, and being nested within other ecosystems that are defined at broader spatial scales, i.e., they are typified by an open connectedness and interaction across the landscapes in which they occur (Christensen et al. 1996).

4.4. A number of other terms are widely used in SCP, several of which I define here, given their relevance to particular issues discussed in the remainder of my evidence:

(a) **Representativeness** – in the international literature representativeness generally refers to ‘*a long-established goal referring to the need for reserves to represent, or sample, the full variety of biodiversity, ideally at all levels of organization*’ (Margules & Pressey 1990). A narrower meaning is sometimes attached to this term in New Zealand, where it is sometimes taken to indicate the extent to which an individual site is capable of representing the biological characteristics of a particular community or ecosystem (New Zealand Biodiversity Strategy – Anon 2000). Note that the concept of representativeness can be applied to biodiversity values on lands of any tenure;

(b) **Irreplaceability** describes the importance of including a particular site in a network of protected (or managed) areas if overall goals of representativeness are to be achieved; sites with high irreplaceability contain ecosystems for which representation cannot be achieved through substitution by other sites (Wilson et al. 2009).

(c) **Integrity** – high ecological integrity occurs at sites that '*maintain the full potential of indigenous biotic and abiotic features, and natural processes, functioning in sustainable communities, habitats, and landscapes. At its simplest, ecosystems have ecological integrity when all the indigenous plants and animals typical of a region are present, together with the key major ecosystem processes that sustain functional relationships between all these components*' (Lee, McGlone & Wright 2006). This is expressed explicitly in the context of New Zealand's aquatic environments by Schallenberg et al. (2011) as '*The degree to which the physical, chemical and biological components (including* *composition, structure and process) of an ecosystem and their relationships are present, functioning and maintained close to a reference condition reflecting negligible or minimal anthropogenic impacts*'.

## 5. SYSTEMATIC CONSERVATION PLANNING – PRACTICALITIES IN NEW ZEALAND

*Legislative and policy expressions*

5.1. A number of systematic conservation planning concepts and principles are embedded in New Zealand's legislative and policy framework for conservation and environmental management. For example, the concept of representativeness occupies a central place in the Reserves Act 1977 whose purposes include the '*providing for the preservation of representative samples of all classes of natural ecosystems and landscapes which in the aggregate originally gave New Zealand its own recognizable character*'. Similarly, the importance of ecosystems is central to the Resource Management Act, which has as its broad purpose '*to promote the sustainable management of physical and natural resources*', while explicitly recognizing the value of '*Safeguarding the life supporting capacity of air, water, soil and ecosystems*'. The need to have particular regard to the '*intrinsic value of ecosystems*' is explicitly recognized in Section 7(d) of this Act. Practical expression to this is given under Section 6, which identifies as a matter of national importance '*the preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and* *development*', '*the protection of outstanding natural features and landscapes from inappropriate subdivision, use and development*', and '*the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna*'.

5.2. At a policy level, clear expression of SCP principles, and particularly the concept of representativeness, is contained within The New Zealand Biodiversity Strategy (Anon. 2002), which is the main policy document setting out goals for the management of New Zealand's biodiversity. For example, this identifies as a desired outcome for terrestrial biodiversity that by 2020 '*A more representative range of natural habitats and ecosystems is secure in public ownership*'. Similarly, the first objective identified for freshwater ecosystems is to '*Protect a full range of remaining natural freshwater ecosystems and habitats to conserve indigenous freshwater biodiversity…*' (p. 52). A supporting action under this objective identifies the need to '*Develop and apply a comprehensive classification system for freshwater ecosystems… …to help identify protection priorities*'.

5.3. A more recent National Policy Statement for Freshwater Management 2011 also takes a strongly ecosystem-centred view of freshwater management. In its preamble, it recognizes that freshwaters not only meet a range of human uses but also possess intrinsic values that include '*healthy ecosystem processes functioning naturally*' and '*healthy ecosystems supporting the diversity of indigenous species in sustainable populations*'. Objective B1 of this policy identifies the need '*To safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems of fresh water, in* *sustainably managing the taking, using, damming, or diverting of fresh water*.’

*Terrestrial tools and frameworks*

5.4. A range of practical tools have been developed to underpin the implementation of these legislative and policy objects, including spatial frameworks or classifications designed to provide a context within which to assess the representativeness and significance of natural ecosystems. For example, New Zealand’s Ecological Regions and Districts framework is a classification of New Zealand’s landscapes into geographical units that are ‘*ecologically homogenous or posses a simple or repeating pattern of ecosystems*’ (Simpson 1982). This has been widely used in the implementation of New Zealand’s Protected Natural Area Programme, which had an initial focus on meeting the representation-related objectives of the Reserves Act 1977 described above; more recently the scope of this programme has been extended to include the identification of natural ecosystems that can be regarded as significant under section 6(c) of the Resource Management Act. The Land Environments of New Zealand (LENZ) classification classifies New Zealand’s landscapes in a subtly different fashion, identifying units with similar environmental characteristics even when these occur in widely scattered geographic locations (Leathwick et al. 2003); the proposed National Policy Statement on Indigenous Biodiversity identifies use of this framework as one mechanism to identify significant indigenous vegetation or habitats of indigenous fauna.

*Freshwater tools and frameworks*

5.5. These approaches have been extended recently by the Department of Conservation to provide explicit consideration of ecosystem patterns, ecological integrity and conservation priority in New Zealand’s freshwater ecosystems (Leathwick et al. 2010b). These developments reflect high levels of concern over both widespread declines in water quality and the inadequacy of current approaches to water management in New Zealand (e.g., Land and Water Forum 2010; Auditor General 2011). Results from this project have been delivered to end-users both within the Department of Conservation and externally as Freshwater Ecosystems of New Zealand (FENZ). Specific components address (i) the development of a riverine classification that uses environmental factors selected, weighted and transformed to maximize the ability of the classification to capture variation in biodiversity character (Leathwick et al. 2011, Appendix I); (ii) spatially explicit estimates of the ecological integrity of rivers and streams based on the estimated impacts of human pressures (Leathwick et al. 2010a), and (iii) the development of a conservation ranking approach for application to rivers (Leathwick et al. 2010a). This ranking approach explicitly recognizes the degree to which activities in one part of a catchment may have impacts that extend over considerable distances in both upstream and downstream directions (Abell et al. 2007, Linke et al. 2007), necessitating consideration of whole of catchment effects when assessing local values and vice versa. These rankings largely supersede earlier rankings produced under the Waters of National Importance (WONI) project, as published in Chadderton et al. (2004), although that document remains a useful resource document describing the conservation values of New Zealand’s rivers.

*Department of Conservation's prioritization of ecosystem management*

5.6. Over the last three years the Department of Conservation has implemented a project designed to implement a systematic approach to the cost-effective management of a full range of New Zealand's ecosystems. This recognizes that maintaining a full range of New Zealand's ecosystems in good condition is both an important objective in its own right, and a highly effective if indirect strategy to support the conservation of a full range of species (Noss 1996). Key steps in this project include:

(a) The identification of a comprehensive set of 'ecosystem management units' (n = 941) designed to include examples of a full range of New Zealand's ecosystems. Selection of these units was based initially around high value sites identified by expert groups convened for different groupings of related ecosystems. These sites were then expanded to form larger, multi-ecosystem management units (average size = 3415 ha), recognising that (i) the protection of functional linkages between ecosystems is as important as the protection of linkages or processes that occur within ecosystems, and (ii) this is best achieved by the protection of groups of related ecosystems forming connected landscape sequences (e.g., Bassett & Miers 1984, Christensen et al. 1996). The total area contained within these units is c. 3.2 million ha, approximately 82% of which is on public conservation land (PCL); the balance is either administered by public bodies (e.g., lakes administered by Regional Councils), in private ownership, or is publically-owned land leased to private individuals, e.g., under high country pastoral leases.

(b) Operations staff have identified a full range of biodiversity pressures (e.g., browsers, predators, weeds) for 750 of these management units (mostly on PCL), and developed costed prescriptions for these units specifying management actions required to mitigate the effects of these pressures on biodiversity.

(c) An interim ranking of these management units was produced using spatial prioritization software to analyse data describing ecosystem patterns, overlaps with the distributions of selected threatened species (vertebrates and selected higher plants), estimated integrity and management costs for each of these units. Our objective was to rank units based on their ability to contribute to the cost-effective protection of a representative range of ecosystems, while exploiting potential overlaps with threatened species projects, and protecting sites that currently have high ecological integrity either because of recent management or because of their inaccessibility, e.g., on offshore islands. Current intentions are to progressively implement management for at least the top-ranked 400 units over the next four years, although extension to include a significant number of lower-ranked units (rankings in the range 400-600) is highly likely, depending on continued adequate funding.

*Ecosystem management units affected by the MHP*

5.7. Four ecosystem management units from this prioritization project have been identified within the area directly affected by the MHP as described below. Only a brief overview of these units is provided here; aspects of their ecology relevant to the MHP are provided elsewhere in my evidence or that of my fellow witnesses as appropriate:

(a) **Matiri-Mokihinui MU** – 15,293 ha – this large management unit contains a diverse mix of geological substrates, landforms and vegetation in a topographically complex inland basin in the middle reaches and headwaters of the Mokihinui River. It includes much of the gentle terrace country occurring in the immediate vicinity of the Mokihinui forks (120 m asl), along with hill-country rising eastwards to the Matiri Range, including large parts of the Matiri Plateau; it reaches a maximum elevation of 1526 m at the high point The Haystack. It contains distinctive high elevation tussock grasslands on the limestone plateau; mountain beech-conifer forests predominantly on limestone and granite; mid- to lower elevation silver beech, mixed silver/red beech and conifer-broadleaved-beech forests, mostly on mudstones; and grasslands on terraces formed from both alluvium and lake sediments. Faunal values of this MU include a wide range of bird species (great spotted kiwi, blue duck), geckos, land-snails, and long-tailed bats.

(b) **Mokihinui Gorge MU** – 15,707 ha – this management unit extends the full length of the Mokihinui gorge, which provides the key functional linkage between the inland basin contained in the previous Matiri-Mokihinui MU and the downstream coastal hills and alluvial plains (around Seddonville). The northern boundary extends around the Radiant Range to Mt Webb, encompassing the catchments of Rough and Tumble Creek and Maori Gully; its southern boundary is formed by a prominent ridge that runs eastwards from the northern end of the Glasgow Range and separates the main stem of the Mokihinui River from Hennessey Creek. A range of geological substrates are present, including greywacke, granite, limestone and mudstone; greywacke predominates in the gorge (Dr Lloyd). Strong tectonic influences are a feature of the unit, and resulted for example in the formation of a short-lived landslide lake (Lake Perrine) at the upper end of the gorge during the 1929 Murchison earthquake. The management unit supports conifer-broadleaved-beech, conifer-beech, and beech forests, with localised dense conifer forests in the lower gorge; small areas of sub-alpine tussock-grassland occur on the northern end of the Glasgow Range. On greywacke substrates in the gorge, short turfs and scrub occur along the river margins on sites subject to recurrent inundation and scouring during high flows. Northern rata is abundant in the lower part of the gorge. Faunal values of this MU are broadly similar to those in the preceding unit.

(c) **Ngakawau MU** – 13,931 ha – The area within this management unit was designated by the former New Zealand Forest Service as an Ecological Area under the Forests Amendment Act 1973 in recognition of its complex and highly distinctive forest and scrub communities growing on infertile tertiary sediments, granite and greywacke. Extensive 'coal-measure' soils support a diverse range of conifers tolerant of harsh soil conditions, along with hard, silver and mountain beech; fire-modified sites support secondary scrub and sedge-fernland. More fertile soils support various mixtures of red, silver and hard beech, northern rata and conifers, with the latter sometimes abundant on more gently sloping sites; the Ngakawau Gorge runs through the centre of the MU.

(d) **Deep Stream/Waimangaroa MU** – 2323 ha – contains some of the last unmodified low-stature coal measure vegetation and exposed sandstone pavement left on the Stockton Plateau. High faunal values include great spotted kiwi, geckos, and the large land snail *Powelliphanta patrickensis*. The very high conservation values of this area are reflected in its identification as a Recommended Area for Protection (RAP) during the Protected Natural Areas Programme (PNAP) survey of the Ngakawau Ecological District (Overmars et al. 1998). Its highly irreplaceable character is also described by Norton (1997), who documents both the naturally restricted distribution of such ecosystems (see also Williams et al. 2007) and the high level of threat to which they are exposed by coal mining, both current and planned.


Figure 1. Location of ecosystem management units in the vicinity of the Mokihinui, part of a larger set of 750 such units used to identify ecosystem management priorities within the Department of Conservation – see paragraph 5.7 for explanation.

5.8. Current rankings, calculated nationally and based predominantly on terrestrial values, identify the Deep Stream/Waimangaroa MU as having the highest priority (rank 159), followed by the Matiri-Mokihinui MU (463), Ngakawau MU (582) and the Mokihinui Gorge MU (655). The first two of these management units are therefore highly likely to receive intensive management in the future as part of a systematic program aimed at protecting a full range of New Zealand’s terrestrial ecosystems.

*Interpretation of ecosystem rankings*

5.9. The developmental and evolving nature of these rankings needs to be clearly understood. Significant further enhancements are planned over the next two to three years; these will include (i) greater consideration of the conservation values and management requirements of riverine ecosystems, and (ii) integration of this work with a parallel project designed to rank projects aimed at ensuring the persistence of a full range of threatened species, including large land-snails. Both of these factors are likely to significantly alter rankings for the management units affected by the MHP.

5.10. Despite current limitations, use of rankings such as these to guide operational management on this scale is ambitious and arguably places the Department at the leading edge of such work internationally. The intent is to identify sites that collectively represent a full range of New Zealand’s natural ecosystems, while operating within an economic environment in which the limited amounts of funding for conservation prevent the application of intensive management across all public conservation lands. Three particular points of interpretation flow from this:

(a) These rankings should be clearly understood as currently having a terrestrial bias, with only partial consideration of (i) riverine ecosystem values, and (ii) the potential synergies achievable through management of sites delivering benefits for both ecosystems and threatened species.

(b) The use of a reduced set of management units for prioritisation is clearly a compromise; ideally we would have developed management prescriptions for all public conservation lands, but this in itself would be a costly undertaking and was not achievable within the required timeframe. As a consequence, our failure to include any particular piece of public conservation land within an ecosystem management unit does not indicate a lack of conservation value or significance, but rather that the values known to occur there have been recognised by experts as also occurring in a management unit elsewhere.

(c) It should be noted that management units identified during this project occur on public conservation lands with widely differing protection status and management designations, including national parks, scenic reserves, forest parks, ecological areas and stewardship areas. This wide variation in protection status reflects the often piecemeal and idiosyncratic manner in which land has been set aside for conservation purposes in New Zealand (e.g., Leathwick et al. 2003).

This project aimed to establish a consistent, high level overview of ecosystem patterns across these various designations to identify a minimum or core set of sites providing representative protection of a full range of New Zealand's ecosystems.

(d) Numbers of management units that will receive intensive management will be limited primarily by financial rather than ecological considerations; as a consequence, lower ranked management units cannot be interpreted as lacking significant ecological values in the broader sense of the term, but rather that the limited amount of funding that is available is insufficient to extend management across all highly-valued public conservation lands, including those considered as part of this ranking exercise.

(e) Finally, a clear policy is still to be established on how to balance management intensity within ecosystem or threatened species management units against management intensity within surrounding public conservation lands, given the contribution that the latter also make to the maintenance of New Zealand's biodiversity. This includes management of sites valued by (and sometimes managed in conjunction with) local communities, and the control of pest species posing widespread risks (e.g., wilding pines, possums as vectors for bovine tuberculosis).

# 6. RIVERINE VALUES OF THE MOHIKINUI RIVER

6.1. Given the background provided by this overview of systematic conservation planning methods and their implementation within New Zealand, I have approached the question of the conservation significance of the Mokihinui by first placing it within the broader context of its similarities to other New Zealand rivers, and then by reviewing river conservation rankings and integrity scores contained within the Freshwater Ecosystems of New Zealand (FENZ) database.

*Establishing a robust context for evaluation*

6.2. Establishing a context within which to assess the significance of the Mokihinui River is complicated by issues of scale. This is because existing classifications of New Zealand's rivers were performed at a river segment[3] scale, but the impacts of the MHP are predicted to affect much of the catchment, including river segments both below and far above the dam site as described in Section 7 below. To provide a broader, catchment-scale perspective, I therefore performed a numerical classification of New Zealand's river catchments (as delineated by NIWA's REC database – n = 9151), based on their proportional representation of environmental groups from the segment-scale FENZ river classification (Leathwick et al. 2010) at a 300 group level. Details of this analysis are provided in Appendix I.

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[3] A length of river or stream between two adjacent confluences.

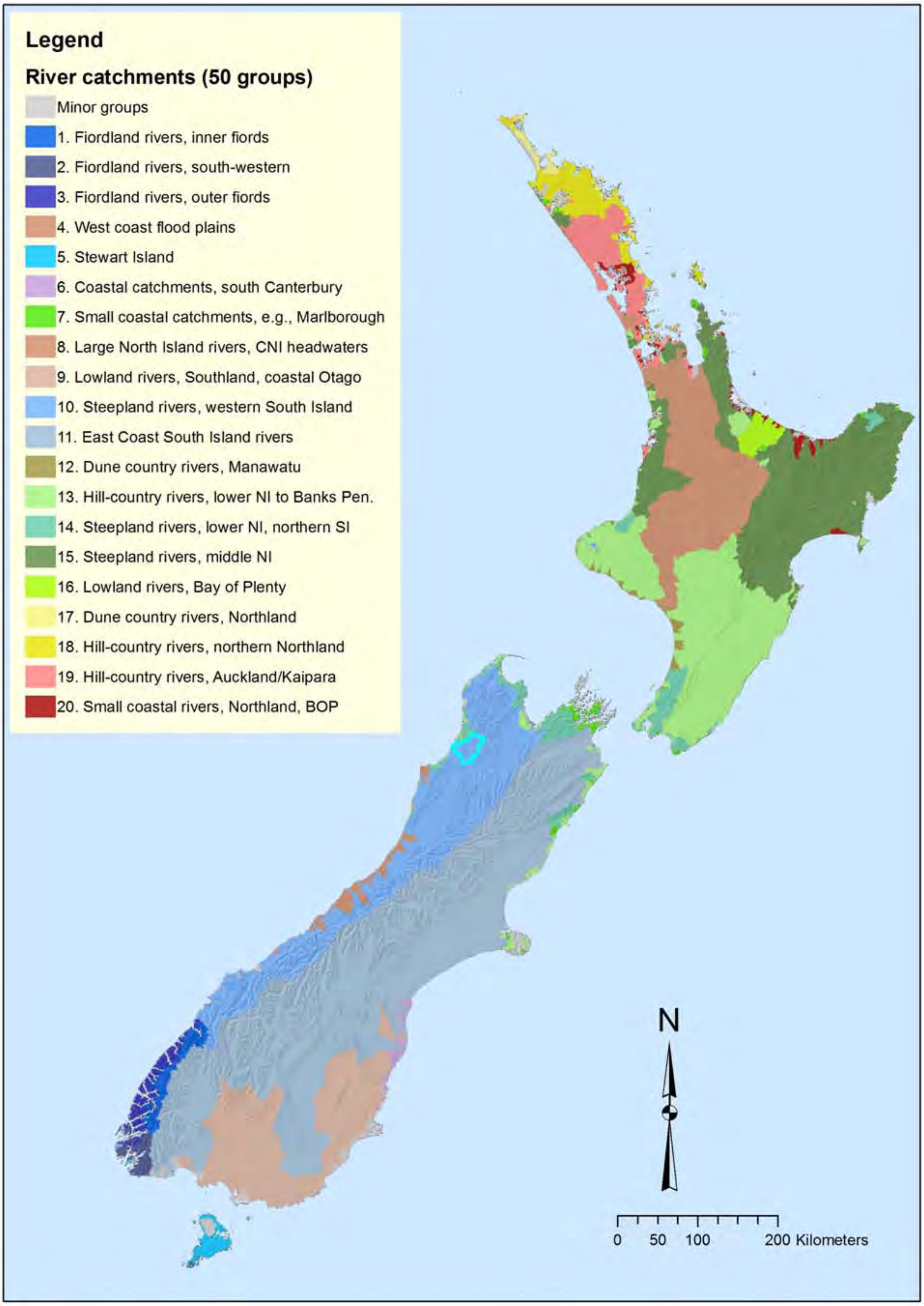


Figure 2. Results from a catchment scale classification of New Zealand's rivers and streams, based on the segment-scale FENZ classification groups (300 groups) they contain – the catchment boundary of the Mokihinui River is highlighted in light blue. Only the 20 most widespread groups are shown. Methods used to define the classification are described in Appendix I.

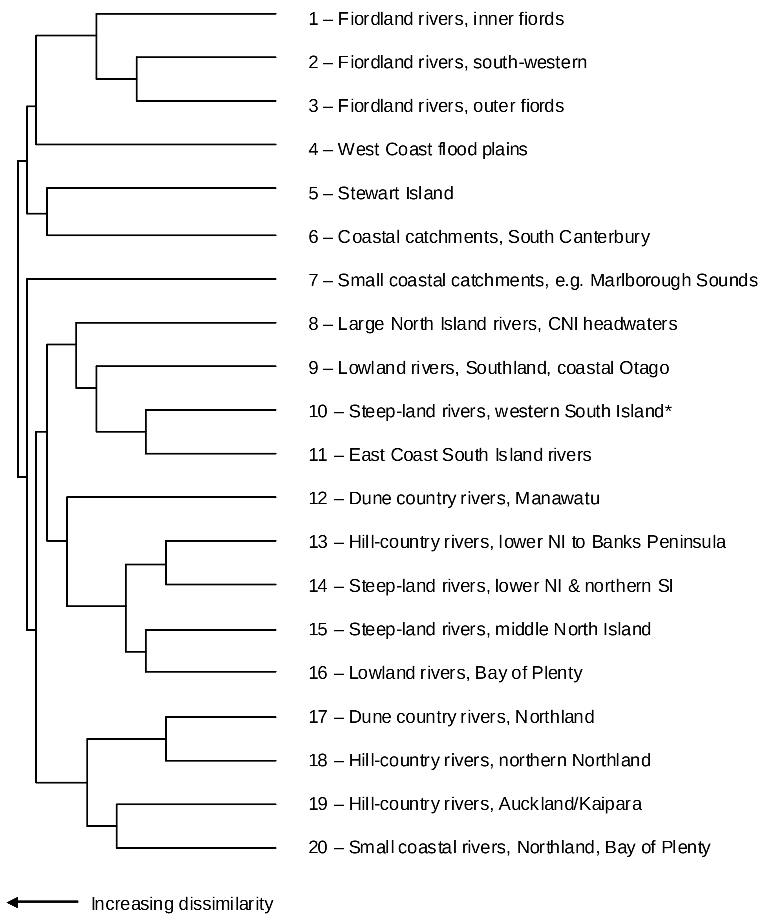


Figure 3. Dendrogram describing ecological similarities between the twenty most widespread groups from a classification of New Zealand's river catchment at a 50-group level of detail. Line-work to the left (the dendrogram) provides a graphical summary of inter-group similarities, so that groups joined by vertical lines towards the right of the dendrogram are more closely related than groups (or groups of groups) joined to the left of the dendrogram. For example, at the bottom of the figure, Groups 17 and 18 are more closely related than Groups 19 & 20, and these two pairs of groups are in turn more closely related to each other than to all other groups.

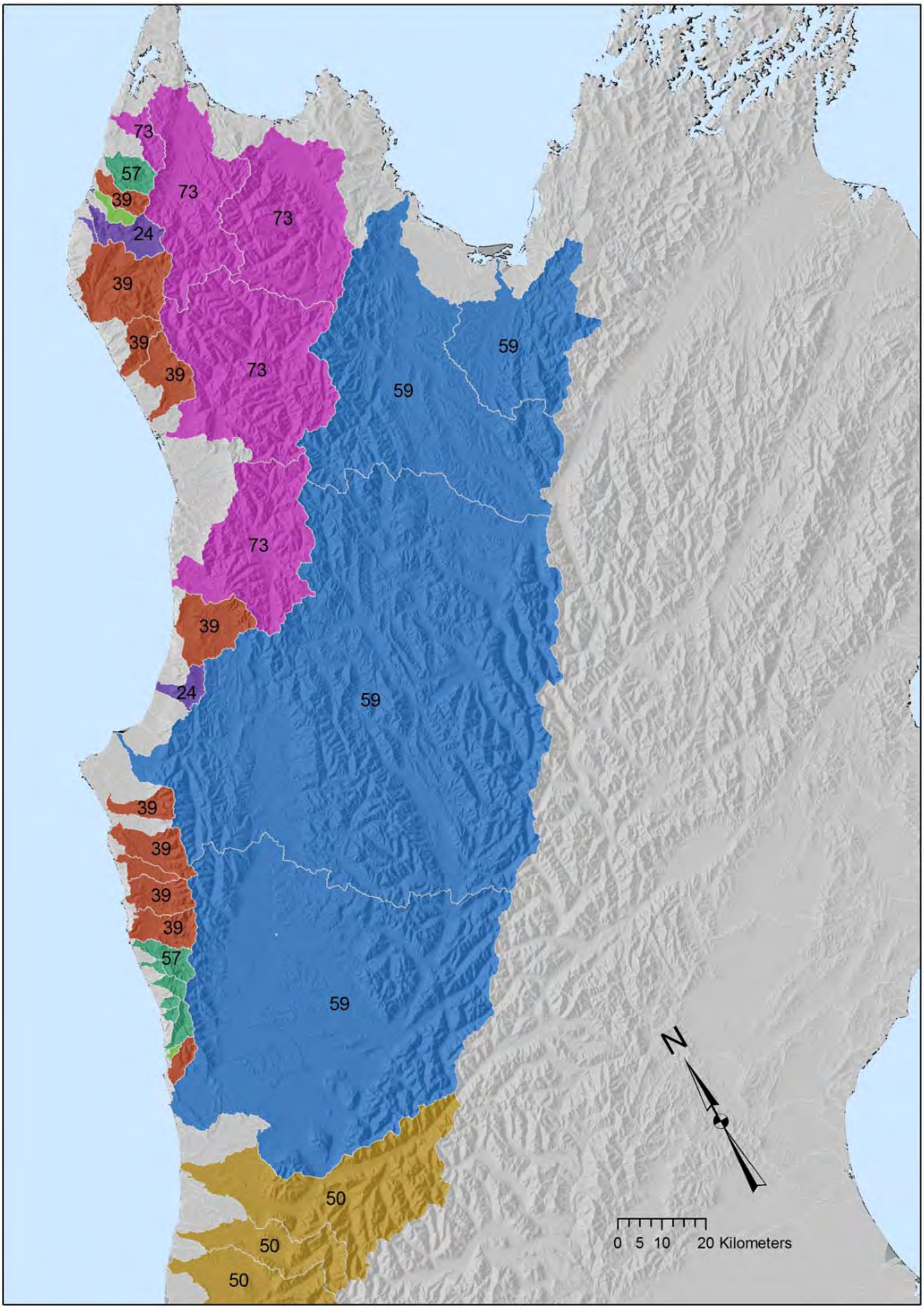


Figure 4. Regional scale similarities between the Mokihinui River and other similar river catchments in the upper South Island. See section 6.4 for explanation.

6.3. By grouping New Zealand's rivers according to their environmental similarity at a whole of catchment-scale, results from this classification provide a more appropriate context within which the conservation values of the Mokihinui can be assessed. At a broad (50-group) level of classification detail, the Mokihinui belongs in a large group of West Coast rivers (Group 10 in Fig. 2) that occurs from near the base of Farewell Spit all the way south to the Hollyford River. Other related groups at this level of classification (as described by the dendrogram in Fig. 3), and in order of increasing dissimilarity, include: Group 11 which occurs throughout much of the eastern South Island; Group 9 which contains larger lowland rivers of the south-eastern South Island, and Group 8 which contains two large rivers arising in the central North Island.

6.4. At a finer-resolution (120-group) level of classification, and focusing just on those rivers to which it is closely related, the Mokihinui River is placed in a group of five mid-sized catchments with montane headwaters that drain to the west or north from the ranges of north-west Nelson (Group 73 in Fig. 4); the other four members of this group are the Karamea, Aorere, Takaka and Paturau Rivers. This group of rivers is most closely related to a group of larger northern South Island rivers with a mix of hilly to steep upper catchments, and extensive alluvial plains in their lower reaches, i.e., the Grey, Buller, Motueka and Waimea Rivers (Group 59 in Fig. 4). Other groups with lower levels of similarity to the Mokihinui group include: Groups 24, 39 & 57 – smaller rivers arising in coastal hill-country, mostly from the Paparoa Range north; and Group 50, which contains larger, montane rivers from the Taramakau River south to the Hollyford River; many of these have strong glacial influence, with consequent differences in ecological character (Milner et al. 2001).

*Conservation significance of the Mokihinui River*

6.5. Having established a context for assessing the significance of the Mokihinui River, I now consider the riverine conservation rankings and estimates of ecological integrity contained within the Freshwater Ecosystems of New Zealand (FENZ) database (Leathwick et al. 2010b). These conservation rankings prioritise New Zealand's rivers and streams using planning units in which streams of first- to third-order[4] are treated as individual entities, but fourth- and larger-order rivers are subdivided into planning units containing their third-order sub-catchments and their main stem. This analysis used segment scale information describing the spatial distribution of different riverine ecosystems from the FENZ Level 3 river classification (described in Appendix I), together with estimates of ecological integrity as affected by human activities, i.e., dams, mines, urbanization, catchment clearance, introduced fish, and nutrient inputs from terrestrial land uses. Estimates of integrity take specific account of the longitudinal connectivity inherent in rivers, so that both the upstream and downstream effects of particular activities are explicitly accounted for as appropriate. Integrity scores vary between '0', which indicates no surviving biological values, through to '1', indicating a pristine site. Longitudinal connectivity considerations are also incorporated into the ranking calculations (Moilanen et al. 2008, Leathwick et al. 2010a) as described above (5.5).

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[4] Rivers and streams are often described in terms of their order – streams with no upstream tributaries are termed 'first-order'; when two first-order streams join they form a second-order stream, when two third-order streams join they form a third-order stream, and so on.

6.6. Ranking values indicate sub-catchments or catchments required to protect a representative range of all of New Zealand's river ecosystems, given some overall protection goal. For example, ranking values in the range from 0–10 indicate the set of sub-catchments that would maximize the representation of a full range of river ecosystems if only 10% of rivers are to be protected, values in the range 10–20 indicate the additional sub-catchments required if protection is to be extended to 20% of rivers, and so on. Highly ranked sub-catchments generally contain the highest-ranked examples of the ecosystem classes for which they provide representation; however, the use of connectivity constraints results in preference being given to those sub-catchments in which upstream and downstream sub-catchments also have high levels of integrity.

6.7. Using FENZ's sub-catchment-scale estimates of conservation value to assess the conservation value of the Mokihinui is complicated by issues of scale in the same manner as applied when establishing a broad context for understanding how the Mokihinui relates to other New Zealand rivers (see section 6.2). That is, because the impacts of the MHP on riverine ecosystem functioning within the Mokihinui extend throughout much of the catchment (see Section 7 below), a catchment-scale assessment of significance is more informative than using finer-scale (sub-catchment) assessments that apply only to these river sections where the dam is to be constructed or that will be submerged within the resulting reservoir.

6.8. In assessing the conservation value of the Mokihinui River, clear understanding is also required of the concept of 'representativeness'. This has particular implications when interpreting the FENZ rankings, which are designed to identify subsets of sites able to represent the full range of

New Zealand's riverine ecosystems. As a consequence a simple comparison of rankings for the Mokihinui against those given to all other rivers is relatively uninformative. This is because a large proportion of these other river segments will be ranked highly to ensure representation of ecosystems that are quite different in ecological character to those occurring within the Mokihinui.

6.9. Given the preceding discussion, I have assessed the conservation value of the Mokihinui River by calculating average values for the FENZ rankings for the 77 largest rivers in New Zealand, i.e., those having catchment extents greater than 50,000 ha and therefore of generally comparable size to the Mokihinui (Table 1). At a superficial level, results from this analysis indicate that the Mokihinui River ranks 14th among New Zealand's 77 large rivers. However, closer examination of this list confirms the need to consider the concept of representativeness, with a number of these high ranked rivers differing strongly in character from the Mokihinui. For example, seven of the rivers having higher average ranks, including the six top-ranked rivers, all differ from the Mokihinui in having at least some degree of glacial influence. Similarly, four of the other rivers with higher average ranks contain contrasting river environments either in dry environments of the north-eastern South Island (Awatere), or in lower elevation hill country in the North Island (Waitotara and Motu). In comparison with the large rivers to which it is most closely related (Groups 73 and 59 in Fig. 4, as identified with an asterisk in Table 1), the Mokihinui ranks third in terms of its ability to contribute to protection of the river ecosystems that typify this group of large rivers of the north-western South Island.

6.10. River integrity scores for the 77 large rivers analyzed are generally correlated with their conservation rankings, although with some exceptions. Highest mean integrity scores (> c. 0.7) occur mostly in rivers with high conservation ranks along the West Coast of the South Island; the main negative pressure for these rivers results from the impacts of introduced salmonids on their native biodiversity values. By contrast, some high ranked rivers have only intermediate integrity scores, e.g., the Waitotara which provides the best opportunity for representation of North Island hill country river ecosystems on Tertiary sediments has a mean integrity score of only 0.59. Overall the Mokihinui has the eighth highest river integrity score out of the entire group of 77 large New Zealand rivers; within the smaller group of rivers to which it is closely related, it has the second highest integrity score. Compared to the Karamea River, its overall ecological integrity score is penalized mainly by the presence of historic mines in its lower catchment, although these are unlikely to now have a significant effect on water quality, particularly upstream of the proposed dam site.

Table 1. Mean conservation rankings and river integrity scores for the 20 top-ranked large rivers (catchment area > 50,000 ha) in New Zealand; four rivers with ranks lower than 20th are included because of their similarity to the Mokihinui. Table values indicate the mean FENZ ranking (see 6.6) and river integrity score (see 6.5) of segments within each catchment. Rivers that are closely similar to the Mokihinui River are indicated with an asterisk.

| Priority | River | Approx. area (ha) | Mean FENZ ranking | Mean river integrity |
|---|---|---|---|---|
| 1 | Waiototo | 53,000 | 7.1 | 0.784 |
| 2 | Whataroa | 59,394 | 13.5 | 0.766 |
| 3 | Hollyford | 113,700 | 16.4 | 0.765 |
| 4 | Arawhata | 93,255 | 16.7 | 0.774 |
| 5 | Wanganui (Westland) | 52,352 | 18.3 | 0.683 |
| 6 | Haast | 135,625 | 20.4 | 0.782 |
| 7 | Karamea* | 121,131 | 21.6 | 0.785 |
| 8 | Waitotara | 116,291 | 22.9 | 0.594 |
| 9 | Wairaurahiri | 70,858 | 24.5 | 0.783 |
| 10 | Aorere* | 68,547 | 25.4 | 0.675 |
| 11 | Motu | 138,433 | 25.8 | 0.677 |
| 12 | Hokitika | 106,836 | 26.5 | 0.635 |
| 13 | Awatere | 157,778 | 28.3 | 0.506 |
| 14 | Mokihinui | 75,174 | 28.4 | 0.705 |
| 15 | Taramakau | 100,543 | 29.5 | 0.669 |
| 16 | Waioeka | 84,051 | 31.0 | 0.603 |
| 17 | Wairau (Marlborough) | 358,486 | 31.1 | 0.560 |
| 18 | Whakatane | 95,576 | 31.5 | 0.595 |
| 19 | Takaka* | 87,170 | 33.0 | 0.698 |
| 20 | Waima | 51,970 | 33.4 | 0.387 |
| 21 | Buller* | 638,253 | 39.0 | 0.619 |
| 26 | Grey* | 394,949 | 41.3 | 0.516 |
| 36 | Waimea* | 77,248 | 50.1 | 0.467 |
| 40 | Motueka* | 205,819 | 52.1 | 0.479 |

6.11. Overall, in my view the preceding analysis identifies the Mokihinui as having highly significant conservation values with respect to its riverine ecosystems, and particularly in the bulk of the catchment that is located above Seddonville. This evaluation is based on both its contribution to the protection of a representative range of New Zealand’s riverine ecosystems, and its very high levels of ecological integrity. The latter results in it supporting ecosystem-level riverine processes that currently function in a much more intact and unaltered fashion than prevails in the vast majority of New Zealand's large rivers, reflecting a general absence of recent human alteration over most of the catchment.

6.12. This assessment differs markedly from that presented on behalf of the applicant by Mr N. Norton, whose approach I question on two grounds, as follows:

(a) First, in my view Mr Norton uses a reductionist approach that considers the rankings and values of only those river segments within the Mokihinui that will be most directly affected by the MHP. In adopting this approach, he ignores the broader impacts of the MHP on ecosystem functioning throughout the majority of this very large catchment, the scale, in my view, at which any assessment must be made.

(b) Second, in my view Mr Norton fails to establish a robust basis for assessing similarity between the Mokihinui and other rivers in the surrounding landscape, and this results in him failing to take adequate account of the concept of representativeness. As a consequence his assessment of both conservation rankings and river integrity is distorted by the manner in which he has compared values for the Mokihinui with those for other rivers that differ markedly in character from the Mokihinui. This is particularly apparent in his Table 3 in which he compares the Mokihinui River with 19 other rivers from the surrounding landscape, all of which, with the exception of the Karamea, are substantially smaller that the Mokihinui.

## 7. IMPACT OF THE MHP ON RIVERINE VALUES

7.1. In assessing the impacts of the MHP on the riverine values of the Mokihinui River, I consider (i) the loss of river segments through inundation by the reservoir, (ii) the likely impacts above the reservoir of impairment of both the upstream and downstream migration of fish, and (iii) the likely impacts of alteration of flow variability below the dam.

*Direct impacts of the MHP through inundation*

7.2. Arguably the most direct impact of the MHP on the Mokihinui River is its irreversible destruction of all river and stream segments upstream of the dam and occurring at elevations of less than 100 m above sea level, i.e., the proposed operational level of the reservoir. I have assessed these impacts by overlaying the proposed footprint of the MHP reservoir on spatial data describing New Zealand's river and stream network and contained in the FENZ database. Based on this analysis I estimate that the total river and stream length that will be destroyed is approximately 22.9 km, of which 14.5 km occurs in the main stem of the Mokihinui and the balance is composed of tributaries (Table 2). In proportional terms, this represents 2.24% of the total length of river and stream segments mapped by the FENZ database within the Mokihinui catchment.

7.3. These river and stream sections will be replaced by an artificial reservoir that will have an impermeable, near vertical 85 m high barrier in the form of a concrete dam at its downstream end (Dr James – Appendix I), and which will be subject to marked daily fluctuations in water level due to the manner in which the MHP's generating capacity will be deployed (Dr Suren – para. 6.15).

7.4. By contrast, natural landslide lakes, several of which occur in the surrounding landscape (e.g., Lakes Phyllis and Marina in the headwaters of the Hemphill River), generally have more stable water levels, with a consequent more stable littoral zone. They also generally have a lower, more permeable barrier at their downstream end, such that climbing capable migratory fish are often not excluded from moving above them.

7.5. Among river segments that will be destroyed by inundation if the MHP proceeds, those in class C3.2b at Level IV of the FENZ river classification (300 groups) will be most affected (Table 2), as calculated both by river length, and by the proportional removal of their broader occurrence in the Mokihinui catchment. Within the Mokihinui catchment, this group forms much of the main stem, as well as parts of the main stems of larger upstream tributaries including Maori Gully, the north branch of the Mokihinui above its junction with the Johnson River, Haystack Creek, Larrikin Creek, Stern Creek, and the south branch of the Mokihinui above Goat Creek. Elsewhere this classification group occurs from the base of Farewell Spit south to about the Hollyford River, generally close to the coast in the north, but in more inland locations south of about Greymouth. It generally consists of large streams or small to moderate sized rivers, typified by moderate flows, gentle to moderate river gradients, and steep catchments experiencing a high frequency of significant rainfall events (65-70 days/year with rainfall greater than 25 mm). It's closest relative (Group C3.2a) is typified by slightly higher flows and more gentle gradients, and occurs in more coastal locations particularly on the Westland coastal plain, where it is more widespread than C3.2b. At level 3, these two groups, now forming Group C3.2, are most closely related to Group C3.1, which occurs mostly in more inland locations, including in the upper Mokihinui, and consists of somewhat steeper segments with lower flow and higher riparian shading. The parent group at level II (C3) occurs from Taranaki (Mt Egmont) south to the Hollyford, and at a very few locations in Fiordland.

7.6. FENZ Group C12.2b is the next most affected group in the Mokihinui, occurring in lower parts of Hodge Creek, Rough and Tumble Creek and Specimen Creek. This group, which generally occurs as larger streams of third or fourth order, is typified by lower flows than the previous group and relatively gentle gradients, but has steep catchments with moderate frequencies of significant upstream rainfall events. Elsewhere it occurs in locations scattered through the ranges of north-west Nelson and the Richmond Range, with some occurrences in the Kaikoura Mountains and the Raukumara Range. The only other group for which more than 1 km will be lost through inundation (C11.1a) consists of small, first- and second-order streams with steep gradients, which are represented here by small side tributaries such as Jones Creek.

Table 2. Inundation of river segments by the proposed MHP reservoir by FENZ class (Level IV). Table values show the number of segments and total length affected by inundation, and the proportion that this represents of that class in the broader catchment, by length.

| FENZ class | Segments | Total length (km) | Percent inundated |
|---|---|---|---|
| C3.2b | 24 | 14.48 | 18.07 |
| C6.4b | 1 | 0.16 | 2.72 |
| C7.1b | 1 | 0.21 | 6.17 |
| C7.2a | 3 | 0.82 | 2.72 |
| C10.1a | 1 | 0.13 | 0.62 |
| C11.1a | 14 | 2.34 | 3.70 |
| C11.1b | 1 | 0.36 | 6.69 |
| C12.2b | 9 | 4.39 | 10.15 |
| **Total** | **54** | **22.88** | |

*Mitigation of the effects of inundation*

7.7. Several of the applicant's witnesses have interpreted the reservoir, which they liken to an earthquake lake, as providing a partial mitigation or offset for riverine values lost by inundation (e.g., Dr James – para. 7.11, Mr N. Norton – para. 3.3a). While the reservoir does constitute a direct replacement of one set of values with another, the values lost are highly natural riverine ecosystems with distinctive seeps and river margins, and the values gained are an artificial reservoir in which (i) the littoral zone will be unstable because of fluctuating levels (Dr Suren – para. 6.15), (ii) waters at depth will be anoxic for up to a decade (Dr James – para. 6.3) or even longer (Dr Schallenberg – para. 18) because of decaying organic matter, and (iii) the downstream end consists of an impermeable, concrete structure 85 m in height (Dr James – Appendix I), rather than a semi-permeable debris dam. In my view, it is therefore difficult to argue that these new 'values' compensate for those that will be lost. In addition, earthquake lakes already occur in the catchment, but are under no threat from human activity, i.e., the creation of the reservoir contributes very little by way of additionality.

*Impacts on migratory fish above the reservoir and its mitigation*

7.8. As acknowledged by the applicant's witnesses, the construction of the MHP will result in the imposition of a barrier that will '*create a total block to migration if no mitigation was provided*', this affecting the natural migratory movements of at least 7 out of 13 native fish species (Mr Bonnett – para. 9.1). Mitigation proposed by the applicant will be based around a trap and transfer operation, primarily designed to accommodate the requirements of long-fin eels (Dr Jellyman – section 10) but which will also be used to transfer other migratory species, including adult lamprey. After capture, species other than eels are to be '*transferred to suitable parts of the Mokihinui catchment*' (Dr James – para. 7.19). Exclusion bars are proposed to reduce mortality of downstream migrating adult eels, but other migratory fish are assumed to be able to pass safely through the turbines or over the spillway (Mr Bonnett – para. 9.19 ff.).

7.9. No details are provided by the applicant as to how or where the catch of upstream migrants from below the dam will be processed and released. Given that several of these species have highly differentiated habitat requirements (e.g., Leathwick et al. 2008) and currently exhibit strong habitat and spatial separation (evidence of Mr Bonnett and Dr Allibone), sorting of the catch to a species level would seem to be required if individual species are to be released into '*suitable parts of the Mokihinui catchment*' in a manner that preserves current distributional patterns of species. However, in my view, the impracticality of such sorting, coupled with the greatly eased conditions for upstream migration in the reservoir compared to those prevailing in the gorge, is likely to result in the trap and transfer operation causing a considerable alteration of the natural migration patterns that currently prevail in this river system. As a consequence, in my view, it is almost inevitable that species that are currently restricted to sites in the lower gorge and its tributaries (Bonnett 5.8), or possibly even those currently occurring only below the proposed dam site, will be assisted to penetrate much further upstream than they currently occur, altering natural distribution patterns of native fish within the upstream catchment. This risk has also been identified by Dr Allibone in his evidence.

7.10. Mitigation to support the parallel need for downstream migration of migratory fish is planned only for breeding adult eels. While some evidence is provided by the applicant to support assertions that larval fish for amphidromous species will safely negotiate the reservoir and dam (Bonnet – Section 9), evidence from other international overseas studies (reviewed by Larinier 2001) mostly of salmonids, but not quoted by the applicant's witnesses, presents a contrary view. It indicates that high levels of mortality (90% or more) can occur in juvenile fish passing through hydro-electric installations, particularly those containing Francis turbines and/or having spillways greater than 50-60 m in height; both of these are planned for the MHP. This contrary evidence raises significant doubts concerning Mr Bonnett's conclusions that a high proportion of larval fish will survive downstream migration past the dam.

7.11. Given that (i) New Zealand’s migratory fish species require freedom of movement both upstream and downstream to complete their lifecycles, (ii) the planned assistance of upstream migration is unlikely to maintain natural processes of dispersal to preferred habitats, and (iii) significant doubts exist around the ability of larval fish to safely negotiate the turbines and/or slipway when migrating downstream, it is my considered view that the MHP is likely to have significant residual negative effects on the movement of native migratory fish in the Mokihinui catchment, with consequent negative impacts on both their distributions and abundance in the wider catchment.

*Assessing the spatial extent of residual effects on migratory fish*

7.12. To estimate the potential geographic extent of these residual negative effects of the MHP on upstream migration by native fish species above the reservoir, I developed a statistical model using a very large set of freshwater fish samples from rivers throughout New Zealand, and used this to predict probabilities of native fish occurrence for all river segments upstream of the proposed dam. This model used 13,369 samples from New Zealand’s Freshwater Fish Database and a response variable that indicates for each sample whether or not one or more diadromous fish species were caught. The model was fitted using an advanced statistical modeling technique, boosted regression trees (Elith, Leathwick & Hastie 2008). Model complexity was optimized using a cross-validation procedure designed to maximize model accuracy when predicting to new sites – details are provided in Appendix II.

7.13. Predictions using this model estimate the likelihood that one or more migratory fish species would be caught in an individual fishing sample for all river segments upstream of the dam. Because uncertainty is an inherent feature of predictions from any such statistical model, I used a re-sampling procedure (bootstrap simulation) to calculate smoothed estimates of catch probability (based on 500 bootstrap samples of the data) along with 95% upper and lower confidence intervals around these estimates. I then adopted a deliberately conservative approach, using the lower confidence intervals to identify those river segments in which there is a probability of 0.5 or higher that one or more diadromous species will be captured in a single fishing event. Further details are provided in Appendix II.

7.14. Results using this highly conservative approach predict that the MHP will negatively impact the natural movement of migratory fish over distances up to approximately 40 km upstream of the proposed dam, depending on the characteristics of individual headwater rivers and streams. These impacts are predicted to affect approximately 69.2% of all river and stream segments (by length) above the dam, assuming that segments are classified as ‘affected’ if their predicted probability of catch exceeds 0.5. Finally, I note that because this is the first obstruction to be imposed on this otherwise natural river system, the MHP will have much greater marginal impacts on the natural migration of its native fish species than would result from the addition of a second dam on an already obstructed river.

*Alteration of downstream flow variability and its mitigation*

7.15. As indicated by the applicant, the proposed flow management regime for the MHP will impose major changes in temporal patterns of flow variability (evidence of Mr Henderson). Except during the white-baiting season and during floods, the proposed management regime will generate once- or twice-daily peak flows that will exceed 100 cumecs. As Mr Henderson describes (para. 3.6) this will result in a ten fold increase daily flow variability, although on days with two generation peaks the increase in flow variability will be even higher[5]. No mitigation has been proposed for the effects of this greatly increased flow variability, other than management of rates of changes in flow to allow movement of individual fish to prevent stranding, for public safety, and to maintain a flow regime that is as natural as possible during the whitebaiting season.

*Estimating downstream impacts*

7.16. While predicting the impacts of changes in flow variability on biota below the dam could be attempted using a statistical modeling approach (e.g., as described in Sections 7.12–7.14), robust prediction would require the building of a model using training data describing biological distributions and environmental conditions from a large number of sites, including observations both under natural flow conditions and from other sites that are comparable to the Mokihinui, and which currently experience a highly modified flow regime similar to that proposed for the MHP. In the absence of such a dataset, I developed a qualitative assessment of the likely downstream impacts of the MHP, based on results from numerical studies both here in New Zealand, including my own work, and from overseas.

7.17. Because detailed information on flow variability within New Zealand's river network is still in the process of being developed, my published analyses of the distributions of freshwater species have used a relatively restricted set of

[5] An alternative analysis of flow variability, based on the frequency of FRE-3 flow events is presented by Dr Kelly, who reaches a similar conclusion that the frequency of high flow events will be substantially increased by the MHP.

variables designed to capture broad variation in natural flow and its variability. These were (i) the mean annual 10-day low flow as a measure of the minimum water resource available to support biota, (ii) the ratio of the mean annual low flow to the mean flow, capturing temporal variation in flow over long time scales, and (iii) the mean frequency of daily rainfall events exceeding 25 mm in the upstream catchment to capture variation in flow over shorter time periods.

7.18. The models I developed using these estimates provide compelling evidence of the major role that natural flow variability plays in structuring biological patterns in New Zealand's native fish and macro-invertebrate communities. For example, in my models of the distributions of fifteen native migratory fish species, all of which have excellent predictive ability (Leathwick et al. 2008), the variable describing short-term flow variability, was the fifth most informative out of 25 environmental predictors on average. Its contribution was only exceeded by variables describing site accessibility (distance to the sea, average and maximum downstream river gradient) and temperature. The variable describing flow variability over longer time scales ranked ninth out of 25.

7.19. Results from parallel analyses of 84 macro-invertebrate taxa (Leathwick et al. 2009) indicate that flow variability plays an even more important role in structuring community composition for these biota. In particular, the variable describing short term flow variability made the highest average contribution to model outcomes both overall, and for five out of seven taxonomic sub-groups. Results from a similar but more recent analysis by NIWA scientists of the distributions of invertebrate taxa using more direct estimates of flow variability than my indirect measures, provide a similar demonstration of the over-riding dominance of flow variability in determining invertebrate community composition and structure (Dr T. Snelder, National Institute of Water and Atmospheric Research – personal communication).

7.20. Results from these three New Zealand analyses are strongly consistent with scientific papers published in the international literature that describe not only relationships between biological characteristics of rivers and their flow variability, but also how biological communities are changed when flow variability is artificially altered. With respect to this latter aspect, Poff et al. (1997) in a synthesis of investigations into the biological significance of flow variability, state that "…*the extreme daily variations below peaking hydroelectric dams have no natural analogue in freshwater systems and represent, in an evolutionary sense, an extremely harsh environment of frequent, unpredictable flow disturbance. Many aquatic populations living in these environments suffer high mortality from physiological stress, from wash-out during high flows, and from stranding during rapid dewatering.*" A later review by Murchie et al. (2008) of literature describing fish responses to modified flow regimes reached a similar conclusion, i.e., that "*There is a clear consensus that modified flow regimes in regulated rivers are affecting fish and fish habitat, but the severity and direction of the response varies widely*." Finally, after reviewing 165 papers describing biological responses to flow alteration, Poff & Zimmerman (2010) concluded that the global literature supports "*the inference that flow alteration is associated with ecological change, and that the risk of ecological change increases with increasing magnitude of flow alteration*" (p. 194).

7.21. Given the context provided by the preceding paragraphs, I have serious misgivings about the credibility of the model predictions presented by Mr Jowett in support of his assertions that the greatly increased flow variability induced below the dam by the MHP will not have '*any significant effects on native fish or trout habitat*' (Jowett – para. 3.5). In particular I note that:

(a) Mr Jowett's evidence depends on use of a highly simplified model that uses only three predictors of habitat suitability, i.e., water depth, flow velocity and substrate size (Jowett – Para 4.18 ff.). His model therefore ignores the influence of other ecological factors operating at other scales (upstream and downstream), and which have been shown to be important determinants of species occurrence in other studies. This is important in that it assumes that a single, relatively simple model describing fish response to just three habitat descriptors provides an adequate basis for prediction throughout New Zealand, regardless of variation in other habitat factors shown to be important in other studies. The shortcomings of such an approach for predicting native fish abundance in New Zealand were identified nearly 20 years ago by McDowall (1993), who advanced strong arguments for the need to explicitly include broader contextual factors when modelling native species, concluding that '*if population density is severely limited by factors other than those included in the model, the model will likely fail*';

(b) Mr Jowett's previous applications of this model have focussed mostly on setting minimum flows in rivers subject to water abstraction (e.g., Jowett & Biggs 2006). By contrast, for the MHP he uses it to make predictions for a river subject not to abstraction, but to a substantial increase in flow variability. This is seriously problematic in that he makes predictions under conditions typified by very high flow variability, despite his model (i) appearing to contain minimal, if any, data from environments with such artificially elevated flow variability, and (ii) completely lacking predictors that are capable of describing the expected changes in flow variability that will occur downstream of the proposed dam. As a consequence, in statistical terms, his model lacks completely any robust technical basis for making predictions under these altered conditions;

(c) Mr Jowett presents no formal statistical assessment of the ability of his model to explain variation in data used for training his model (e.g., Jowett & Richardson 1995). Although he provides some reporting of its predictive ability at new sites (Jowett & Biggs 2006), this is limited to generally qualitative comparisons at six sites, five of which relate to modified flow regimes downstream of lakes, rather than riverine dams as proposed for the Mokihinui. Five of these are subject only to reductions in flow, with no increase in flow variability as is proposed for the Mokihinui; the single example that evaluates the effects of increased flow variability assesses impacts only on macro-invertebrates in a lake outflow, with no consideration of impacts on native fish. In my view, this casts serious doubt on the relevance of these evaluations to the predictions that are being made here;

(d) Finally, despite the wide availability of appropriate techniques (e.g., as described above (7.13) and in Appendix II), Mr Jowett fails to provide any statistical assessment of the likely degree of uncertainty that is associated with his specific model predictions for the MHP.

7.22. While I acknowledge that Mr Jowett has many years of experience in advising on the setting of minimum flow levels, in my opinion, the issues described above that centre around use of his model to make predictions under major changes in flow variability, together constitute a fundamental departure from accepted robust practice for making predictions from statistical models (e.g., Larose 2005, p.79). This in turn casts serious doubt on the fitness of Mr Jowett's model and the accuracy of its predictions in the highly modified flow conditions that will occur downstream of this proposed dam.

7.23. Given the preceding discussion, and after balancing the problematic evidence provided by the applicant's witnesses against the much more robust but indirect evidence provided by quantitative studies using extensive datasets both here in New Zealand and overseas, I disagree with the assertion by Dr James that the effects of markedly increased flow variability on benthic communities below the dam "*will be small and have very limited consequences for the ecosystem because of the frequent floods that exist now*" (3.4). Similarly, I disagree with the assertion by Mr Jowett that "*Frequent flow fluctuations induced by hydro-electric operation… …would not have any significant effect on native fish or trout habitat*" (3.5).

7.24. On the contrary, I would argue that results from quantitative analysis of extensive datasets describing the national distributions of New Zealand's fish and macro-invertebrate species and including explicit measures of natural flow variability, together with results from reviews of international studies of the effects of artificial alteration of river flows, indicate a very high probability that biological communities below the dam will experience significant modification as a result of the large-scale, artificial changes in flow variability that will be imposed on this section of river by the MHP.

7.25. Finally, I note that my assessment of these likely impacts is consistent with concerns raised by other witnesses appearing for the Department of Conservation, including Dr Allibone, Dr Death and Dr Kelly. In addition, Dr Schallenberg identifies additional risks to biota that would result from discharge of waters from the hypolimnion of the reservoir, and these negative impacts would be in addition to those associated with the alteration of flow variability that I have identified.

## 8. OVERALL IMPACTS OF THE MHP ON RIVERINE CONSERVATION VALUES

8.1. To estimate the collective impact of these residual negative impacts of the MHP on riverine conservation values in the

Mokihinui River, I recalculated the FENZ rankings presented in Table 1, using a set of input data in which I modified the ecological integrity estimates for segments within the Mokihinui catchment to a level consistent with implementation of the MHP. This assumed that (i) the dam had been built as planned, with consequent complete loss of values in inundated segments, (ii) impairment of the natural upstream and downstream movement of migratory fish results in significant residual impacts on their recruitment and reproduction upstream of the dam, and (iii) downstream impacts on both fish and macro-invertebrates through alteration of flow variability are as assessed both in my evidence and that provided by the Department's other witnesses. The ranking for the Mokihinui River in these recalculated priorities drops by 30 places, i.e., from 14th to 44th place out of the total set of 77 large rivers. That is they indicate that implementation of the MHP is likely to demote the Mokihinui from the top 20% of New Zealand's large rivers down to a position in the bottom half of those rivers.

## 9. VEGETATION PATTERNS IN THE MOHIKINUI'S GORGE AND SURROUNDS

9.1. While evidence presented by Dr Payton provides some degree of documentation of similarities between forests of the Mokihinui gorge (i.e., between the proposed dam site and the forks) and those in the surrounding region, he provides only a minimal description of vegetation composition and patterns in the Mokihinui catchment and its surrounds. To provide a more informed context for assessing the impacts of the MHP, I therefore classified available plot data from the Mokihinui and surrounding catchments (n = 234), including both plot data collected by the applicant and other plot data collected in the catchment and surrounds (details are provided in Appendix III). I note that particularly in the lower Mokihinui and the Heaphy, these plots are biased towards the sampling of sites adjacent to the main stem of the river, and therefore provide less adequate detail concerning forests occurring at greater distances above the river, i.e., on mid- and upper-slope sites. In addition, no plots were available for the forests of the South Branch of the Mokihinui, i.e., the area proposed by the applicant as an offset, but information from historic plot data indicates that these are likely to be broadly similar to those in the North Branch of this catchment.

9.2. Using results from this analysis (at a 25-group level of classification – see Appendix III), I identified 12 groups of plots having similar species composition. Each of these groups contains five or more plots; together they contain 200 plots, i.e., 85% of the total available dataset[6], and provide a reasonable basis for description of vegetation patterns within the area affected by MHP. They also allow limited comparison between the forests of the Mokihinui gorge and adjacent forests both in upstream parts of the Mokihinui and in the adjacent Karamea catchment.

9.3. Based on the twelve groups from this analysis, coupled with field inspection in the company of Mr W. Shaw of the vegetation of both the Mokihinui gorge and the transmission line route, I provide the following description of the broad regional vegetation pattern and the more local

[6] The remaining thirty four plots occurred in another 13 classification groups, each of which contained fewer than 5 plots. These generally sample outlier sites and have not been considered further in this description.

effects of disturbance. A more detailed description of these patterns, including mapping, is provided by Dr K Lloyd.

9.4. Broad scale patterns of forest composition across the Mokihinui catchment show climatic influences typical of the wider region, e.g., as described in Wardle's authoritative account of compositional patterns in New Zealand's *Nothofagus*-dominant forests (Wardle 1984 – p. 80 ff.). This regional pattern can be summarized as follows:

(a) The more coastal, lower elevation forests (Groups 2–5 in Appendix III) generally contain abundant northern rata, hard beech, kamahi and quintinia, with diverse under-storeys containing tree-ferns, lower statured broadleaved trees and shrubs, and ground ferns; emergent podocarps, particularly rimu, are often prominent, particularly on more stable sites.

(b) With progression inland and to higher elevations, northern rata largely disappears, and hard beech is gradually replaced by red and silver beech (Groups 6-7); in the Mokihinui this transition first becomes apparent in the upper two-thirds of the gorge. The abundance of both podocarps and broadleaved trees gradually diminishes in these forests as beech become increasingly dominant. Note however, that red beech and silver beech occur sporadically in the lower gorge, particularly on riparian sites along the immediate river margins.

(c) With progression to still higher elevation, red beech gradually diminishes in abundance leaving silver beech as the main canopy dominant (Group 8), but particularly on rock types less favourable for tree growth or on sites with poor drainage, silver beech is replaced by mountain beech, often growing in combination with shrubs and/or shorter podocarps that are tolerant of infertility, such as pink pine and/or mountain toatoa (Groups 9 & 10).

(d) Sites with extreme low fertility such as occur along the proposed transmission line route in the Ngakawau Ecological Area provide an exception to this largely climate-driven regional pattern. Forests on these 'coal-measure' sites are generally dominated by novel mixes of species such as rimu, mountain beech, yellow-silver pine, mountain toatoa, silver pine (*Manoao colensoi*), pahautea (*Libocedrus bidwillii*) and hard beech, most of which are known for their tolerance of infertile soils and/or generally occur at higher elevation (Group 11).

(e) At the highest elevations along the transmission line route, small patches of distinctive low vegetation dominated by *Chionochloa juncea*, and stunted silver pine and manuka are scattered across fractured sandstone pavements as described by Dr Lloyd (para. 96). This presumably reflects the infertile and weathering-resistant nature of the underlying rocks, the very harsh climatic conditions (cool temperatures, high rainfall, frequent westerly gales and temperature inversions) and poor drainage; fire may have also had some influence. Small patches of forest occur in a few gullies (e.g., in Cypress Stream) and is composed of a diverse mix of low stature podocarps and broadleaved trees tolerant of infertile soils.

9.5. This broad regional pattern is complicated by the effects of disturbance, with the impacts of earthquake-related landsliding appearing to have played a major role in influencing both the stature and composition of many of these forests (e.g., Pearce & O'Loughlin 1985), including those of the Mokihinui. This has produced locally complex vegetation mosaics consisting of (i) lower stature scrub and shrubland (Group 1) on the most recently disturbed sites with exposed rock and/or mineral soils, (ii) low forest dominated by shrubs, treeferns and lower stature broadleaved trees (e.g., kamahi) on sites with less recent disturbance (as in Group 2), (iii) more advanced, taller-stature forest including some hard beech, generally on steep hill-slopes (as in Group 3), and (iv) taller forest on more stable toe slopes and terraces and flatter ridge crests, often with prominent emergent rimu and/or northern rata (as in Group 4).

9.6. Disturbance by fire appears to have played an important role in modifying vegetation occurring along the proposed transmission line route, with forest replaced over large areas by either (i) manuka-dominant scrub and shrubland with advance growth of forest species (Groups 11 & 12), or (ii) low-stature sedge-fernland dominated by species such as *Gleichenia*, *Baumea*, and *Gahnia*, again with invasion by forest species, particularly closer to the margins of taller vegetation. No quantitative data is available describing the composition of this latter community.

9.7. Results from this analysis indicate moderate similarities between the forests of the Mokihinui gorge and the Karamea gorge as indicated particularly by the occurrence of groups 2 & 3 in both locations. Note, however, that the fourth forest group that contains the greatest abundance of rimu, is not strongly represented in plots from the Heaphy gorge. By contrast, clear differences in composition are apparent between the forests of the lower to middle sections of the Mokihinui gorge that will be most affected by the MHP, and forest occurring above the forks. In particular, forests that will be inundated in the gorge are dominated generally by hard beech along with a diverse mix of podocarp and broadleaved tree species, while forests above the forks are much more floristically simple, and are mostly dominated by red, silver, and/or mountain beech. Such compositional differences are also described by Dr Payton (para. 3.5) and Dr K. Lloyd.

## 10. IMPACTS OF THE MHP ON THE VEGETATION OF THE MOHIKINUI RIVER AND ITS SURROUNDS

10.1. The most direct effect of the MHP on terrestrial values will result from the inundation of land in the gorge through the formation of an artificial reservoir; this will destroy all vegetation, including turfs, seepage zones, and forest, shrubland and scrub of varying successional stages across an area of approximately 300 ha, i.e., the area of the proposed reservoir (337 ha), less the area currently occupied by the river and its channel. A more detailed analysis of these losses is provided by Dr K Lloyd.

10.2. A detailed analysis of the significance of these values, including both the forests and the riparian zone, is presented by Dr Lloyd, whose evidence I defer to on these matters. In addition to his assessment that these values are highly significant, I note that the forest communities of the valley floor that will be affected within the gorge are generally more spatially heterogeneous than the mid to upper hill-slope forests that occur immediately upslope of them. This reflects the generally greater topographic diversity that occurs close to the valley floor, and the complex disturbance history to which these sites have been exposed. As a consequence, the valley floor contains a disproportionate representation of stands of rimu-dominant forest, and, to a lesser degree, forests containing northern rata. Dr O'Donnell presents evidence as to the high habitat value of these forests to fauna, including both the roosting value of tall forest stands, and the food value of early successional stands to frugivorous birds. Inundation caused by the MHP reservoir will therefore have a disproportionately greater impact on the more diverse and valuable forest ecosystems occurring in the gorge.

10.3. Construction of the proposed transmission line will result in a large number of small scale disturbances across an extensive area of ‘coal measure’ vegetation, including sandstone pavement ecosystems on the Stockton Plateau; recovery at these cleared sites is likely to be slow because of the infertile soils that prevail here, and this will increase the probability of weed invasion (evidence of Dr Lloyd, paras. Evidence presented both by Dr Lloyd and by Dr D. Norton emphasizes the very high conservation values of the sandstone pavement ecosystems at higher elevations, drawing particular attention to their irreplaceability, and the high levels of threat to which they are exposed by other human activities, both current and proposed. I support strongly Dr Norton's view that an alternative route should be found for the transmission line that leaves intact what is probably the best remaining example of this highly distinctive and threatened ecosystem.

## 11. SUMMARY OF BIOLOGICAL IMPACTS OF THE PROPOSED MHP

11.1. Based on the evidence presented above, the residual impacts of the MHP after mitigation can be summarized as affecting directly a range of biological values in both riverine and terrestrial ecosystems (Table 3).

Table 3. Summary of major impacts expected from the MHP.

| **Aquatic** | **Impacts** |
|---|---|
| Inundation of 22.88 km of river and stream length by the reservoir | Complete and irreversible destruction of existing biological values to be replaced by a 337 ha artificial reservoir with fluctuating water levels. |
| Obstruction of both upstream and downstream movement by migratory fish | 85 m high dam will result in high likelihood of marked reductions in native fish recruitment in 70% of the upstream catchment, given low feasibility of proposed mitigation of upstream movement and uncertainty about the safety of downstream movement of larval fish past the dam. |
| Alteration of downstream flow regime through greatly increased flow variability; risks of discharge of anoxic water from the hypolimnion | Changes in composition of both macro-invertebrate and fish assemblages highly likely given the greatly increased flow variability compared to the river in its natural state; potentially extreme stresses on biota imposed by periodic discharge of anoxic, chemical-laden water. |
| **Terrestrial** | **Impacts** |
| Direct inundation of a little less than 337 ha of forest, scrub and marginal turfs and associated fauna | Irreversible and complete destruction of all biological values; reduction in availability of roosting sites and seasonal food supplies for fauna. |
| Transmission line construction | Intensive point disturbance of highly distinctive and irreplaceable ‘coal-measure’ vegetation along the transmission route during construction, with likely slow recovery. |

11.2. Of the aquatic impacts, the irreversible destruction of river and stream segments by inundation is the most severe, but is relatively limited in geographic extent, resulting in the loss of approximately 2.2% of river and stream segments by length within the Mokihinui catchment.

11.3. By contrast, upstream impacts of the MHP by altering fish migration are more subtle but spatially pervasive. They are conservatively estimated to affect the majority (c. 70%) of the upstream catchment, given that (i) proposed actions to mitigate these impacts are highly likely to alter both the diversity and abundance of native fish species occurring in this catchment, and (ii) there are significant uncertainties around the ability of both larval fish and migrating adults to safely pass the dam during their downstream migration. This will profoundly impair arguably the most distinctive functional process of this river ecosystem, which will become entirely dependent on human intervention for its (partial) maintenance.

11.4. Impacts on biological values below the dam are more geographically restricted in extent, and their magnitude is difficult to predict with current information. Circumstantial evidence indicates that large biological changes are almost certain, given the degree to which artificially imposed changes in the frequency of high flows (daily or twice-daily) will exceed greatly natural patterns of daily flow variability currently occurring in the river; added risks are posed by the potential for discharge of anoxic and chemical-laden waters from the hypolimnion.

11.5. Together these three impacts constitute a profound and spatially pervasive compromising of the natural integrity of the Mokihinui catchment – this is reflected in a predicted decline in its conservation ranking among New Zealand's

77 large rivers from 14th to 44th place should the MHP proceed.

11.6. My assessment of these impacts ascribes to them a substantially greater magnitude than that identified by the applicant, whose witnesses generally fail to consider broader catchment-scale impacts of the MHP on ecosystem functioning. In particular, in my view evidence presented on behalf of the applicant (i) ignores independent and credible evidence as to the high likelihood that the greatly increased flow variability will significantly impact ecosystem values downstream of the dam (Mr Jowett, Dr James, Dr Suren, Mr Bonnett); and (ii) adopts an overly optimistic stance on the feasibility of maintaining an unproven trap and transfer method (Mr Bonnett) that is highly unlikely to maintain natural distribution patterns and movement of migratory fish above the dam.

11.7. Of the terrestrial impacts, the complete loss of terrestrial ecosystems in the 337 ha to be inundated is the most severe, as detailed by Dr K Lloyd. Forests within the affected area are of high ecological value, both for their botanical and faunal values, all of which will be irreversibly lost. While the disturbance that is likely to occur along the proposed transmission line is likely to be less severe in its effects, it will impact arguably the best example of one of New Zealand's most distinctive and irreplaceable ecosystems, which both here and elsewhere is exposed to very high levels of threat from human activities.

## 12. OFFSETTING PROPOSED BY THE APPLICANT

12.1. In reviewing the applicant’s offsetting proposals, I am aware of the complex legal and ecological arguments that exist around the differentiation between “offsets”, “mitigation” and “compensation”. My intention is to not engage in that debate, but rather to consider the degree to which actions proposed by the applicant lessen the net impacts of the MHP on the biodiversity values of this catchment and its surrounds.

12.2. As described above, the MHP proposal has three fundamental areas of impact on natural ecological values on the Mokihinui River and its surrounds; (i) on the river ecosystems both above and below the dam, (ii) on the terrestrial ecosystems that will be destroyed by inundation, and (iii) on the vegetation along the transmission line. I consider each of these in turn.

*Aquatic values*

12.3. In my view, and not withstanding the impacts on terrestrial ecological values that I discuss below, the most significant long term impacts of the MHP are on the riverine ecosystem values of the Mokihinui River. These include the direct destruction of river and stream segments by inundation, the disruption of linkages between marine and headwater environments through the impairment of natural migration by native fish species, and the less well quantified but likely significant impacts of the greatly increased flow variability (and possible discharge of anoxic and chemical-laden waters from the hypolimnion) on fish and macro-invertebrate species below the dam.

*Offsetting of loss of aquatic values*

12.4. No attempt has been made to offset the significant residual adverse effects of the MHP on freshwater values in the proposal presented by Dr Ussher, nor does he acknowledge the existence of these impacts in his calculations, other than to advance the curious proposition that offsetting cannot be applied in freshwater ecosystems. By contrast, I am of the view that (i) there is no fundamental difference between terrestrial and aquatic ecosystems that negates the applicability of offsetting principles and practice to freshwater environments; I note that several international examples of offsetting can be found for wetlands (e.g., Bendor 2009), and (ii) the descriptive framework for New Zealand's riverine ecosystems as provided in FENZ constitutes a far more robust and comprehensive framework within which to apply offsetting than the very coarse-scale forest mapping (FSMS 6 maps at 1:250,000 scale) used by Dr Ussher in his terrestrial offsetting proposal (Section 11.12).

12.5. If a realistic offset of aquatic impacts of the MHP were to be attempted, the catchment-based classification I presented in Section 6 combined with direct use of the segment-scale FENZ classification and integrity estimates, simplifies greatly the identification of river catchments and specific segments within them (high similarity to segments directly impacted in the Mokihinui and with low ecological integrity) that would benefit from restoration management as an offset to the negative impacts of the MHP. Elements of such an approach can also be seen in Mr N. Norton's evidence on freshwater values in which he uses the FENZ classification to identify other rivers having similar characteristics to those affected by the MHP. However, finding a suitable candidate site for such offset management is likely to be challenging given the distinctive combination of values that occurs in the Mokihinui gorge.

*Avoiding impacts along the transmission line route*

12.6. This is inherently difficult given the irreplaceability of the coal measure vegetation occurring along large parts of the transmission line route, and the high levels of threat that these communities are under from both current and proposed mining on the Stockton Plateau. I concur with the conclusion of Dr D Norton that avoidance of impact through relocation of this transmission line, rather than mitigation or offsetting of impacts along the currently proposed route, is highly desirable, given the irreplaceable nature of these rare and distinctive ecosystems.

*Forest offsetting proposal*

12.7. In my view the proposal to offset forest impacts presented by the applicant, while delivering some benefits for both vegetation communities and wildlife, has significant shortcomings for the following reasons:

(a) In my opinion the historic FSMS6 class mapping used by the applicant in their proposal is at too coarse a spatial scale (1:250,000) and is too lacking in classification detail to provide a robust basis for identifying a suitable offset area within the Mokihinui or its surrounds. Other relevant data that could have informed the selection of an offset area, including the forest plot data from the lower gorge and surrounds that Dr Lloyd, myself and others used, and the comprehensive descriptions of forest pattern in this region provided by Wardle (1984) appear to have been ignored.

(b) My vegetation analysis, together with evidence presented by Dr Lloyd, indicates distinct differences between the forests of the gorge that will be impacted by the MHP and those of the catchment above the Mokihinui Forks, including those that are proposed for intensive management. As a consequence, the applicant proposes to manage forests that, in general terms, differ significantly in composition from those in the area that will be inundated should the MHP proceed as proposed. This ignores the concept of representativeness, i.e., the values in the offset area cannot be regarded as a like-for-like replacement, and there will therefore be a net loss of at least some biodiversity components.

(c) The management regime proposed for the offset area by Mr Parkes is designed primarily around the periodic application of the toxin 1080 across an area of approximately 35,000 ha. Although some consideration is given to initial use of alternative techniques, such as trapping, the primary reliance on regular use of 1080 is likely to be less efficient than an approach that combines less frequent use of 1080 to control larger vertebrates (possums and deer) and rats during mast seed years, aerial and ground shooting to control goats, and more frequent and targeted trapping in selected locations to control predators with large home ranges, such as mustelids. This latter approach is also likely to have greater and more sustainable social acceptability. A more detailed critique of the proposed management regime is provided by Dr O'Donnell.

(d) Work proposed by the applicant is not entirely new as required under accepted offsetting principles, as existing control is already being carried out over part of the area by the Department of Conservation as described by Mr Farrell.

(e) **Waimangaroa Bush –** this later addition to the proposed offset contains a relatively small remnant of native forest on the sand plains north of Westport (described in detail by Dr K Lloyd), which is of undoubtedly high conservation value, given the extensive clearance of native vegetation that has occurred on this landform in the surrounding landscape. However, this forest is of fundamentally different ecological character to forests affected by the MHP in the lower Mokihinui gorge and along the proposed transmission line route, given the coastal landform on which it occurs and its at least partially altered composition and structure. In addition, management proposed by the applicant provides minimal additionality – the block is already well fenced with minimal stock ingress, it receives ongoing control of possums by the Animal Health Board, and mustelids are currently being controlled by the landowner. Last, the management proposed by the applicant fails to address the likely most significant threat to the long-term viability of this block, i.e., that posed by coastal erosion at the south-western end.

(f) Finally, in my view the significance of the work proposed in managing the forest ecosystems of the Mokihinui has been substantially overstated by the applicant’s witnesses. In particular, the management proposed by the applicant is very similar to that used in ecosystem management projects carried out both by the Department of Conservation and other agencies, and a number of these extend over similar or greater spatial extents, and/or are more ambitious in the intensity of their management. For example, the Department has regularly carried out similar extensive pest control operations using aerial and/or ground control techniques, including in the Catlins, on Secretary Island, in South Westland, the South Branch of the Hurunui, the Otira, Hawdon and Poulter valleys in Arthurs Pass National Park, the northern Te Urewera, and on Moehau (see also evidence presented by Dr O'Donnell). Similar work is being carried out by community groups, some of it on an impressive scale, e.g., at Maugatautari. While the extent of the management proposed by the applicant may be more spatially extensive than for some of these operations, size in itself is not necessarily beneficial, unless the area being managed contains ecological values that have been robustly assessed for their conservation value within a broader regional or national context – I could not find such an analysis within the evidence presented by the applicant’s witnesses.

*Overall performance of the proposed offset*

12.8. From a theoretical perspective, biodiversity offsetting can work well where there is a full and transparent inventory of the biodiversity losses incurred by a project, and a robust identification of sites with similar biodiversity values that can be managed to either recover their values or prevent future losses, giving overall gains that offset the development losses (e.g., Quétier & Lavorel 2011). When well constructed, such proposals have the potential to produce genuine win:win outcomes for both parties in conflicts between development and conservation.

12.9. Alternatively, as a recent review describes (Walker et al. 2009), offsetting when misapplied has considerable potential to deliver outcomes that produce a net loss for biodiversity. For example, the cost-benefit balance of a development offset can be manipulated either through the exclusion or understatement of the biodiversity losses of a project, or through the over-estimation of the biodiversity gains resulting from an offset; the latter can include the claiming of gains in non-related ecosystems. Given this risk, the key criteria used to assess the robustness of an offset proposal must include not only the technical nature of the offset calculations, but also a realistic appraisal of the degree to which choices about what inputs to use in the calculations accurately reflect both the true impacts of the biodiversity losses, and the relevance of the benefits to be delivered by the offset activities.

12.10. Given this context, in my view, the proposal presented on behalf of the applicant by Dr Ussher fails to provide a substantial and realistic offset of the residual impacts of MHP. To meet the generally accepted understanding of offsetting, this proposal requires substantial modification to (i) take a full and transparent account of the significant residual negative impacts of the MHP on aquatic ecosystem values of the Mokihinui River, with additional offset or mitigation activities that address those impacts, and (ii) fully consider the impacts of the transmission line on the highly irreplaceable ecosystems of the Ngakawau Ecological Area and Stockton Plateau. Furthermore the proposed offsetting of forest impacts is weakened by the coarse scale approach used to estimate ecological similarities and differences between the impacted and offset forests (and other vegetation types), and the relatively simplistic nature of the management regime that is proposed. In my opinion the modeling presented by Dr Ussher, however computationally sophisticated it might appear to be (see evidence presented by Dr Langford), does nothing to compensate for these fundamental omissions and shortcomings.

12.11. Finally, I have considerable difficulty with Dr Norton's assessment of the benefits of the MHP and BES on New Zealand's biodiversity. For example, his assertion that the MHP will have '*an overall net gain for biodiversity at a regional and national scale*' (para. 3.3) is in my opinion incorrect, given that it fails to consider the substantial adverse impacts of the MHP on the aquatic biodiversity and ecosystem functioning of the Mokihinui. I further disagree with his later proposition that the ecological values of the Mokihinui will continue to decline without the MHP, and that '*the MHP provides an opportunity to reverse this trend, which would not occur in the absence of this project*' (para 3.6). In my opinion, this analysis indicates not only an incomplete assessment of the full range of aquatic and terrestrial values that will be negatively impacted by the MHP, but also a lack of appreciation of initiatives currently underway within the Department to enhance and expand the systematic management of a full range of New Zealand's ecosystems, including those represented within the Mokihinui catchment and its surrounds.

## 13. CONCLUSIONS

13.1. From a systematic conservation planning perspective, the area affected by the MHP contains a highly diverse range of communities and environments with high levels of ecological integrity that are highly significant, given their contribution to the protection of a full range of the ecosystems that give New Zealand its distinctive natural character. The area exhibits very high geological diversity, including subalpine limestone, mudstones, greywacke, granite and infertile 'coal-measure' sandstones. Together these support a striking array of ecosystems, and within the Mokihinui catchment, are drained by one of New Zealand's least modified large rivers. This river is a notable example of a system that is dominated by New Zealand's distinctive migratory fish, thirteen species of which occur here. Human-induced impacts on this fauna are limited over most of the catchment to competition from introduced brown trout.

13.2. Construction of the MHP would have a profound negative impact on these values and their significance for the conservation of biodiversity, both aquatic and terrestrial.

13.3. Aquatic impacts are perhaps the most serious and spatially pervasive, given the inundation of the gorge, and expected impacts on the movement of migratory fish into the upper catchment that can be only partially mitigated; additional negative impacts will result from the greatly increased flow variability downstream of the dam. Terrestrial impacts include both the complete loss of forests and marginal turfs through inundation, and more diffuse impacts caused by construction of the transmission line across two of New Zealand's most distinctive and irreplaceable ecosystems, 'coal-measure' forests and sandstone pavements.

13.4. Measures proposed by the applicant to offset these impacts in my view fall far short of accepted international principles for offsetting. However, even if these measures were very substantially modified, in my view it is highly unlikely that requirements for 'no net loss' could be realistically achieved.

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# Appendix I.

## Technical description of the classification used to group together New Zealand's rivers at a catchment scale

1.1 To provide a broader context within which to consider the conservation values of the Mokihinui River than that provided by existing segment-scale river classifications (REC – Snelder & Biggs 2002; FENZ – Leathwick et al. 2008) I developed a catchment-scale classification of New Zealand rivers as follows:

(a) First, I matched all river segments contained within the FENZ river classification database (based on the REC river network layer), against polygons that delineate river catchment boundaries for New Zealand (also based on the REC database). The resulting set of data indicates for each of 565,031 river segments, its length in metres, the catchment in which it belongs, and its membership in the FENZ Level IV (300 group) classification.

(b) The FENZ classification used in this analysis was developed as a multivariate equivalent to the earlier rule-based River Environment Classification, with the explicit intent of defining a classification with greater ability to distinguish biological variation in New Zealand's rivers (a detailed description is contained in Leathwick et al. 2011). It was constructed using a statistical approach that uses extensive biological datasets (fish and macro-invertebrates) to objectively guide the selection, transformation and weighting of the environmental variables used to define the classification. This results in a classification that is tuned to maximise its ability to discriminate variation in biological characteristics of rivers.

(c) An important additional feature of the FENZ river classification is its relative insensitivity to human impacts on New Zealand's rivers. Human impacts variables *were* included when analysing relationships between the biological and environmental datasets, this being required because so many of the species samples came from environments with a high level of human modification. However, these human impacts variables were excluded when the classification was constructed, so that the resulting groups are formed using just the natural physical drivers of biological variation across our rivers.

(d) The linked dataset containing classification information for all segments was then imported into the statistical analysis environment, R (R Development Core Team 2010). Here, I used the data to construct a large matrix with one row for each catchment and one column for each FENZ environment – cell values indicated the length of each classification group occurring in each catchment. I then standardised each column by dividing all of its values by the maximum value occurring for that environment across all catchments, so that all river classification groups have an approximately equal contribution to classification outcomes. Finally, I classified this matrix to group together river catchments having similar mixtures of segment-scale classification groups, i.e., river catchments placed in the same group will tend to contain segments with similar mixes of river environments, while those in contrasting groups will contain different mixes of river environments. I performed this classification using the Bray-Curtis measure of compositional distance using a group average agglomerative clustering routine contained in R (‘agnes’ from the package ‘cluster’). This combination of distance measure (Bray-Curtis) and standardisation (attributes divided by their column maximum) was one of the highest performing options in an extensive test of clustering methods for ecological data performed by Faith, Minchin & Belbin (1987).

(e) Because classifications such as this can be viewed at widely varying levels of detail, I exported a reduced dataset describing for each catchment, its membership in the catchment classification at varying levels of classification detail (50, 75, 100 and 120 groups). I then imported this file into ArcMap, joining it to the catchment spatial data layer to allow classification results to be inspected visually. Based on this inspection, I chose two levels of classification detail, 50-groups and 120 groups, these providing an informative picture of ecosystem similarities between the Mokihinui River and other New Zealand rivers at national and regional scales respectively.

# APPENDIX II.

## Details of the method used to predict diadromous occurrence through the Mokihinui catchment

1.1 To estimate the spatial extent of the residual impacts of the MHP on migratory fish above the reservoir I drew on datasets and statistical modelling skills developed during several analyses I performed of relationships between the national-scale geographic distributions of native fish species and environment using extensive sets of sampling data from rivers and streams throughout New Zealand (Leathwick et al. 2005, Leathwick et al. 2008, Leathwick et al. 2009). This work was carried out over a period of approximately five years while I was employed at NIWA, during which my work was supported by interaction with a broad array of NIWA staff.

2.1 I predicted potential impacts of the MHP upstream of the planned reservoir using a statistical model that describes relationships between the capture of native migratory fish species and the physical environment using a set of 13,363 observations from the New Zealand Freshwater Fish Database (= the training data). This model predicts the probability of capturing one of more migratory fish species at each sample site, given its environmental conditions. The environment at each site was described using a set of 23 functionally-based predictors describing environmental conditions at the sample site (e.g., river flow and gradient), in the upstream catchment (e.g., catchment slope and natural cover), and between the sample site and the coast (distance and maximum downstream slope) (Leathwick et al. 2008).

3.1 This model was fitted using a newly developed statistical modelling tool, Boosted Regression Trees (Friedman 2002), which was developed within the machine learning community. It has become increasingly used in ecological analyses (Elith, Leathwick & Hastie 2008), and gives significant gains in performance compared to conventional multiple regression approaches (e.g., Leathwick et al. 2006). Such models provide a powerful tool when fitted to large training data sets, as they can then be used to make predictions to new locations for which equivalent predictors are available. In this case, I made predictions to a set of equivalent environmental data for all river segments in the Mokihinui catchment (= the prediction data). However, care is required when implementing such an approach for two reasons.

4.1 First, if prediction of some response (in this case probability of fish capture) is required at new sites, model complexity, i.e., numbers of terms to include in the model, is best specified using a procedure that maximises the power of the model when predicting to new sites (Hastie, Tibshirani & Friedman 2001); by contrast, the more conventional approach is to set model complexity based on ability to explain variation in the training data. If the latter approach is used to build a model primarily used for prediction, there is a high likelihood that terms will be included that are relevant only to the training data observations, and that these will degrade predictive performance at the new sites for which predictions are required (Hastie, Tibshirani & Friedman 2001, p. 193 ff.).

5.1 Second, when predicting to new sites, estimates of the predictive power of the statistical model cannot be reliably assessed by measuring its ability to summarise variation within the training data. This is because evaluations of model performance based on the training data will generally over-estimate performance when predicting to the prediction data. These predictive approaches are therefore most effective when (i) the statistical model is explicitly tuned to maximise its predictive performance to new sites, e.g., using cross-validation, and (ii) appropriate methods such as bootstrap re-sampling are used to estimate predictive uncertainties at new sites.

6.1 To accommodate these requirements, I determined the required level of complexity in my model of probabilities of migratory fish capture using 10-fold cross validation as described in Hastie, Tibshirani & Friedman (2001, p. 214 ff.). In this procedure 10 mutually exclusive and randomly selected subsets were identified in the training data, each containing 10% of the total observations (Elith, Leathwick & Hastie 2008). Ten models were then fitted to ten temporary datasets, each containing 90% of the observations from the training data, i.e., with one of the ten subsets omitted. Each model was made progressively more complex, with the predictive performance assessed on the with-held subset of data at each step; average performance when predicting to the withheld data subsets was assessed at each step. This typically results in a rapid initial improvement in predictive performance as model complexity increases, reaching a maximum and then declining as the models become over-fitted, i.e., as they include terms that explain observations occurring in the training data, but which degrade performance when predicting to the prediction data. At this point, the process was stopped, and a final model was fitted to the entire training dataset using the level of model complexity that maximises predictive performance.

7.1 Finally, I used boostrap resampling to provide individual estimates of the predictive error at each of the individual river segments within the Mokihinui catchment. I implemented this by taking 500 bootstrap samples of the training dataset, each consisting of 13,336 observations sampled at random *with replacement* (Hastie, Tibshirani & Friedman 2001, p. 225 ff.), and each *on average* containing 63.2% of the observations from the full dataset. I then fitted a new model to each of these samples, using each of these models to make predictions to those observations that were omitted from each sample. I then used these multiple estimates for each segment to calculate both the mean predicted probability of capture of one or more native migratory fish species (the mean of the bootstrap predictions), and 95% confidence intervals around this mean.

**Model specifics and results**

8.1 The model used to predict native migratory fish occurrence used a 0/1 response variable, with 1s indicating sites where one or more such species were captured in samples, and 0s indicating where no migratory fish species were captured.

9.1 The model used 23 predictors, i.e., *SegSumT, SegTSeas*, *SegLowFlow*, *SegFlowStability*, *SegShade*, *SegSlope*, *SegN*, *DSDist*, *DSAvgSlope*, *DSMaxSlope*, *DSDam*, *USAvgT*, *USRainDays*, *USSlope*, *USNative*, *USCalcium*, *USHardness*, *USPhosphorus*, *USPeat*, *USLake*, *USGlacier*, *SimpMethod* and *Effort*. Details of all variables are provided in Leathwick et al. (2008), with the exception of *Effort* – this variable describes the length of river segment that was fished at each sample.

10.1 The model was fitted using the 'gbm' library within R, using a tree complexity of 5, a learning rate of 0.05, and with a Bernoulli (=binomial) error term – see Elith, Leathwick & Hastie (2008) for details. Cross validation indicated that maximum predictive performance is achieved using 1600 trees. The mean null deviance for the final model fitted using this degree of complexity was 1.186, and the residual mean deviance was 0.431 as assessed on the training data, and 0.652 when assessed on prediction data; the larger value for this latter estimate clearly demonstrates the overly optimistic nature of performance estimates that are based on training data. Similarly, the correlation between the actual and predicted values was 0.840 when assessed using the training data and 0.711 when assessed using the prediction data. The latter value indicates a high level of performance when predicting to new sites. The four most important predictors were *DSDist*, *SegJanT*, *DSMaxSlope*, and *USRainDays*.

11.1 The mean predicted probability of capture for all river and stream segments upstream of the proposed dam, based on predictions made from models fitted to 500 bootstrap samples, is 0.864; estimated 95% confidence limits around this mean are 0.633 to 0.961.

## Appendix III

## Analysis of vegetation plot data from the Mokihinui River and surrounds.

1.1 My analysis of vegetation patterns in the Mokihinui catchment and its surrounds used data from 234 plots, each consisting of a 20 by 20 m plot or quadrat, and extracted from Landcare Research's National Indigenous Vegetation Survey Databank (NIVS). This included plots distributed from the Heaphy River south to the Denniston Plateau, sampling (i) the lower Heaphy and along the coast south to Kohaihai Bluff, (ii) the lower Karamea, (iii) the Mokihinui both in its lower gorge, and in the North Branch above the forks, and (iv) along the approximate line of the proposed transmission line in the Ngakawau Ecological Area and across into the head of the Waimangaroa catchment.

2.1 I imported the plot data into R, where I used the individual tree diameter measurements to calculate basal areas in $m^2$ per ha. After editing out a small number of species of dubious integrity, I created a plot (234 rows) by species (99 columns) matrix, cell values consisting of the summed basal area for each species in each plot. The 10 most abundant species in decreasing order of abundance were kamahi (*Weinmannia racemosa*) – 9.45 $m^2$ $ha^{-1}$, silver beech (*Nothofagus menziesii*) – 4.58, red beech (*N. fusca*) – 2.60, wheki (*Dicksonia squarrosa*) – 2.23, kanono (*Coprosma grandifolia*) – 2.21, *Cyathea smithii* – 1.99, hard beech (*N. truncata*) – 1.67, *Quintinia acutifolia* – 1.72, pepperleaf (*Pseudowintera colorata*) – 1.25 and toro

(*Myrsine salicina*) – 1.23. The mean total basal area per plot was 45.8 $m^2$ $ha^{-1}$ with a range from 0.216 to 185.0 $m^2$ $ha^{-1}$.

3.1 I then performed a clustering in which I first standardised all species values by species maximum, i.e, differences in gross abundance between species are evened out by converting all values in each column to a proportion of their maximum. To put it another way, all species columns shared the same maximum value of ‘1’ after the standardisation, approximately equalising their contribution to classification outcomes (Faith et al. 1987). I then used the Bray-Curtis distance measure (which is insensitive to 0-0 matches) and group-average clustering. Results indicate a lot of noise in the data, e.g., at a 25-group level of classification, eight of the groups have only one or two plots, and only twelve groups have five or more plots (Table 1). These latter groups, reordered approximately by elevation, are as follows:

(a) Group 1 – scrub and low forest dominated by tutu and putaputaweta – 6 plots – relatively low basal area indicates recent disturbance; contains a wide range of other early successional species and occurs predominantly along the Mokihinui gorge on sites with recent instability; one occurrence in Mokihinui North Branch;

(b) Group 2 – low forest dominated by kamahi, tree-ferns and kanono – 41 plots – diverse range of other early successional species or species typical of disturbed or forest margin sites, including  mahoe, kowhai, pigeonwood and putaputaweta,  Widespread in both the Mokihinui and Karamea gorges, mostly in close proximity to the river, also occurring in the upper Mokihinui, and the lower reaches of the Heaphy River.

(c) Group 3 – forest dominated by kanono, kamahi, mahoe, broadleaf and wheki, with some hard beech – 20 plots – other species include northern rata, putaputaweta and wineberry. Similar distribution to the previous group.

(d) Group 4 – forest dominated by wheki, kamahi, toro and quinitinia with scattered large emergent rimu – 19 plots. Occurs predominantly in the lower to middle sections of the Mokihinui Gorge, but three plots occur in the Heaphy Gorge, and a further four in the Mokihinui North Branch – however, rimu is less abundant at these latter four sites than in the lower elevation plots in the lower gorge.

(e) Group 5 – forest dominated by kamahi, hard beech and quinitinia, with some red and silver beech – 36 plots – other species include mingimingi, broadleaf and toro. Occurs predominantly in the upper Mokihinui (17 plots), but also occurs in the lower Mokihinui (4) and Heaphy gorges (7) – other occurrences in the lower Heaphy River and along the coast south of its mouth.

(f) Group 6 – forest dominated by kamahi and toro, with small amounts of red, hard and silver beech – 5 plots – occurs mostly on midslopes, with three plots along the Charming Creek Road, and one on the coast just south of the Heaphy River.

(g) Group 7 – forest dominated by silver beech and red beech with abundant kamahi – 21 plots – other species include putputaweta, *Coprosma propinqua* and *Myrsine divaricata* – occurs predominantly in the

North Branch of the Mokihinui (14 plots), but with four occurrences in the Heaphy River, and one each in the Heaphy, lower Mokihinui, and Waimangaroa Rivers.

(h) Group 8 – forest with a canopy dominated by silver beech with some red beech – 14 plots – understorey is dominated by pepper-leaf, *Myrsine divaricata*, *Neomyrtus*, lancewood and broadleaf – occurs predominantly in the upper Mokihinui but with one plot in the Karamea.

(i) Group 9 – forest dominated by mountain beech and pink pine with some silver beech – 5 plots – occurs at high elevations in the upper Mokihinui;

(j) Group 10 – forest of low to medium stature dominated by *Dracophyllum traversii*, *Archeria traversii*, silver and mountain beech, *Coprosma pseudocuneata*, and mountain toatoa – 15 plots – with the exception of one plot adjacent to the Ngakawau River, just upstream from its junction with Charming Creek, this group occurs almost exclusively in the upper Mokihinui, mostly at higher elevations.

(k) Group 11 – low stature forest and scrub dominated by manuka and yellow-silver pine along with some rimu, mountain toatoa, and kamahi – 13 plots – occurs mostly along the transmission line route between Seddonville and the Ngakawau River, but also at three scattered riverine sites in the upper Mokihinui.

(l) Group 12 – manuka scrub with low basal area – 5 plots – other species include yellow-silver pine, mountain beech, southern rata, kamahi, lancewood, rimu – occurs along the transmission line route (3 plots) and in the Mokihinui North Branch;

Table 1. Species composition of twelve groups containing five or more plots. Species are included if their average basal area across all groups exceeds 1 $m^{-2}$ $ha^{-1}$, or if their basal area in any one group exceeds 5 $m^{-2}$ $ha^{-1}$.

| | | **1. Tutu-putaputaweta scrub** | **2. Kamahi-treefern-kanono forest** | **3. Kanono-kamahi-mahoe-broadleaf-treefern forest** | **4. Wheki-kamahi-toro-quintinia-rimu forest** | **5. Kamahi-hard beech-quintinia forest** | **6. Kamahi-toro-mixed beech forest** | **7. Silver beech-red beech forest** | **8. Silver beech forest** | **9. Mountain beech-pink pine forest** | **10. Mixed coal-measure forest** | **11. Manuka-yellow-silver pine scrub and low forest** | **12. Manuka scrub** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | No. of plots | 6 | 41 | 20 | 19 | 36 | 5 | 21 | 14 | 5 | 15 | 13 | 5 |
| *Melicytus ramiflorus* | mahoe | 0.2 | 1.5 | 3.9 | 0.1 | 0.0 | - | 0.0 | - | - | - | - | - |
| *Hedycarya arborea* | pigeonwood | - | 1.0 | 0.2 | 0.1 | 0.0 | - | 0.0 | - | - | - | - | - |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Metrosideros robusta* | northern rata | - | 0.0 | 1.5 | 0.0 | 0.1 | 0.0 | - | - | - | - | - | - |
| *Sophora microphylla* | kowhai | - | 1.6 | - | - | - | - | - | - | - | - | - | - |
| *Coriaria arborea* | tutu | 7.7 | 0.0 | 1.4 | - | 0.0 | - | 0.0 | 0.0 | - | - | - | - |
| *Coprosma grandifolia* | kanono | 0.8 | 3.7 | 15.6 | 0.7 | 0.5 | 0.0 | 0.1 | 0.0 | - | - | 0.0 | - |
| *Leucopogon fasciculatus* | mingimingi | - | 0.2 | 0.2 | 0.1 | 1.4 | 0.1 | 0.0 | 0.0 | - | - | 0.0 | - |
| *Dicksonia squarrosa* | wheki | - | 3.6 | 3.1 | 15.8 | 0.1 | - | 0.0 | 0.0 | - | - | - | - |
| *Myrsine salicina* | toro | - | 1.6 | 0.7 | 6.6 | 1.0 | 6.8 | 0.0 | - | - | - | 0.0 | - |
| *Cyathea smithii* | | 0.1 | 9.4 | 0.5 | 1.0 | 0.2 | 0.1 | 1.0 | 0.2 | - | - | 0.0 | - |
| *Metrosideros umbellata* | southern rata | 0.0 | 0.1 | 0.1 | 0.1 | 0.5 | 1.5 | 0.1 | 0.0 | - | 0.0 | 0.1 | 0.0 |
| *Weinmannia racemosa* | kamahi | 0.4 | 9.7 | 10.3 | 14.8 | 25.3 | 9.7 | 6.3 | 4.0 | 0.3 | 0.6 | 1.8 | 0.0 |
| *Coprosma tenuicaulis* | | - | 0.1 | - | 1.1 | - | 3.2 | - | - | - | - | 0.0 | - |
| *Nothofagus truncata* | hard beech | - | 0.6 | 2.3 | 0.9 | 7.0 | 2.2 | 0.0 | 0.7 | - | 0.0 | 0.2 | - |
| *Griselinia littoralis* | broadleaf | 0.5 | 0.7 | 3.3 | 0.1 | 1.0 | 0.7 | 0.2 | 2.1 | 0.1 | 0.1 | 0.0 | - |
| *Dracophyllum elegantissimum* s.*venter* | | - | 0.0 | 0.0 | 2.6 | 0.9 | 0.5 | - | - | - | 0.2 | 0.1 | - |
| *Neomyrtus pedunculata* | | - | 0.3 | 2.0 | 1.4 | 1.2 | 0.8 | 0.1 | 5.0 | - | 0.4 | 0.1 | - |
| *Coprosma rugosa* | | - | 0.0 | 0.0 | - | 0.1 | - | - | - | - | - | - | - |
| *Carpodetus serratus* | putaputaweta | 1.1 | 3.5 | 1.6 | 0.2 | 0.1 | 0.5 | 1.3 | 1.1 | 0.0 | 0.0 | 0.0 | - |
| *Quintinia acutifolia* | | - | 0.6 | 0.6 | 4.1 | 6.2 | 0.2 | 0.2 | 0.7 | - | 0.3 | 0.2 | - |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aristotelia serrata* | wineberry | 0.6 | 0.1 | 1.4 | - | - | - | 0.1 | 0.0 | - | - | - | - |
| *Nothofagus fusca* | red beech | 0.2 | 0.4 | 0.4 | 0.4 | 2.5 | 2.1 | 16.6 | 4.6 | 0.3 | 0.4 | - | - |
| *Pseudopanax crassifolius* | lancewood | 0.0 | 0.2 | 0.1 | 0.8 | 0.1 | 0.1 | 0.2 | 4.6 | - | 0.0 | 0.1 | 0.0 |
| *Coprosma tayloriae* A.P.Druce | | - | 0.7 | 0.0 | 0.0 | 0.1 | 0.2 | 0.1 | 2.0 | - | 0.6 | 0.0 | - |
| *Hebe salicifolia* | | 0.6 | 0.1 | 0.7 | - | - | 0.1 | 0.3 | 0.0 | - | 0.0 | - | - |
| *Pseudowintera colorata* | pepperleaf | - | 0.3 | 0.0 | - | 0.4 | 0.1 | 0.7 | 16.7 | 0.1 | 0.5 | - | - |
| *Nothofagus menziesii* | silver beech | 0.0 | 1.5 | 0.4 | 0.8 | 1.6 | 2.2 | 24.9 | 11.6 | 4.1 | 8.0 | 0.2 | - |
| *Pittosporum tenuifolium* | kohuhu | - | - | - | - | - | - | 0.0 | - | - | 0.0 | - | - |
| *Dacrydium cupressinum* | rimu | - | 0.5 | 0.1 | 3.9 | 0.6 | 1.1 | 0.2 | 0.4 | - | - | 4.0 | 0.0 |
| *Coprosma linariifolia* | | - | 0.1 | - | - | - | - | 0.0 | 0.8 | - | - | - | - |
| *Coprosma propinqua* | | 0.3 | 0.2 | 0.2 | - | 0.0 | 0.3 | 1.3 | 0.0 | - | 0.4 | - | - |
| *Raukaua simplex* | | - | 0.0 | - | - | 0.1 | - | 0.0 | 0.0 | 0.0 | 0.1 | - | - |
| *Olearia avicenniifolia* | | 0.6 | 0.0 | 0.0 | - | - | - | 0.1 | - | - | - | - | - |
| *Myrsine divaricata* | | - | - | - | - | 0.0 | 0.0 | 1.5 | 7.3 | 0.0 | 2.4 | 0.0 | - |
| *Hoheria sexstylosa* | | 0.0 | 0.0 | - | - | - | - | 0.0 | 0.3 | - | - | - | - |
| *Coprosma foetidissima* | | - | 0.2 | 0.7 | 0.2 | 0.8 | 0.5 | 0.1 | 0.4 | 0.0 | 0.0 | 0.0 | - |
| *Dracophyllum townsonii* | | - | - | - | 0.0 | - | - | - | - | - | - | - | - |
| *Phyllocladus alpinus* | mountain toatoa | - | 0.0 | 0.0 | 0.3 | 1.0 | 0.4 | 0.0 | 0.0 | 0.1 | 3.0 | 1.4 | - |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Dracophyllum traversii* | | - | - | 0.0 | - | 0.2 | 0.1 | 0.9 | 0.6 | 1.0 | 12.4 | - | - |
| *Halocarpus biformis* | pink pine | - | - | - | 0.0 | - | - | 0.0 | - | 16.4 | 1.3 | 0.0 | 0.0 |
| *Archeria traversii* | | - | - | 0.0 | - | 0.4 | - | 0.0 | 0.0 | 0.6 | 9.9 | - | - |
| *Coprosma pseudocuneata* | | - | - | - | - | 0.0 | - | 0.0 | 0.4 | 0.0 | 3.1 | - | - |
| *Nothofagus solandri* var. *cliffortioides* | mountain beech | - | 0.0 | - | 0.1 | 0.0 | 1.5 | 0.9 | 0.0 | 22.7 | 4.3 | 1.0 | 0.0 |
| *Lepidothamnus intermedius* | yellow-silver pine | - | 0.1 | 0.1 | 0.1 | 1.0 | 0.7 | - | - | - | 0.1 | 9.0 | 0.1 |
| *Leptospermum scoparium* | manuka | - | 0.0 | - | 0.3 | - | 0.1 | 0.0 | - | - | 0.4 | 14.0 | 0.2 |
| *Dracophyllum longifolium* | | - | 0.0 | - | - | - | - | 0.0 | - | 0.1 | 1.1 | 0.9 | 0.0 |
| | | | | | | | | | | | | | |
| Total basal area ($m^2$ $ha^{-1}$) | | 13.23 | 42.54 | 51.43 | 56.36 | 54.40 | 35.88 | 57.35 | 63.61 | 45.88 | 49.56 | 33.22 | 0.39 |