**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
**PAUL WORTHING WILLIAMS**
FOR DIRECTOR-GENERAL OF CONSERVATION
Dated: 13 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 Paul Worthing Williams

1.2. I hold PhD and ScD degrees from the University of Cambridge. I am a Senior Fellow of the International Association of Geomorphologists; a member of the Geoscience Society of New Zealand (formerly the Geological Society of New Zealand); a member (and former Chair) of the Australian and New Zealand Geomorphology Group; and a member of the World Commission for Protected Areas. Since 1972 I have been employed by the University of Auckland as a Professor in the School of Environment.

1.3. My professional expertise is in geomorphology and hydrology. I have taught, researched and examined geomorphology and hydrology to doctoral level; I have co-authored and edited three books in these fields and have published almost 100 refereed scientific papers and book chapters; I serve or have served on the editorial boards of four international scientific journals concerned with geomorphology and hydrology.

1.4. I am familiar with the geomorphology of New Zealand, in general, and have recently written an account of the evolution of the mountains of New Zealand (Williams 2004). I am currently writing a book on the geomorphology of New Zealand. This partly draws on personal knowledge of northwest South Island, where I have walked extensively and have engaged in field research and teaching.

1.5. I am a member of the World Commission for Protected Areas and frequently act as a formal reviewer for IUCN of nominations for inscription of natural properties on the World Heritage List. I have also advised several State Parties regarding the suitability of potential properties for World Heritage nomination.

1.6. In preparing this evidence I have reviewed the literature noted in the References and in particular have reviewed the statements of evidence in chief provided by: Stephen Brown, Murray Gillon, Roderick Henderson, Murray Hicks, Ian Jowett, Gavin Lister, Mark Mabin, Ian Payton, Peter Rough and Royden Thomson.

1.7. I have participated in a helicopter survey of the Mokihunui and neighbouring Ngakawau catchments. This included overviews of distal tributaries in the Matiri Range, Glasgow Range, Radiant Range and Allen Range and close aerial overviews of the Ngakawau Gorge, Mokihinui Gorge and proposed dam site. I have also walked the entire length of the gorge and have made geomorphological observations en route.

1.8. I have read the Environment Court's Code of Conduct for Expert Witnesses, and I agree to comply with it. I confirm that the issues addressed in this brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed. I have indicated where my opinion is partly based on other sources of information.

## 2. SCOPE OF EVIDENCE

2.1. The evidence presented here relates to the general geomorphology of the Mokihinui catchment and the likely impacts on that geomorphology of the proposed Mokihinui Hydro Project (MHP). It specifically excludes consideration of the transmission corridor and detailed consideration of fluvial and coastal geomorphology, including sediment transport and deposition in the river. These topics are dealt with separately by other witnesses.

2.2. In terms of the ‘Pigeon Bay’ factors, my focus is on natural science considerations, the formative natural processes and the value of the natural landscape from an earth science perspective.

2.3. In terms of the West Coast Regional Policy Statement, the evidence provided here is relevant to Policy 9.1, which concerns preservation of the natural character of the West Coast’s wetlands, lakes and rivers and their margins, because it provides information that can be used to judge whether or not the proposed development of the Mokihinui dam and reservoir is an appropriate or inappropriate use of the river and its gorge.

2.4. I shall address a series of questions:

(i) What is the geological and geomorphological context of the Mokihinui catchment, including its gorge?

(ii) Does the Mokihinui catchment, including its gorge, have any rare or important geomorphic attributes?

(iii) What is the geomorphological significance of the Mokihinui Gorge and its landform features?

(iv) Will the MHP proposal have significant effects on landforms, geomorphological processes or geomorphological values in the Mokihinui catchment, including its gorge?

(v) Can any adverse effects of the MHP on landforms, geomorphological processes or geomorphological values in the Mokihinui catchment, including its gorge, be appropriately avoided, remedied or mitigated?

## 3. EXPLANATION OF TERMS

3.1. Information presented here will be prefaced by explanations of terms used (in italics) in order to clarify their meaning and avoid possible misunderstanding.

3.2. *Geomorphology* is the scientific study of landforms and the processes which produce them. The central focus of the subject is the comprehension of the form of the ground surface, its history, the processes which have moulded it, and the nature and rate of present on-going processes. Sub-fields include the study of rivers (fluvial geomorphology), coasts (coastal geomorphology), glaciated landscapes (glacial geomorphology), landscape evolution (historical geomorphology), etc.

3.3. A *natural landscape* is made up of individual *landforms* (such as hills, valleys, river channels, glacial cirques and beaches) that together constitute the *physical landscape* and, when climatic conditions permit, the soil and vegetation that covers it. Geomorphology is concerned with the nature and history of physical landscapes over geological time, including superficial deposits, but does not study the vegetation except for its effects on geomorphological processes (such as weathering).

3.4. The term *gorge* is not well defined in the literature, as is evident from the entry in Goudie (2004) Encyclopedia of Geomorphology. It is a word with common usage rather than a strictly scientific term; so the Oxford Dictionary definition of gorge as a "narrow opening between hills" is acceptable but rather general. More helpful in the present context are terms which refer to the origin of gorges:

> an *antecedent gorge* is one that developed as a result of a pre-existing river maintaining its course by incision across actively uplifting rocks;
>
> a *superimposed gorge* is one formed where a river flowing on weaker cover beds is lowered onto and incises underlying more resistant rocks.

3.5. In geomorphological and hydrological usage the terms river *catchment* and river *basin* are often used interchangeably; hence the Mokihinui catchment is the same as the Mokihinui basin (here river basin being taken as understood). However, the word basin can also sometimes be qualified as, for example, inland basin, where it refers to a topographic feature of unspecified origin or function.

3.6. I consider the Encyclopedia of Geomorphology (2 vols), edited by Goudie (2004), to be the most authoritative and useful reference for the explanation of terms used in geomorphology.

# 4. KEY FACTS AND OPINIONS

4.1. The Mokihinui catchment provides a superb example of the way river basins have evolved in this region of New Zealand; on a block of Fiordland rocks that has been translocated to northwest South Island and in the process has been compressed, uplifted and dissected. One can find a few comparable chapters of this history elsewhere in the region, especially in the Buller catchment, but the Mokihinui is special because it so clearly demonstrates the story.

4.2. The Mokihinui River system is the legacy of processes that extend back tens of millions of years and the Mokihinui Gorge will have developed within the last few million years as the Glasgow and Radiant Ranges rose across its path.

4.3. Evidence within the Mokihinui Gorge clearly shows the dynamic nature of fluvial processes, including rock scour, rounding and sorting of river boulders and pebbles, fluvial sedimentation and flood water deposition, all set in the context of a confined bedrock channel with a sequence of pools and rapids and tributary junctions. The gorge provides a text book example of fluvial processes at work in a tectonically uplifting landscape.

4.4. As an antecedent gorge, the Mokihinui Gorge is not unique in the region, but is nevertheless one of the best examples of an antecedent gorge in the Buller District.

4.5. With the upgrade of the track and the new hut at Specimen Creek, the gorge would be a perfect and accessible place to bring groups of students to demonstrate in a dramatic way the nature of slope processes, the work of rivers and the way these processes interact.

4.6. The proposed MHP would be located in an unusual river system of considerable antiquity and scientific significance.

4.7. The most significant geomorphological effect of the proposed MHP impoundment is that it will totally alter natural processes in the lower Mokihinui catchment by drowning the channel near the outlet of the system. This will prevent the throughput of sediment and eliminate the rapid flow of water and, as a consequence, shut down channel-forming processes and on-going incision of the gorge.

4.8. Although the MHP inundation would involve only a few percent of the depth of the Mokihinui Gorge, it occurs in a critical place – in the main transportation corridor: the centre of action of gorge forming processes. It will reverse processes in the gorge from one of erosion and sediment transportation to that of sediment entrapment and accumulation. The MHP would therefore have a profound geomorphic impact.

4.9. The sedimentation effect of the proposed MHP impoundment would eventually extend upstream beyond the limits on the Mokihinui reservoir into the intermontane basin in the vicinity of the Forks.

4.10. Attempts to argue that the effect of the proposed dam would be minor, because it would look like a natural landslip-dammed lake are misplaced. This is a poor argument because the similarity holds only when the dam is not in view and only for a relatively short time. While there are some similarities, such as delta building and drowned trees, the landscape change (geomorphic development), evolving visual appearance over time and hydrological processes operating in a man-made reservoir are generally distinctly different to the processes and sequence of events in a natural impoundment, mainly because a natural dam is broad, permeable and lowers (or is skirted around) over time. Whereas a natural landslide dammed lake undergoes a sequence of filling and emptying and the river gets practically back to normal (the time depending on the size of the slip and the lake), a dam-impounded reservoir lake will not undergo that process except over a very long time. It will immediately stop the fluvial downcutting and reverse the natural process to a relatively long-term state of sediment accumulation with no change to the lake level and impoundment. Unlike a natural dam which is broad, rocky and becomes vegetated, an artificial dam is slim, high, and bare. For the above reasons, it is simplistic and inaccurate to suggest that man-made dams and their reservoirs are similar to landslide-dams and their lakes.

4.11. I cannot identify any way in which adverse effects of the proposed MHP impoundment on the geomorphology of the Mokihinui Gorge might be remedied or mitigated; they can only be avoided by not building the dam.

## 5. THE GEOMORPHIC ENVIRONMENT OF MOKIHINUI

**What is the geological and geomorphological context of the Mokihinui Gorge and its catchment?**

5.1. The Mokihinui River basin in northwest South Island occupies an area of almost 750 km² (685 km² upstream of Burke Creek near Seddonville). The geology of the region is described by Rattenbury et al. (1998) and Nathan et al. (2002). The rocks in the area are similar to those found in Fiordland, because the region fractured from Fiordland along the line of the Alpine Fault (but on the opposite side of the fracture to Fiordland) and has moved progressively northeast about 460 km to its present position. Initial fracturing occurred about 23-22 million years ago, but most of the movement has taken place in the last 6 million years. The forces that provoked this were produced by the convergence of the Pacific and Australian tectonic plates along a boundary that runs diagonally southwest to northeast across New Zealand. The convergence of the plates is oblique, and so this produces a lateral stress that has shifted northwest South Island to the northeast relative to the rest of the island. In addition to generating on-going slippage along the Alpine Fault, the convergence also compresses rocks near the plate boundary and forces their uplift, resulting in the formation of the Southern Alps (discussed further in Williams 2004).

5.2. The Mokihinui catchment lies to the northwest of the Alpine Fault in a region where compression and uplift has been less severe than further south closer to the Alpine Fault. Nevertheless, compression, folding and uplift has occurred and is continuing in this region with the result that mountains rise to 1500 m and faulting imparts a north-south tectonic grain to the country. In the Buller valley, just south of the Mokihinui, the effect of these processes in the recent geological past can be gauged by a river terrace (a former floodplain) formed about 260,000 years ago that has been uplifted 250-340 m above the present river and has been warped and faulted in the process (Suggate 1988). Tectonic compression including folding and faulting is on-going, so some faults crossing the Mokihinui catchment are active as shown by their rupturing in 1929 Murchison and 1968 Inangahua earthquakes (Roder and Suggate 1990).

5.3. The White Creek Fault runs N-S along the eastern edge of the inland basin of the Mokihinui and continues south across the upper Buller gorge, where a vertical displacement of 4.2 m along the fault trace was observed following the 1929 earthquake. The 1968 earthquake also generated movement on the Glasgow Fault, which crosses the Mokihinui River about 1 km downstream of the proposed dam site (Gillon 2011 section 6.4). Evidence for its movement was identified where it crosses the Buller valley; Suggate (1988) and Roder and Suggate (1990) providing details and further references. So the White Creek Fault must be considered active in the Mokihinui basin and the Glasgow Fault is likely to be.

5.4. While knowledge of rates of folding, uplift and faulting is necessary for an appreciation of modern geological processes, to gain an understand of the history of the Mokihinui River, the development of its gorge and the significance of its geomorphology, it is necessary to obtain a much longer term perspective on the geological evolution of the region.

5.5. Before the present Australia-Pacific plate boundary was established, the landmass of New Zealand had been eroded almost to sea level. This was at the end of the Cretaceous Period – about 75 million years ago. At the time the land was gradually sinking beneath the sea. In marshes and estuarine embayments, organic sediments, that later became coal measures, began to accumulate; and as the land subsided more they became covered in sands and marine mudstones with shell fragments. With further subsidence the sea became deeper and clearer, and the sea bed became covered in thick sheets of shell fragments which, in turn, were later covered by more mudstones. Deposition of this sort continued for up to 40 million years or so with the result that the old basement rocks became buried by thousands of metres of estuarine and marine sediments. This resulted in the sequence of Paleogene and Neogene (Tertiary) sedimentary rocks that we see today (Figure 1) mantling the basement rocks of the Mokihinui and neighbouring catchments (Figure 2). The process of sediment accumulation ended in the late Miocene once the present plate boundary was established and convergence and uplift had commenced (this was about 6.4 million years ago according to Cooper and Norris 2008).

Figure 1. Matiri Tops in the Mokihinui headwaters. A Tertiary limestone plateau overlying impermeable basement rocks.

Figure 2. The dashed line marks the approximate position of the contact between the eroded ancient basement rocks below and younger marine sediments above.

5.6. When the land began to emerge from the sea again, the surface was covered with thick marine sediments. In western South Island, drainage flowed across these rocks towards the Tasman Sea. The rivers incised into the marine sediments and continued to erode them as uplift, folding and faulting occurred around them. As a result, most of the cover of Tertiary sediments was eventually removed and the incising rivers were gradually superimposed (lowered) onto the underlying ancient basement rocks that were progressively being exposed once more. As this was taking place, movement along the Alpine Fault was simultaneously transporting the large piece of Fiordland terrain on which the Mokihinui basin is situated in a northeasterly direction towards its present location.

5.7. In the course of mountain building activity over the last several million years, up-thrust blocks have been pushed up across the courses of rivers in northwest South Island and elsewhere. Only the largest of these rivers have been able to maintain their courses: those with sufficient erosive power to incise their channels downwards at a pace that matched the rate of uplift. Thus in some places gorges were (and are still being) cut across uplifted blocks. These are termed *antecedent gorges* and the main Mokihinui Gorge and the smaller North Branch Gorge are of this type (Figures 3 and 4). The Mokihinui River course was initiated by superimposition from overlying weaker sediments (remnants of which can still be seen on the Matiri Tops in the upper catchment) and then antecedent gorges formed in places where uplift occurred across its path.

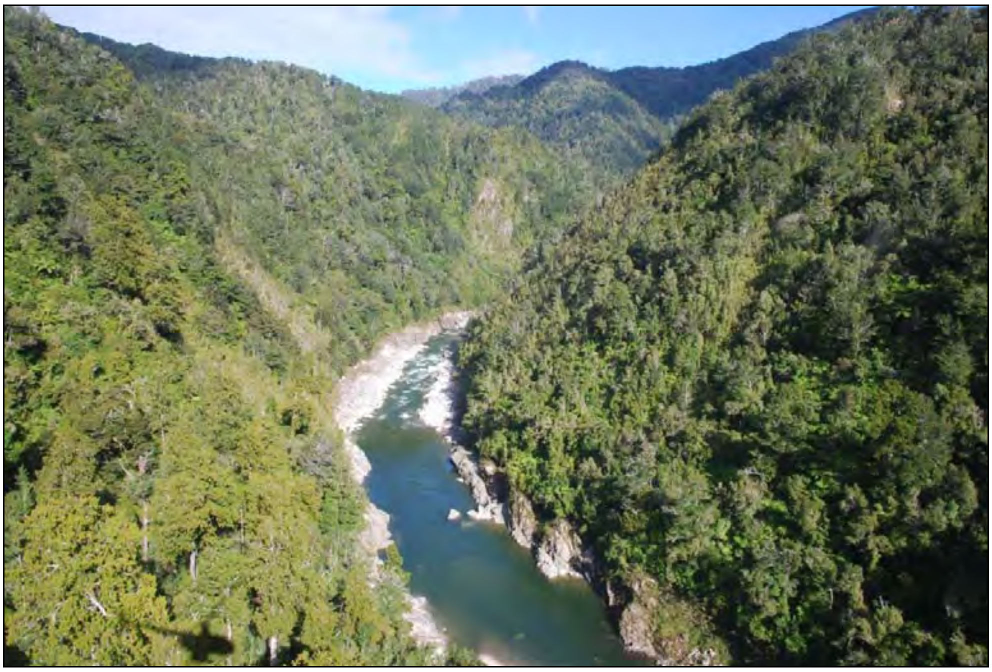

Figure 3. Middle reaches of the Mokihinui Gorge.

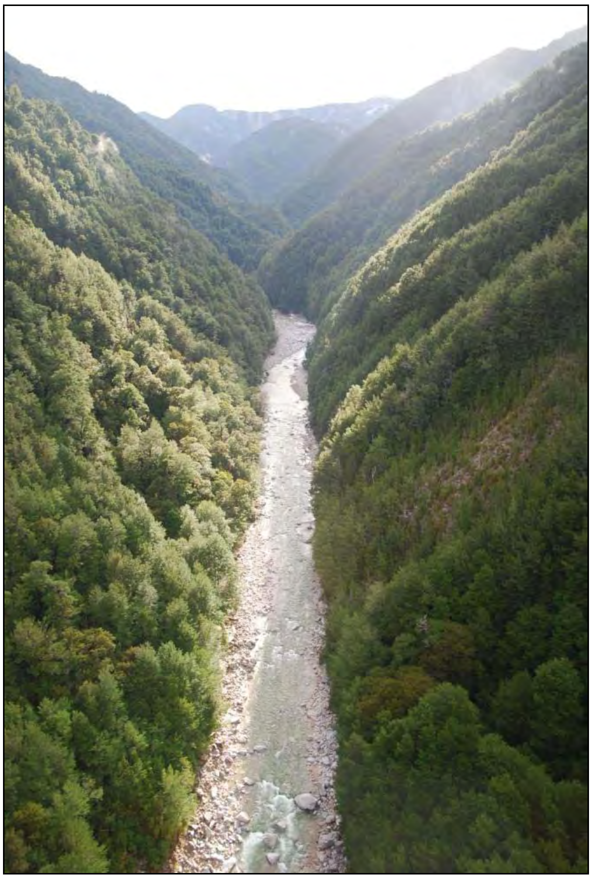

Figure 4. The Mokihinui North Branch Gorge. Convex valleyside slopes indicate that river incision may not be keeping pace with the rate of tectonic uplift.

5.8. The rate at which gorge development occurred varied over time, because rates of uplift and faulting also varied and climate changed; the latter affecting river discharge. For example, in the Pleistocene (the last 2 million years or so), parts of the upper Mokihinui catchment were glaciated (above about 400 m), so river flow and sediment production would have changed through warm and cold cycles. The average effect can be judged in the Buller valley, where in places the rate of valley incision over the last 260,000 years or so has been about 1.1 m /1000 years.

5.9. In the Buller region, the preeminent example of a superimposed river with antecendent gorges is the Buller River itself. Other examples are the Karamea-Leslie and the Mokihinui. Stripping of the cover beds is still continuing in the Mokihinui catchment. Thus, for example, the headwaters that drain the Matiri Range flow across a sequence of Tertiary rocks including limestones and calcareous mudstones that still cap the planed surface of the underlying basement rocks (Figure 1); the latter being exposed on valley sides (Figure 2). These rivers were initiated on Tertiary cover beds, but erosion eventually resulted in their being lowered onto and superimposed on ancient underlying rocks. Where the erosive power of the river was strong enough, its course was maintained even if tectonic forces raised blocks across its path. In such cases, channel incision kept pace with the rate of uplift and so antecedent gorges were cut across upthrust blocks. The Lower and Upper Buller Gorges and Mokihinui Gorge are cases in point.

5.10. Antecedent gorges are found quite frequently. Good examples are found between Punakaiki and Charleston, including the Punakaiki, Pororari, Fox and Waitakere

(Nile) gorges. Further north, in addition to the upper and lower gorges of the Buller, are the gorges of the Ngakawau, Mokihinui, Karamea and Oparara.

5.11. Among the rivers of the Buller region between Punakaiki to the south and Kahurangi Point to the north one can recognise:

(i) Original trunk rivers that drain to the west and cut across the terrain regardless of rock type and geological structure. These are ancient superimposed streams. They usually have relatively large discharges and possess reaches with antecedent gorges (Figure 3).

(ii) Tectonically directed streams that are guided by the generally NNE-SSW geological structure of the region. These are usually major tributaries of main trunk rivers (Figure 5).

(iii) Small tributary streams that drain the flanks of uplifted blocks and follow the direction of local slope (Figure 6).

Figure 5. The Mokihinui South Branch flowing from the south along the inland basin.

Figure 6. Hennessy Creek, a small stream draining the Glasgow Range. Note glacial form of valley in upper reaches.

Figure 7. Maori Gully/Hemphill River (centre) joins the Mokihinui North Branch (top right) as it enters the inland basin and meets the South Branch (bottom right) at the Forks.

5.12. The Mokihinui River trunk stream is of the first category, as are the Karamea-Leslie and Buller trunk streams. The Heaphy, Little Wanganui and Ngakawau may also be of this kind, but are smaller streams. Where up-thrust blocks and/or anticlines cross these rivers there are antecedent gorges. Consequently, the Mokihinui Gorge is not unique to the Buller District, but is nevertheless one of the best examples of an antecedent gorge. The Ngakawau Gorge is a smaller example though incised more steeply.

5.13. Although field evidence may show that a trunk river has been superimposed, this does not necessarily extend to its tributaries, some of which may be much younger than the main river and may have had their courses directed by emerging geological structures. Thus, for example, compression of the region arising from plate tectonic activity caused faulting and folding to occur, imparting a NNE-SSW grain to the topography. Fault-angle intermontane depressions were therefore sometimes produced between uplifted and tilted blocks, and the Forks depression is one of the best examples in the district and region. The north flowing Mokihinui South Branch (Figure 5) and the south flowing Maori Gully (Figure 7) are guided by the faulted and folded structure in this way and are examples of the second category of streams (tectonically directed), although there are numerous other examples in the general neighbourhood.

5.14. Examples of the third category of streams in the Mokihinui catchment are those that drain east from the Glasgow Range, an uplifted and tilted block of granite (Figure 6). These streams are left bank tributaries of the Mokihinui South Branch.

5.15. The upstream entrance to the Mokihinui Gorge receives drainage from a roughly north-south oriented fault-angle depression. This basin is bounded to the east by the reversed White Creek Fault, one of the more active in the region. The inland basin is a younger feature than the Mokihinui trunk stream because it developed only after major compressional faulting, folding and rapid uplift had imparted an actively developing NNE-SSW tectonic grain to the country. The Mokihinui River with its North Branch headwaters was superimposed from overlying Tertiary sediments, with remnant patches still remaining on the Matiri Tops, whereas the South Branch only came into existence after the fault-angle depression had formed.

5.16. In conclusion, I agree with the general interpretation of the regional geomorphology made by Dr Mabin and, in particular, with his view that the geomorphic character of the Mokihinui region is typical of the wider Westport-

Karamea region (Mabin 2011 section 4.18). I find his general interpretation of the regional geomorphology as depicted in his Figure 2 to be appropriate and the quantitative data presented in Tables 1-4 to be useful in conveying the dimensions and proportions of topographic features found in the region.

**Does the Mokihinui catchment, including its gorge, have any rare or important geomorphic attributes?**

5.17. Numerous interesting landforms and geological features occur around the eastern headwaters of the Mokihinui drainage system. Particularly notable is the Matiri Range (1100-1500 m) and associated Thousand Acres Plateau (Figure 1). This consists of a tableland of Tertiary sediments (24-40 million years old) deposited on an ancient undulating land surface cut about 75 million years ago across Devonian granite (intruded about 400 million years ago). The Tertiary sediments have been uplifted but otherwise are hardly disturbed since they were on the sea floor. They comprise almost horizontal to tilted Oligocene calcareous mudstones and limestones overlying Eocene sandstones. Karst landforms such as sinkholes and caves are developed in the limestones (Figure 8).

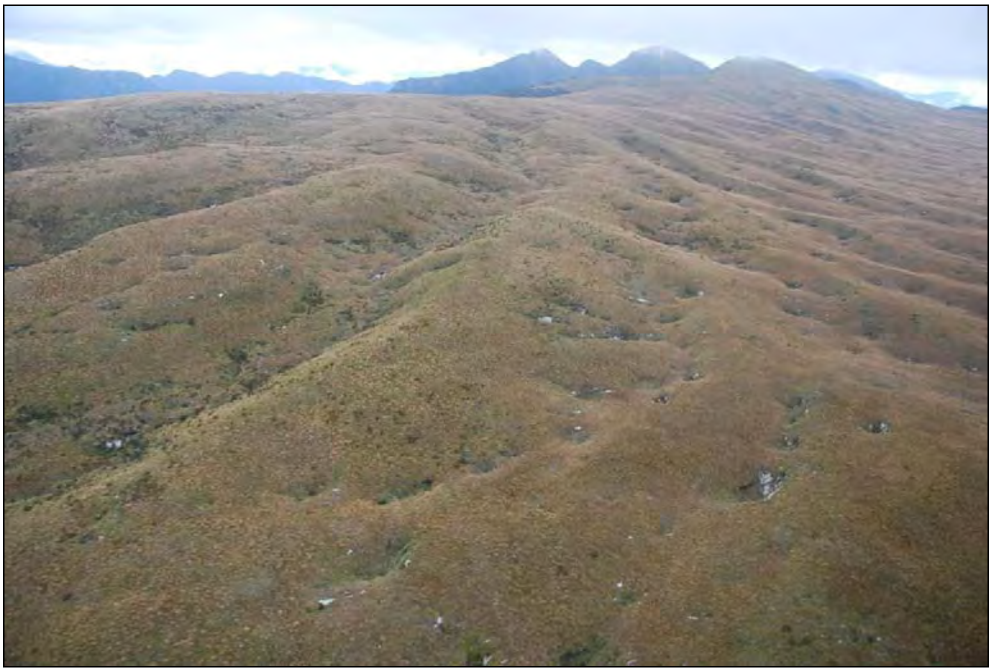

Figure 8. Matiri Tops plateau pocked by karst sinkholes. These are located along former stream courses and drain underground.

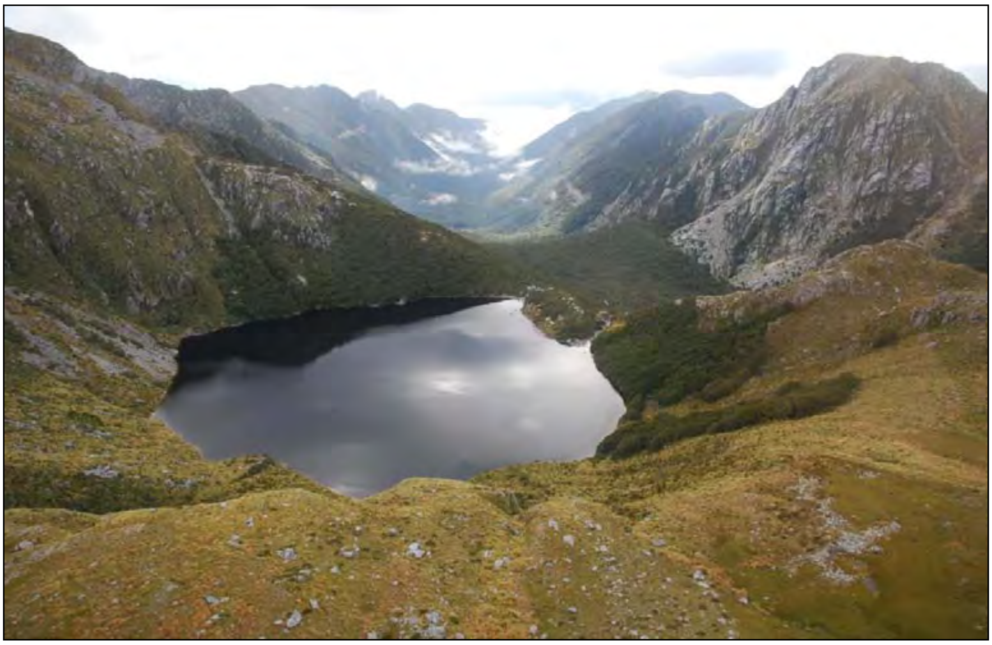

Figure 9. Glacial tarn in the Glasgow Range with glaciated Hennessy Creek valley beyond.

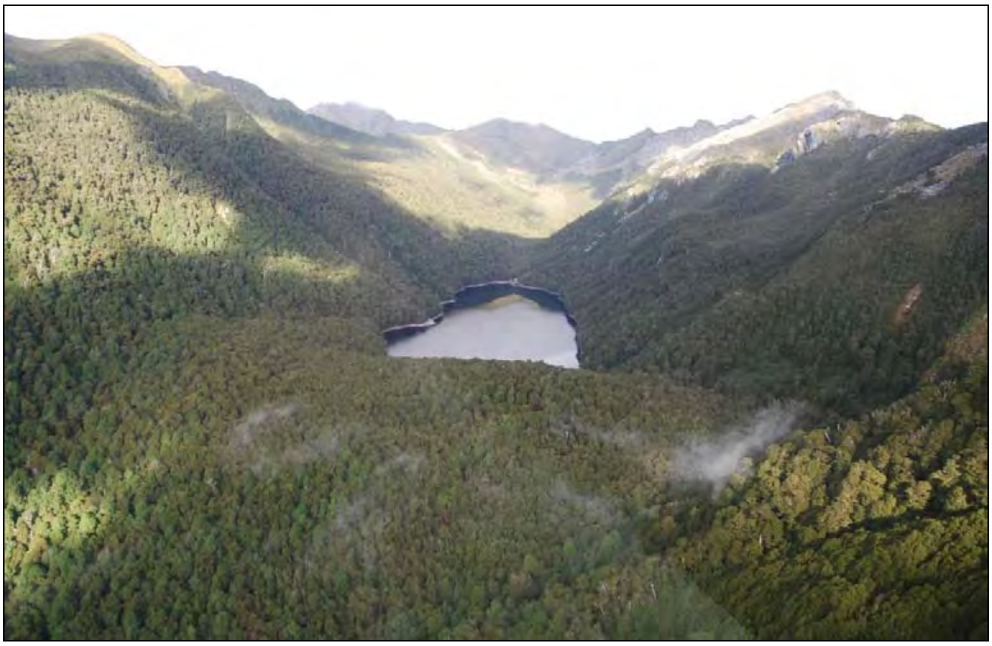

Figure 10. Landslide dammed lake in Owen Creek, Glasgow Range. Landslide descended from right (north). Now fully forested.

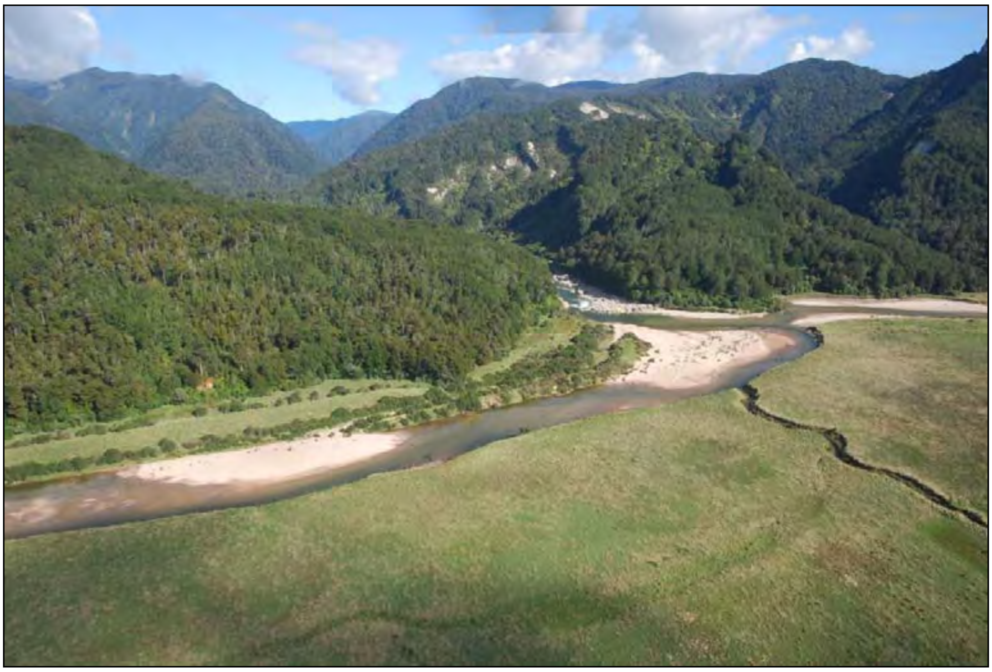

Figure 11. Entrance to the Mokihinui Gorge at the Forks.

5.18. The Glasgow Range (to 1424 m) in the southwest of the basin forms the divide between the Mokihinui and Ngakawau drainage systems. The Range is rugged and in places reminiscent of Fiordland mountains with deep steep-sided glaciated valleys and cirques above 400 m carved into hard granites and granodiorites (Figure 9). Particularly notable are the lakes, not all of which are in glacial cirque basins; some are dammed by massive landslide deposits (probably earthquake generated) that impounded streams on valley floors (Figure 10). Some of the earthquake lakes are attributable to earthquakes last century, but others are very much older (Adams 1981). The Allen Range (to 1510 m) that forms the northern boundary of the catchment merges with the Radiant Range to the northwest. Their glaciated summits form the divide between the Mokihinui and the Little Wanganui River.

5.19. Many of the tributaries flowing from the above ranges drain into the long north-south intermontane depression near the centre of the Mokihinui basin, and their collected flow then enters the Mokihinui Gorge (Figures 7 and 11). It is a particularly fine example of an intermontane depression, but is not unique given the tectonised nature of the terrain in the South Island.

5.20. Given the points made thus far in this section, and to answer the question of whether or not the Mokihinui catchment and its gorge have any rare or important geomorphic attributes, it is evident that the catchment provides a superb example of the way river basins have evolved in this region of New Zealand; on a block of Fiordland rocks that has been translocated to northwest South Island and in the process has been compressed, uplifted and dissected. One can find a few comparable chapters of this history elsewhere in the region, especially in the Buller catchment, but the Mokihinui is special because it so clearly demonstrates the story. It contains superimposed and antecedent elements and the three classes of streams of different age recognised above. The

Mokihinui River system is the legacy of processes that extend back tens of millions of years and the Mokihinui Gorge will have developed within the last few million years as the Glasgow and Radiant Ranges rose across its path. Dateable evidence is insufficient to be more precise, but it is clear that the MHP would be located in an unusual river system of considerable antiquity and scientific significance.

5.21. The assessments made above would seem relevant to any evaluation of the Mokihinui that might be made under Policy 9.1 of the West Coast Regional Policy Statement.

**What is the geomorphological significance of the Mokihinui Gorge and its landform features?**

5.22. Drainage from the upstream tributaries of the Mokihinui River converges in a north-south aligned fault-angle intermontane basin with its lowest threshold at the entrance to the gorge (Figure 11). From this location, known as the Forks, to the downstream exit of the gorge near the proposed dam site (Figure 12), the Mokihinui River has a channel length of about 17 km and drops 90 m (from 115 m at former Lake Perrine to about 25 m at the start of the Seddonville floodplain). The gorge rim is not easy to define (see Figures 3, 11 and 13), but measured from skyline summits each side of the river, in its upstream reach between Specimen Creek and Jones Creek the gorge is about 1.5 km wide and 600 m deep; in its mid-reaches below the confluence of Maori Creek the gorge is 2.8 km wide and 700 m deep; and in its downstream reach between Rough and Tumble Creek and the proposed dam site it is about 6 km wide and 1150 m deep. It is therefore evident that the gorge widens and deepens overall with distance downstream. The gorge is not straight, but follows the rather open irregular incised meanders of the river. Its slopes are steep, averaging 30° to 40°, being generally steeper on outside bends where there can be local over-steepening to 60°. The tendency for slight convexity of lower slopes near the channel implies that the incision rate of the river may not be keeping pace with the rate of uplift.

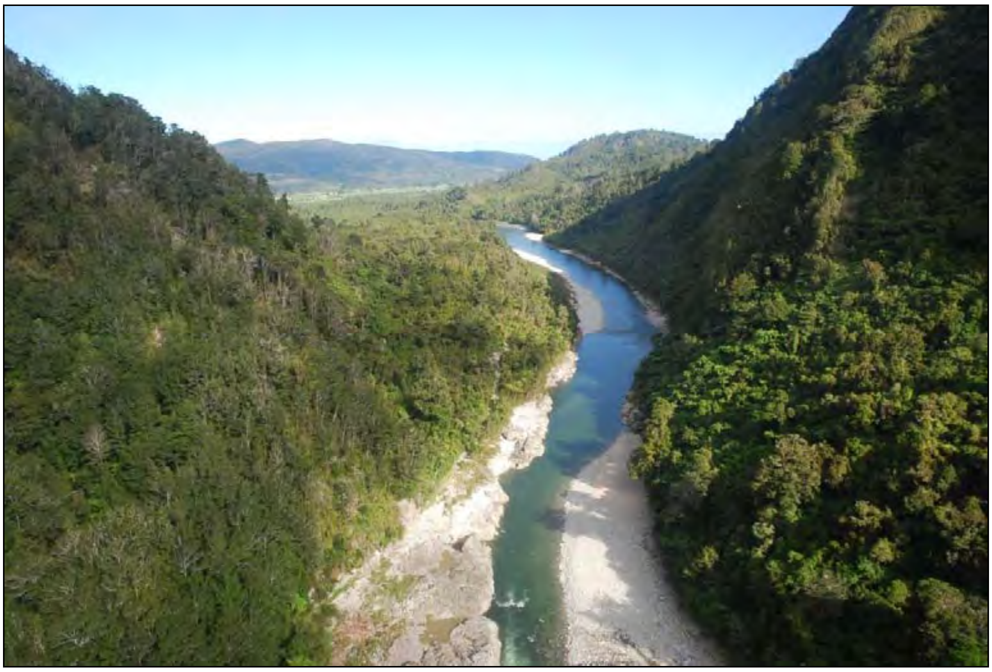

Figure 12. Downstream exit of the Mokihinui Gorge near the proposed dam site. The river channel is incised into bedrock.

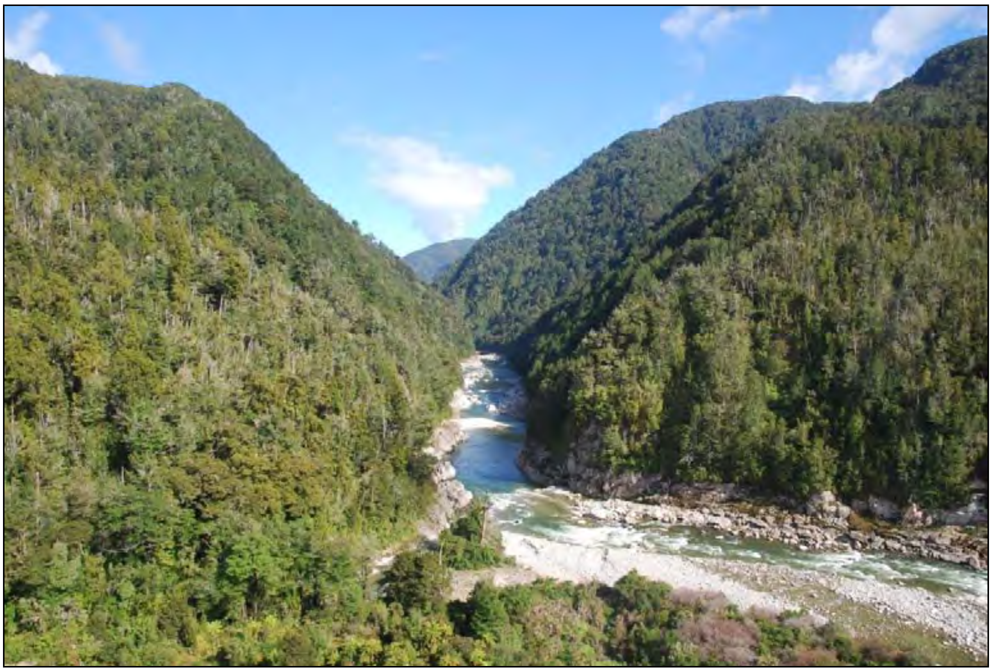

Figure 13. The upper Mokihinui Gorge confined by resistant Palaeozoic rocks.

Figure 14. ‘Flat-iron’ topography in steeply dipping Tertiary marine sediments at the entrance to the Mokihinui Gorge.

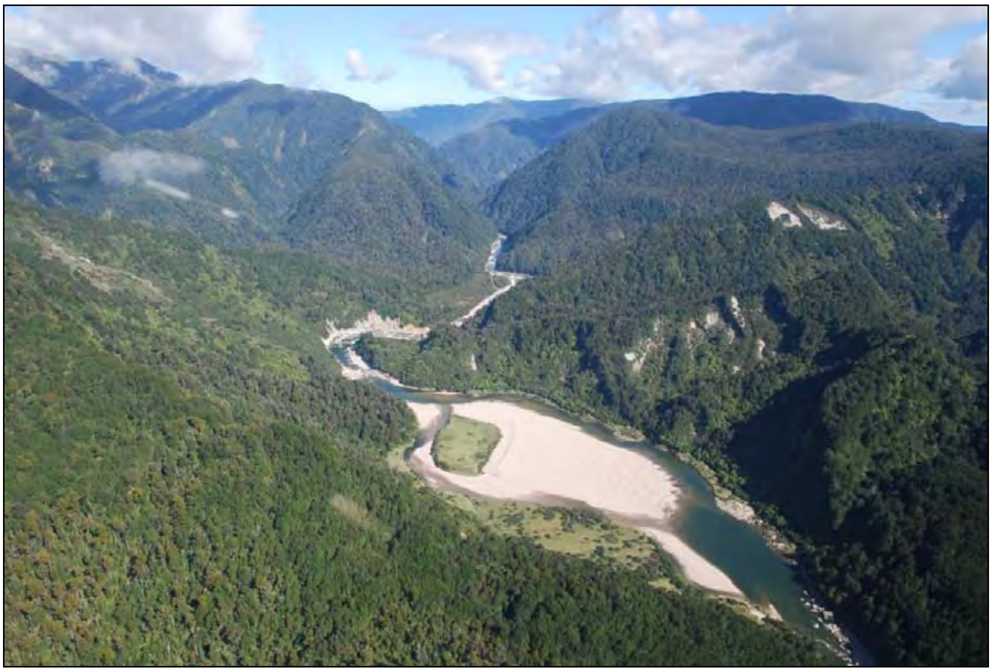

Figure 15. The open upper Mokihinui Gorge in Tertiary sediments becomes confined as it crosses onto more resistant Palaeozoic rocks.

Figure 16. Confluence of Rough and Tumble Creek with Mokihinui River in the Gorge.

5.23. An interpretation of the limits of the Mokihinui Gorge is provided by Dr Mabin in his Figure 13. As noted above in 5.3.1 the gorge rim is not easy to define, so although I find myself in agreement with the mapped limits along the right (N) side of the gorge, I would include the whole of Anderson, Johnny Cake and Welcome Creek catchments on the left (S) side upstream of the proposed dam site.

5.24. The geology through the gorge changes in a downstream direction. Either side of the upstream entrance to the gorge the rocks comprise steeply eastwards dipping Palaeogene marine sediments (Nile Group sedimentary rocks of Oligocene age), eroded into shapes known as ‘flat-irons’ (Figures 14). These consist of calcareous mudstones interbedded with limestones, overlain by more massive limestones. They are underlain by a relatively thin strip of Eocene mudstones and muddy sandstones that lie unconformably on basement rocks beneath. These sedimentary rocks cover an age range of about 40 to 24 million years and so contrast strongly with the basement rocks on which they rest, which are 490-390 million years old and much more resistant to erosion. Slopes developed on the Tertiary sediments are more open than those developed on basement rocks, so there is a narrowing of the gorge as basement rocks are encountered (Figures 13 and 15).

5.25. Underlying basement rocks outcrop about 3 km downstream from the Forks. They are much harder than the overlying Tertiary sediments and so the channel is more closely confined. From this point almost to the confluence of the right bank tributary, Rough and Tumble Creek (Figure 16), the gorge is incised in early Ordovician (490 million years old) Greenland Group rocks which consist of erosion-resistant micaceous quartz sandstones and siltstones. Then from just upstream of Rough and Tumble Creek to the exit of the gorge, the river channel is incised in hard Karamea Suite granites and granodiorites of mid-Devonian age (ca. 390 million years old), but with the upper slopes of the gorge still cut through Greenland Group rocks into which the granites were intruded (Figures 17).

5.26. The downstream exit of the gorge is abrupt (Figure 12), being determined by the Glasgow Fault which downthrows the basement rocks on its seawards side. This results in the river once more encountering the overlying and more readily erodible Tertiary sediments, and so it develops a relatively broad floodplain around Seddonville before incising across a narrow up-thrown limestone block in its tidal reach between Mokihinui and Summerlea immediately before discharging to the sea (Figure 18).

Figure 17. The lower Mokihinui Gorge. Note bare sides of channel where vegetation has been stripped by vigorous flood flows.

Figure 18. The Mokihinui River below its gorge crosses a wide floodplain, but is confined again by a short antecedent gorge before discharging to the sea, just visible in the distance.

Figure 19. Angular landslide debris descends into the river. Flood scoured banks opposite.

Figure 20. Trees drowned by the formation of Lake Perrine are now being exhumed.

5.27. Because the gorge is steep-sided and has a narrow floor, there is little or no floodplain development beside the rocky channel (Figure 17) and, because shallow mass movement and fluvial scour are very active, any floodplain remnants are soon effaced; thus few terraces are preserved in the gorge. One of the best remnants is on the left bank on the inside bend of the river around Anderson’s Flat, where it is about 50 m above channel level. Terraces are much better preserved downstream of the gorge exit in the vicinity of Seddonville, where several terraces can be seen on the south side of the valley

5.28. Evidence within the gorge clearly shows the dynamic nature of fluvial processes, including rock scour, rounding and sorting of river boulders and pebbles, fluvial sedimentation and flood water deposition, all set in the context of a confined bedrock channel with a sequence of pools and rapids and tributary junctions. The gorge provides a text book example of fluvial processes at work in a tectonically uplifting landscape.

5.29. The gorge also clearly demonstrates the interaction of slope and fluvial processes, because numerous landslides (see Gillon 2011, figure 7) project angular slope and vegetation materials into the river (Figure 19), where they are sorted and swiftly transported downstream. Not all landslides are earthquake-generated. Many are triggered by heavy rain, so many in the gorge are recent.

5.30. Evidence within the gorge clearly shows the impacts of earthquakes on the landscape. This is especially well seen at former Lake Perrine at the upstream entrance to the gorge, where landslides from both sides impounded the river, backed-up a temporary lake, and trapped river sediments that buried floodplain vegetation some kilometres upstream from the Forks. But the landslide dam is now breached, the lake is drained (the gravel flats in Figures 14 and 15 show its former site), lake bed sediments are being incised and buried tree stumps are being exposed (Figure 20); the landslide lake sequence is almost complete - and is clear to demonstrate and see.

5.31. The geomorphological significance of the Mokihinui Gorge rests principally in the large scale landform (see 5.4 to 5.12 above) rather than in any small scale geomorphic features contained within it. But the gorge also facilitates visibility concerning landscape forming natural processes. From the track beside the river one can readily observe fluvial processes at work and active slope processes are evident from the numerous landslide scars and deposits. Former Lake Perrine offers one of the more accessible examples demonstrating the sequence of landslide lake evolution.

These small scale features are not rare, but are readily observed and well expressed.

5.32. With the upgrade of the track, and the new hut at Specimen Creek, the gorge would be a perfect and accessible place to bring groups of students to demonstrate in a dramatic way the nature and interaction of slope processes and the work of rivers.

**Will the MHP proposal have significant effects on landforms, geomorphological processes or geomorphological values in the Mokihinui catchment, including its gorge?**

5.33. The most significant geomorphological effect of the proposed MHP impoundment is that it will totally alter processes in the lower Mokihinui basin by drowning the channel near the outlet of the system. This will prevent the throughput of sediment and eliminate the rapid flow of water and, as a consequence, shut down channel-forming processes and on-going incision of the gorge. Although the inundation would involve only a few percent of the depth of the gorge, it occurs in a critical place – in the main transportation corridor: the centre of action of gorge forming processes. It will reverse processes in the gorge from one of erosion and sediment transportation to that of sediment entrapment and accumulation.

5.34. As can be seen from former Lake Perrine, ponded water bodies catch fluvial sediments. But whereas a natural landslide dam undergoes a sequence of filling and emptying and the river gets back to normal, a dam-impounded reservoir lake will not undergo that process. It will immediately stop the fluvial downcutting and reverse the natural process to a relatively long-term state of aggradation (sediment accumulation). The nature and possible rate of this sedimentation is detailed in Dr Hicks' evidence. The reservoir will be full of sediment after approximately 450 years (Hicks 2011, sections 3.3 and 6.4), although significant earthquake-generated slips could dramatically shorten the time. Unlike natural landslide dams, the man-made dam will be impermeable and will not be gradually incised or by-passed by natural processes. It will catch everything until the reservoir volume is reduced sufficiently to permit some suspended sediment to escape by over-topping it.

5.35. The sediment load from incoming streams around the reservoir will be captured and accumulate as deltas in the impoundment lake; the largest delta progressing downstream from the upstream end of the inundation reservoir. Once built well out into the reservoir, a phase of retrogressive floodplain aggradation (build up) will follow that will progress upstream across present floodplain flats, because high reservoir levels will occur during floods and the channel bed will build up rather than incise. It is estimated that because of this process the upstream end of the delta will reach 120 m above sea level (Hicks 2011 section 6.4). This implies that it will progress upstream of the Forks and will involve up to about 5 m of sediment deposition over the site of former Lake Perrine at the upstream entrance to the gorge.

5.36. Road and track building in the gorge and at the dam construction site will involve benching of loose slope deposits and will cut though rock spurs. This will alter gorge side landforms much more profoundly than the existing pack track and will generate pulses of sediment discharges during construction. Sediment discharge associated with blasting and building activities at the dam site will be the biggest single cause of construction related water quality deterioration in the river.

5.37. Slope deposits from the gorge sides (including landslide debris) will accumulate as fans at the toe of slopes and sometimes project into the lake – even crossing the reservoir and bisecting it if earthquake failures like those of 1926 and 1968 recur. If slips of the order of the one that produced Lake Perrine fall into the lake, then massive impulse waves will sweep downstream to the dam and send a surge of water over the spillway. Earthquake-generated fault rupture and associated slope failure is well known in the region and is thoroughly documented by Adams (1981), Pearce and O’Loughlin (1985), Roder and Suggate (1990) and Suggate (1988). Details of anticipated effects are provided in evidence by Gillon (2011).

5.38. Lake margin processes around the reservoir will undercut unconsolidated slope deposits, although the waves will be small because the fetch would be insufficient to generate large waves. Reworking of these materials will, in places, create narrow beaches of coarse angular colluvium; and limited undercutting by waves will generate small, localised slips. Gorge slopes are steep and the operating range of the lake is only 3 m, so beaches will mainly be narrow stony strips. I agree in a general way with the assessment of the effects of these lake margin processesmade by Dr Mabin in paragraphs 7.18 to 7.25 of his evidence in chief (Mabin 2011).

5.39. Immediately downstream of the dam the existing channel will be starved of sediment. Existing fines will be winnowed and transported away and a coarse gravel and boulder lag will armour the channel bed. There will be a tendency for the channel to incise, but this will be limited by the modest fall to sea level. In his evidence Dr Hicks estimates these effects (Hicks 2011).

5.40. Beyond the scope of this evidence, but important to mention, is the fact that the most significant geomorphological impact of the dam, apart from the flooding of the gorge, would be reduced sediment delivery to the coast, which will exacerbate beach erosion either side the river mouth; a problem that would persist for the foreseeable future. Evidence of the likely magnitude and spatial distribution of this effect is provided by Dr Hicks (2011) and I understand will be further discussed by Dr Hudson and Mr Todd.

**Can any adverse effects of the MHP on landforms, geomorphological processes or geomorphological values in the Mokihinui catchment, including its gorge, be appropriately avoided, remedied or mitigated?**

5.41. I cannot see how any adverse effects of the proposed MHP impoundment on the geomorphology might be remedied or mitigated; they can only be avoided by not building the dam. The landforms are of essentially uniform significance along the length of the gorge, so no impoundments or diversions can be made elsewhere within the gorge that will not have comparable effects.

5.42. Attempts to argue that the effect of the proposed dam would be minor, because it would look like a natural landslip-dammed lake are misplaced, even though there are many such lakes in the region (example in Figure 10). This is a poor superficial argument because the similarity holds only when the dam structure is not in view and only for a relatively short time. The geomorphic evolution, visual appearance over time and hydrological operation of a man-made reservoir and a natural impoundment are quite different. A dam is made to be impervious and its lake is held about a relatively constant level within a narrow operating range. Its reservoir eventually fills with sediment and the dam is overtopped unless there is further engineering intervention. By contrast, landslide-formed lakes have permeable boulder dams that leak, sometimes collapse and are gradually incised or by-passed while the impounded lake is infilled and gradually lowers; lake levels vary with hydrological conditions; ecological processes in the river are interrupted but almost unaffected after a few years. Only the largest landslide-dammed lakes (like Waikaremoana) have a landscape-changing effect as long-lasting as hydro dams.

5.43. I cannot accept the conclusions reach by Dr Mabin that the proposed MHP will have a minor effect on the geomorphic environment and that the characteristics of landforms lost will be insignificant within the context of the Mokihinui region (Mabin 2011 section 8.4).

5.44. The dam and its reservoir would have a profound and long-lasting effect on the geomorphology and associated geomorphic processes within the Mokihinui catchment, especially from the inland basin at the Forks to the sea:

(i) The entire natural geomorphic system of the Mokihinui River would be disrupted until the dam becomes full of sediment and is overtopped (centuries into the future), because the reservoir would reverse the function of the gorge, turning it into a zone of sediment accumulation rather than a mainline of sediment transmission and discharge.

(ii) The mouth of the river would no longer receive and discharge to sea large amounts of fluvial sediment; thus - and as Hicks (2011) points out - the neighbouring beaches would be partly starved of sediment and prevailing beach erosion would exacerbate (engineering works would have to be maintained into the far distant future to afford protection).

(iii) The best (largest, longest and most accessible) example of an antecedent gorge north of the Buller would be damaged beyond practical repair.

5.45. These effects are profound and long-lasting, and certainly cannot justify description as either minor or insignificant, quite the contrary.

5.46. In weighing up the importance of the potential adverse effects of the MHP on the Mokihinui catchment one must appreciate that the main trunk of the river follows one of the oldest valleys of the region. It is a superimposed drainage system, one of the few for which there is remaining evidence in the region, and a long, deep, antecedent gorge is a prominent feature of its lower reaches. This is not just ‘another river’; it exemplifies particularly well the evolution of ancient drainage systems in northwest South Island over tens of millions of years. This evolution is on-going, but the building of a dam would stop it in its tracks, because the mainline of sediment transfer and gorge incision would be severed, perhaps for

450 years (according to Hicks 2011) until the dam was full. From a geomorphic perspective this is a massive impact. The potential losses and gains of minor landforms in the gorge pale into insignificance. Even the potential exacerbation of erosion on the coast becomes relatively insignificant at that scale, because at least that can be mitigated. The natural evolution of the river would only be able to recommence once the reservoir was full of sediment and the dam over-topped and breached by the river.

## 6. CONCLUSIONS

6.1. The MHP dam and its reservoir would have a profound and long-lasting effect on the geomorphology and associated geomorphic processes within the Mokihinui catchment, especially from the inland basin at the Forks to the sea:

(i) The entire natural geomorphic system of the Mokihinui River would be disrupted until the dam becomes full of sediment and is overtopped (centuries into the future), because the reservoir would reverse the function of the gorge, turning it into a zone of sediment accumulation rather than a mainline of sediment transmission and discharge.

(ii) The mouth of the river would no longer receive and discharge to sea large amounts of fluvial sediment; thus - and as Hicks (2011) points out - the neighbouring beaches would be partly starved of sediment and prevailing beach erosion would exacerbate (engineering works would have to be maintained into the far distant future to afford on-going protection).

(iii) The best accessible example of an antecedent gorge in the region north of the Buller would be damaged beyond practical repair.

6.2. The Mokihinui River exemplifies particularly well the evolution of ancient drainage systems in northwest South Island over tens of millions of years. This evolution is on-going, but the building of a dam would stop it in its tracks, because the mainline of sediment transfer and gorge incision would be severed, perhaps for 450 years until the dam was full. From a geomorphic perspective this is a massive impact.

6.3. The evidence presented here is relevant to any evaluation of the Mokihinui catchment that might be made under Policy 9.1 of the West Coast Regional Policy Statement because:

(i) the Mokihinui Gorge is an “outstanding natural feature”;

(ii) the proposed dam and reservoir would have highly significant and cumulative effects “on natural character”;

(iii) the scenic, recreational and scientific value of the Mokihinui Gorge would be transformed and much degraded; and

(iv) it would not be possible to reduce significantly the impacts of the dam and reservoir on the natural character of the gorge and mitigation of downstream effects on coastal erosion would require an extremely long-term commitment.

6.4. It is difficult to escape the conclusion that, in terms of the West Coast Regional Policy Statement, the building of the dam and impoundment of the Mokihinui River would be an inappropriate use of an outstanding natural feature and landscape.

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