BEFORE THE ENVIRONMENT COURT
I MUA I TE KOOTI TAIAO O AOTEAROA

UNDER	the Resource Management 1991
IN THE MATTER	of of appeals under Clause 14 of the First Schedule of the Act
BETWEEN	**TRANSPOWER NEW ZEALAND LIMITED** (ENV-2018-CHC-26)
	FONTERRA CO-OPERATIVE GROUP (ENV-2018-CHC-27)
	HORTICULTURE NEW ZEALAND (ENV-2018-CHC-28)
	ARATIATIA LIVESTOCK LIMITED (ENV-2018-CHC-29)
	WILKINS FARMING CO (ENV-2018-CHC-30)

(Continued next page)

STATEMENT OF EVIDENCE OF DR ANTONIUS SNELDER ON BEHALF OF THE SOUTHLAND REGIONAL COUNCIL
14 December 2018

Judicial Officer: Judge Borthwick and Judge Hassan

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GORE DISTRICT COUNCIL, SOUTHLAND DISTRICT COUNCIL & INVERCARGILL DISTRICT COUNCIL
(ENV-2018-CHC-31)

DAIRYNZ LIMITED
(ENV-2018-CHC-32)

H W RICHARDSON GROUP
(ENV-2018-CHC-33)

BEEF + LAMB NEW ZEALAND
(ENV-2018-CHC-34 & 35)

DIRECTOR-GENERAL OF CONSERVATION
(ENV-2018-CHC-36)

SOUTHLAND FISH AND GAME COUNCIL
(ENV-2018-CHC-37)

MERIDIAN ENERGY LIMITED Act 1991
(ENV-2018-CHC-38)

ALLIANCE GROUP LIMITED
(ENV-2018-CHC-39)

FEDERATED FARMERS OF NEW ZEALAND
(ENV-2018-CHC-40)

HERITAGE NEW ZEALAND POUHERE TAONGA
(ENV-2018-CHC-41)

STONEY CREEK STATION LIMITED
(ENV-2018-CHC-42)

THE TERRACES LIMITED
(ENV-2018-CHC-43)

CAMPBELL'S BLOCK LIMITED
(ENV-2018-CHC-44)

ROBERT GRANT
(ENV-2018-CHC-45)

SOUTHWOOD EXPORT LIMITED, SOUTHLAND PLANTATION FOREST COMPANY OF NZ, SOUTHWOOD EXPORT LIMITED
(ENV-2018-CHC-46)

TE RUNANGA O NGAI TAHU, HOKONUI RUNAKA, WAIHOPAI RUNAKA, TE RUNANGA O AWARUA & TE RUNANGA O ORAKA APARIMA
(ENV-2018-CHC-47)

PETER CHARTRES
(ENV-2018-CHC-48)

RAYONIER NEW ZEALAND LIMITED
(ENV-2018-CHC-49)

ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NEW ZEALAND
(ENV-2018-CHC-50)

Appellants

AND **SOUTHLAND REGIONAL COUNCIL**

Respondent

Introduction

1 My full name is Antonius Hugh Snelder.

2 I am a director of LWP Ltd and consultant/researcher in the field of water and land resources management.

3 I hold a bachelor of agricultural engineering degree from the University of Canterbury, a post graduate diploma in hydrology from the University of New South Wales (Australia) and a PhD in environmental management from Lincoln University. I have 31 years of experience in the field of water resource management, including 14 years as a water resources scientist at the National Institute of Water and Atmosphere (**NIWA**), and prior positions in regional councils and in consultancies as a water resources engineer.

4 In my current and previous positions, I was the leader of many projects that have assessed water quality in freshwater environments, and the association between water quality and land use at regional and national scales. I have written several guidelines for the management of water quality and quantity and developed several tools for water management purposes. I have authored or co-authored 45 scientific publications in the field of water resources management, including those that address water quality. I am a specialist in the field of spatial frameworks that support environmental and resource management (such as Southland's Physiographic Zones).

5 While working as a research scientist at NIWA, I led the development of the River Environment Classification (**REC**) system and published several papers describing its development, performance and use in management. The REC classifies all New Zealand's rivers into types that differ with respect to their natural characteristics and sensitivities to resource use. The REC has been used extensively across New Zealand as a framework for both regional and national-level policy and environmental reporting. The REC is one component of the Physiographic Zones framework that is employed by the proposed Southland Water and Land Plan (**pSWLP**).

6 I have been involved in the development of the Physiographic Zones, which are used in the pSWLP. My involvement included reviewing the development of the underlying conceptual basis and advice concerning mapping the spatial distribution of the Physiographic Zones. I also led a

project that performed statistical tests on the performance of the Physiographic Zones, which are fully described in Snelder et al. (2016)[1]. I am not a specialist in all aspects the Physiographic Zones work. In particular, I am not an expert in hydro-chemistry, soils, or geology which are important components of the physiographic work and I do not have detailed understanding of the water quality risks associated with each Zone[2]. However, I have broad knowledge of most aspects of the physiographic work, and specific expertise in water quality and the development and use of spatial classification systems as frameworks for resource and environmental management.

7 I have been engaged by the Southland Regional Council (**Council**) to prepare evidence for these proceedings.

Code of Conduct

8 I confirm that I have read the Code of Conduct for expert witnesses as contained in the Environment Court Practice Note 2014. I have complied with the Code of Conduct when preparing my written statement of evidence and will do so when I give oral evidence.

9 The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence. The reasons for the opinions expressed are also set out in my evidence.

10 Other than where I state I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope

11 My evidence addresses:

(a) The background to the development of Physiographic Zones in the proposed pSWLP;

(b) The limitations of the Physiographic Zones;

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1 Snelder, T., B. Hughes, K. Wilson, and K. Dey, 2016. Physiographic Zones for the Southland Region: Classification System Validation and Testing Report. LWP Client Report, LWP Ltd, Christchurch, New Zealand.

2 The water quality risks of each Physiographic Zone is addressed in the evidence of Mr Rodway.

(c) The utility of the Physiographic Zones; and

(d) The use of the Physiographic Zones in decision making.

12 In preparing this evidence, I have read and considered several documents, which are cited in my evidence.

Executive Summary

13 The Southland Physiographic Zones is a landscape scale classification that broadly stratifies land in the Southland region in terms of land use risks to water quality. The Physiographic Zones comprise nine Zones and additional 'variants' that differ with respect to transport, dilution and attenuation processes associated with four main contaminants: nitrogen (N), phosphorus(P), sediment (S) and microbes (M). Scientific knowledge of these differences has been built up through a development process and has enabled Council to identify the main water quality risks and mitigation objectives associated with each zone and variant.

14 The Physiographic Zones are based on an underlying conceptual model that postulates that physiographic characteristics (topography, geology and soils) broadly control transport, dilution and attenuation processes at landscape scales. This conceptual model is also the basis for mapping the distribution of the Physiographic Zones across the region. I note that the approach taken to developing the Physiographic Zones is similar to that taken for other environmental classification systems including the REC.

15 Statistical testing indicates the Physiographic Zones are a robust description of the broad (i.e., landscape-scale) variation in water composition and water quality risk across the Southland region. However, the maps of the Physiographic Zones have three key limitations:

(a) The level of resolution of detail and spatial accuracy of the map boundaries means Zone membership does not describe all sources of water quality risk at the scale of an individual property.

(b) The Physiographic Zone boundaries are indicative of areas where there is a transition from one set of conditions to another. Because the mapped boundaries are an abstract representation of a transition, the main water quality risks in these areas will be described by one or both of the Zones that the boundary separates. This means that the main water quality risks at the property scale can be guided by the Physiographic Zones but require “on the ground” judgment and interpretation.

(c) The boundaries of the Physiographic Zones as described by the mapping rules will sometimes be inaccurate at the property scale (i.e., as judged by a person standing in the landscape). This means that the main water quality risks at the property scale can be guided by the Physiographic Zones but require “on the ground” judgment, interpretation and validation.

16 I consider that the Physiographic Zones can provide a basis for directing certain activities away from situations in which they may pose a particular risk because of dominant flow paths and water quality risks.

17 I also consider the Physiographic Zone information could be used as a starting point for identifying the dominant flow paths, water quality risks and mitigation objectives at the scale of individual properties given their membership of a Physiographic Zone. However, any use of the Physiographic Zones needs to be cognisant of the three limitations described above. Because of these limitations, I do not consider it would be generally appropriate to specify actions associated with managing water quality risks for individual properties based purely on that property’s membership of a physiographic zone (as defined by the map). Relying on the property’s membership of a Physiographic Zone may result in inappropriate actions in some circumstances.

Development of the Physiographic Zones in the pSWLP

18 The Southland Physiographic Zones project initially grew from a need to understand variation in nitrate-nitrite-nitrogen (often referred to as NNN and hereafter referred to as nitrate) concentrations in groundwater across Southland. The influence of human (land use) activities on groundwater quality is evident, in the elevated nitrate concentrations, observed across many of the more intensively farmed parts of the Southland Region. Analysis of trends in groundwater and surface water nitrate indicate more sites have increasing nitrate concentrations than decreasing concentrations (Liquid Earth, 2010[3], Moreau and Hodson,

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[3] Liquid Earth, 2010. Environment Southland; State of the Environment: Groundwater Quality Technical Report.

2015[4]). This observation is evidence of the cumulative effect of ongoing land use intensification on water quality across the Southland Region.

19 The occurrence of elevated groundwater nitrate concentrations across Southland is important in terms of both the availability of water for drinking and the down-gradient impacts on ecosystems. Elevated groundwater nitrate is a significant contributor to the load of nitrogen entering Southland's rivers, lakes and estuaries. Nitrogen is a plant nutrient and, in excess of natural levels, leads to the degradation of receiving water bodies by stimulating plant growth in a process known as eutrophication.

20 Data obtained from over 20 years of water quality monitoring across the region also indicates that areas of Southland are subject to water quality issues other than excess nitrogen. For example, levels of *E. coli*, a microbial indicator of the risk to human health from contact with water, do not meet national targets. In addition, direct measures of ecosystem health that are made by the Council, including macroinvertebrate community index (MCI) and periphyton (i.e., algae) biomass in rivers, indicate poor water quality in some locations.

21 It has been noted for some time that there are areas across the region that have particularly high concentrations of groundwater nitrate, approaching or exceeding the maximum allowable value (MAV) for drinking water (e.g., Hamill (1998)[5], Hamill (1999)[6], Environment Southland (2000)[7], Rissmann (2012)[8]). In some instances, areas with high nitrate concentrations, or 'hotspots' were subject to similar land use and farming activities to adjacent areas in which nitrate concentrations were lower (Rissmann, 2012). This led to the conclusion that there is substantial variation in the susceptibility of groundwater to nitrate contamination in different parts of the landscape. A more general

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4 Moreau, M. and R. Hodson, 2015. Trends in Southland's Water Quality: A Comparison between Regional and National Sites for Groundwater and Rivers. GNS Science Consultancy Report, Institute of Geological and Nuclear Sciences, Wellington, New Zealand.

5 Hamill, K.D., 1998. Groundwater Quality In Southland: A Regional Overview. Southland Regional Council Publication, Southland Regional Council, Invercargill, New Zealand.

6 Hamill, K.D., 1999. Nitrate Hotspots Survey of Wells with Excessive Nitrate. Southland Regional Council Publication, Southland Regional Council, Invercargill, New Zealand.

7 Southland's State of the Environment Report for Water - October 2000

8 Rissmann, C., 2012. The Extent of Nitrate in Southland Groundwaters: Regional 5 Year Median (2007–2012 (June)). Environment Southland Technical Report, Environment Southland, Invercargill, New Zealand.

conclusion that arises is that there is significant variation across the region in the way all contaminants are lost from land, and are subsequently transported and transformed, before being discharged to receiving water bodies. This means that water quality outcomes vary across the region, even between locations that have similar land use.

22 The Southland Physiographic Zones project was a concerted effort by the Council to better understand the regional variation in the chemical composition of water and water quality outcomes associated with different landscape settings. The project comprised two phases that overlapped in time: development phase and application phase.

23 The development phase focussed on understanding the chemical composition of water in terms of its provenance, including the influence of hydro-chemical processes as water moves through the landscape (Rissmann et.al., 2016).

24 The application phase focussed on describing the spatial variation in the risk posed by land use to water quality and culminated in the production of the Physiographic Zones (Hughes et al., 2016)[9]. The application phase was strongly informed by the development phase, but its objective was the development of the Physiographic Zones management framework used in the pSWLP, whereas the development phase developed the underpinning science. The approaches and key outputs of the two phases, as they pertain to the main issues addressed in my evidence, are summarised below.

25 The first step in the development phase was the characterisation of chemical composition of water (hereafter water composition) based on an analysis of data provided by groundwater and surface water samples. Water composition data from 1,734 wells and 393 surface water sites distributed across the Southland region (Figure 1) were used in this analysis (Rissmann et al., 2016)[10]. Depending on the site, the data

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9 Hughes, B., K. Wilson, C. Rissmann, and E. Rodway, 2016. Physiographics of Southland: Development and Application of a Classification System for Managing Land Use Effects on Water Quality in Southland. Technical Report, Environment Southland, Invercargill, New Zealand.

10 Rissmann, C., E. Rodway, M. Beyer, J. Hodgetts, T. Snelder, L. Pearson, M. Killick, T.R. Marapara, A. Akbaripasand, R. Hodson, J. Dare, R. Millar, T. Ellis, M. Lawton, N. Ward, B. Hughes, K. Wilson, J. McMecking, T. Horton, D. May, and L. Kees, 2016. Physiographics of Southland Part 1: Delineation of Key Drivers of Regional Hydrochemistry and Water Quality. Technical Report, Environment Southland, Invercargill, New Zealand.

comprised the measured concentrations of a range of water quality and/or hydro-chemical variables obtained from either one-off samples or a series of samples over time. Hydro-chemical variables comprise several measures of the isotopic and ionic concentrations that provide information about a water sample's provenance; both the source of the water and some of the chemical transformations that have occurred subsequent to its introduction to the drainage network as precipitation. For example, data describing the isotopic and ionic composition of water samples reveal differences associated with the altitude of the source area, from high alpine, to hill country and lowland areas.

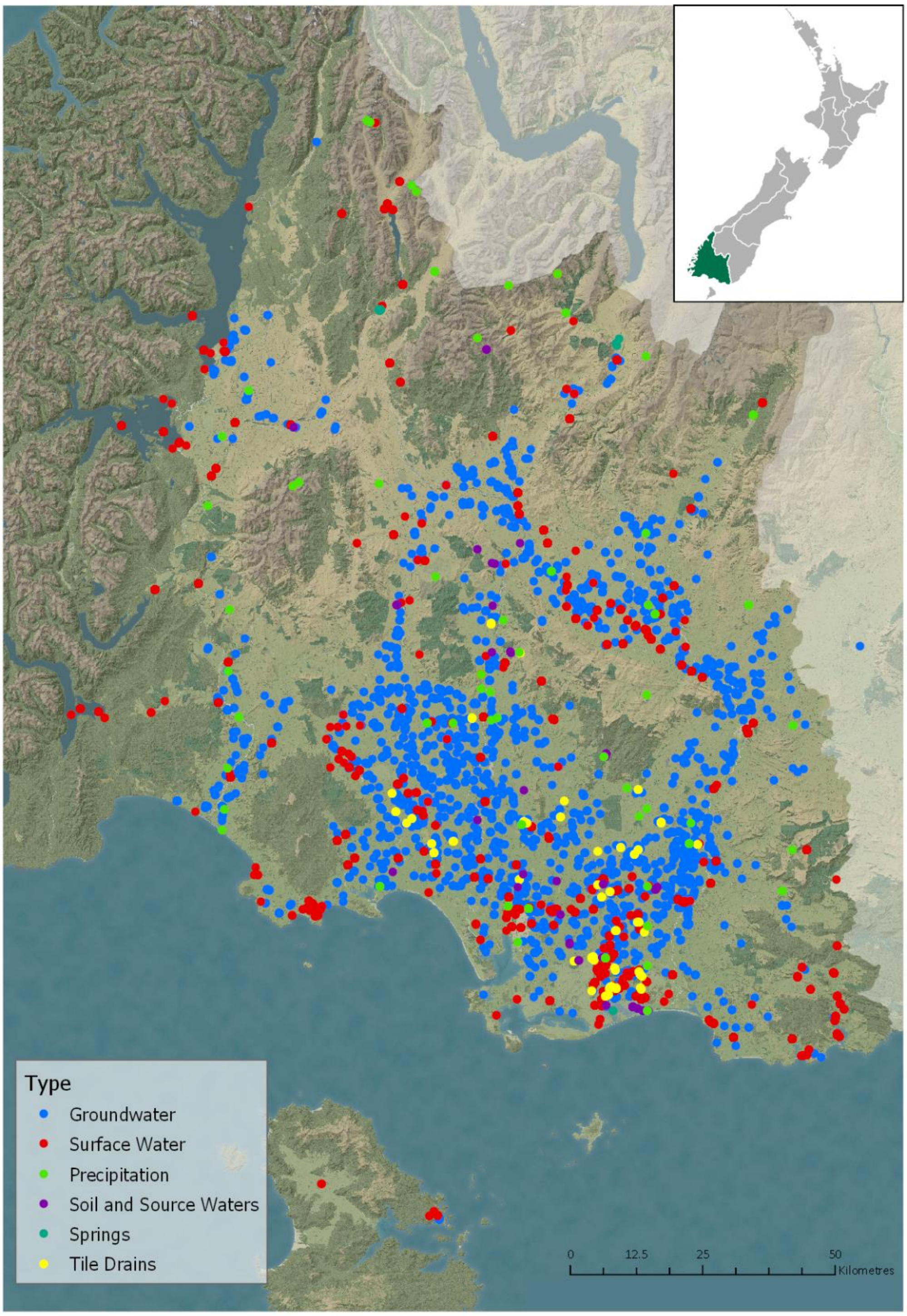

Figure 1. Distribution of sites with measured concentrations of water quality and/or hydro-chemical variables that were used in the development of the Southland Physiographic Zones.

26 Of particular interest was the concentration of nitrate in water, given the existence of nitrate 'hotspots' in the Regions aquifer systems. When the concentration of oxygen in an aquifer is low, nitrate can be converted to nitrogen gas through a biochemical process known as reduction. The

nitrogen gas is lost to the atmosphere, leading to lower concentrations of nitrate in the water, which is referred to as denitrification. Denitrification attenuates (i.e., reduces) the concentrations and loads of nitrate transported to downstream receiving environments (surface and groundwater). Conversely, attenuation does not occur in groundwaters that are high in oxygen (i.e., oxic waters). Therefore, nitrate that is lost from land to aquifers containing reducing groundwater poses less risk to water quality than nitrate that is lost from land to oxic grounwater. The analysis of the 'redox' characteristics (i.e., oxidation-reduction potential) of the water samples revealed patterns in the propensity of parts of the regional groundwater system to reduce (i.e., to attenuate) nitrate.

27 The second step in the development phase was the identification of aspects of the physical geography (i.e., the physiographic character) of the landscape that is the source of water (either the surface water catchment or the groundwater capture zone) that:

(a) had a mechanistic link to the observed water composition; and

(b) were shown to be correlated with the observed patterns in water composition across the region.

28 The four physiographic aspects that most strongly met these criteria were:

(a) precipitation source;

(b) recharge mechanism and water source;

(c) combined soil and geological reduction potential, and;

(d) the combination of geomorphic setting and substrate (rock or biological sediment) composition.

29 Variation in these physiographic aspects is recognisable as landscape-scale variation across the region. For example, mountains, hills and lowlands, broadly distinguish differences in precipitation sources. Variation in geology and soils distinguishes differences in combined soil and geological reduction potential. Available spatial data layers such as topographic, geological and soils maps were used to derive a series of spatial data layers (referred to as driver layers) representing this physiographic variation. Statistical analysis was used to show that different combinations of all four factors was associated with variation in

water composition. The hydrochemical data was used to infer the mechanisms that led to water composition differences occurring in waters with different provenance.

30 The development phase of the project therefore mechanistically and statistically linked variation in regional physiography to the variation in water composition across the region. It is important to note that the four physiographic aspects do not include land use, so they do not predict water quality *per se,* but they do discriminate differences in the provenance of the water and the chemical processes that it has undergone in different parts of the landscape.

31 The first step in the application phase that defined the Physiographic Zones was to postulate a conceptual model describing variation in transport, dilution and attenuation processes associated with four main contaminants: nitrogen (N), phosphorus (P), sediment (S) and microbes (M).

32 The model was based on the assumption that, at landscape-scales, these processes are broadly controlled by the same physiographic aspects that were identified by the development phase. Some additional elements were included in the conceptual model based on hydrological principles. In particular, the conceptual model includes a variety of flow paths that are the dominant transport mechanism for contaminants at the landscape-scale. The flow paths represented include: overland flow (horizontal flow across the surface), lateral flow (horizontal flow through the soil), artificial drainage (soil water is removed from the soil via constructed drains), deep drainage to groundwater via the soil profile (vertical flow path via soil profile) and deep drainage as natural by-pass flow (water drains vertically via cracks, fissures and macropores thereby by-passing the soil profile).

33 A key assumption of the conceptual model is that landscape-scale variation in transport, dilution and attenuation processes is associated with different combinations of the physiographic factors. This assumption enabled the mapping of the Physiographic Zones and was justified by the findings of the development phase. In addition, it is assumed that combinations of the physiographic aspects give rise to specific water quality risks. This assumption was justified by the mechanistic understanding that was also informed by the development phase.

34 The second step in the application phase identified nine Physiographic Zones, described each zone's water quality risks, and mapped their spatial distribution. The number of zones and the consequent resolution of water quality variation was strongly informed by the development phase, but also pragmatic decisions regarding a balance between:

(a) the available water composition data across the region to develop the conceptual model and test the Physiographic Zones;

(b) the landscape-scale resolution implied by the conceptual model; and

(c) the practical differences in water quality risk that can be addressed by management actions.

35 The Physiographic Zones therefore represents a subdivision of the region's water quality risk that is justifiable based on landscape considerations, empirical evidence, and which stratifies unique risks and appropriate management actions.

36 The Physiographic Zones identified in Southland are:

(a) Alpine;

(b) Central Plains;

(c) Gleyed;

(d) Bedrock/Hill Country;

(e) Lignite/Marine Terraces;

(f) Old Mataura;

(g) Oxidising;

(h) Peat Wetlands; and

(i) Riverine.

37 The Physiographic Zones stratify the region's physiographic conditions that give rise to specific water quality risks. For example, particular soils and geologies lead to dominantly vertical drainage in some locations. Vertical drainage via the soil profile leads to low risks associated with sediment and microbial contaminants due to filtration and sorption. However, vertical drainage transports nitrate into groundwater systems. Within areas with predominantly vertical drainage, there is variation in

the redox characteristics of soils and underlying aquifer material leading to variation in the risk to groundwater (and subsequently surface water) posed by nitrate. It is noted that redox also influences the risk posed by phosphorus, which is also a plant nutrient. The variation in redox character therefore required further subdivision of areas with predominantly vertical drainage to recognise the variation in risk posed by these nutrients. The nine Physiographic Zones therefore describe appreciable regional differences in the risks to water quality outcomes in at least one of the four main contaminants (N, P, S and M).

38 The conceptual model recognised that within five of the nine Physiographic Zones (Bedrock/Hill Country, Gleyed, Lignite/Marine Terraces, Oxidising and Riverine), there are locations where the drainage pathway includes overland flow and/or artificial drainage on an intermittent basis, generally when soils are saturated. These situations are referred to as variants and are associated with additional water quality risks due to reduced contaminant attenuation. Variants were delineated using assessments of overland flow potential and artificial drainage density.

39 Whereas the development phase used statistical methods to link water composition to the physiographic conditions (drivers), the boundaries of the Physiographic Zones were based on expert-defined mapping rules that were applied to available topographic, geological and soils maps. For example, the boundary of the Alpine zone was defined by the 800-meter elevation contour with all land areas higher being assigned to this zone. The mapping rules are transparent about the different combinations of physiographic conditions that define the Physiographic Zones and make the criteria that define their boundaries easily understood.

40 The final step in the definition of the Physiographic Zones was a statistical validation using the available water quality data (Snelder et al., 2016)[11]. The validation study showed that the Physiographic Zones strongly discriminate variation in the water quality observed at river monitoring sites. Differences in groundwater quality observed at monitoring wells was less well explained by the Physiographic Zones.

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11 Snelder, T., B. Hughes, K. Wilson, and K. Dey, 2016. Physiographic Zones for the Southland Region: Classification System Validation and Testing Report. LWP Client Report, LWP Ltd, Christchurch, New Zealand.

These differences reflect better characterisation of river water quality due to more frequent sampling compared to groundwater. In addition, it was considered that the Physiographic Zones performed well for river water quality, because each river site represented an integrated measure of the overall hydrological and biogeochemical characteristics of a Physiographic Zone. By contrast, it was generally more uncertain what Physiographic Zones the groundwater observations represented. For example, groundwater quality in an individual monitoring well may reflect mixing of waters derived from multiple physiographic zones across a spatially extensive up-gradient recharge area. Groundwater quality may also vary vertically within an aquifer, with groundwater at different depths reflecting the geochemical characteristics of the host geology as well as the mixing of water quality characteristics from recharge areas of differing spatial extent.

41 The tests also showed that the temporal behaviour of individual water quality variables (for example their seasonal patterns and propensity for observations to vary over time) differed between the Physiographic Zones. Furthermore, statistical tests were made to compare the observed temporal behaviour of water quality with the expected behaviour, based on the conceptual model underlying the Physiographic Zones. Where there was sufficient data, these tests indicated that differences were generally consistent with expectations developed from the conceptual model. The tests therefore supported, as far as was possible given the data, the conceptual model, the stratification of the region into Zones, and the water quality risks associated with the individual zones.

42 The nine Physiographic Zones and their key features are summarised in Table 1 and are discussed in further detail in the evidence of Mr Rodway. Council has developed a framework around the Physiographic Zones and their variants to assist in managing the effects of land use on water quality. The framework comprises technical information describing in detail each of the zones, including their physiographic character, water quality implications and risks, variants, associations with other zones and mitigation objectives.

Table 1. The Physiographic Zones and their key features. The water quality risks associated with each Zone are discussed in the evidence of Mr Rodway.

Physiographic zone	**Key features**
Alpine.	High elevation, steeply sloping areas with thin soils or bare bedrock that receives high volumes of dilute precipitation. Soils and geology have a little influence on hydrochemistry and water quality.
Bedrock/Hill Country	Prominent landforms where soils overly bedrock or glacial till, and where there is a history of dense vegetation cover. Soils can exert a strong influence on hydrochemistry and water quality depending on residence time.
Central Plains	Clay-rich soils that shrink and swell with changing soil moisture levels resulting in bi-modal drainage (i.e., deep drainage when soils are dry and artificial drainage when soils are wet). Reducing soils overlie oxidising groundwater.
Gleyed	Fine textured, poorly drained soils that exhibit redoximorphic features such as mottling and gleying.
Lignite/Marine Terraces	Underlying geology contains carbonaceous sediments that can exert a strong influence on hydrochemistry and water quality
Old Mataura	Highly weathered soils and geology on elevated terraces that have few permanent surface water features. Oxic soils and groundwater.
Oxidising	Well drained soils that overlie alluvial deposits that contain an extensive groundwater resource. Located on intermediate terraces. Oxic soils and groundwater.
Peat Wetlands	High organic carbon content in soils and underlying geology that exerts a strong influence over hydrochemistry and water quality. Soils are poorly drained, acidic and peaty.
Riverine	Highly connected rivers and adjacent groundwater that contain large volumes of alpine-sourced water with low contaminant concentrations. Soils are shallow and well-drained overlying shallow aquifers.

Limitations of the Physiographic Zones

43 The conceptual underpinning and the underlying data used in the definition of the Physiographic Zones determines the limits of their resolution of water quality risk in three ways. First, they are a coarse stratification of water quality risk. Second, rather than being distinctive entities, the nine Zones represent a coarse subdivision of continuously varying physiographic conditions. The Physiographic Zone boundaries are therefore an abstract representation of an area of transition from one zone to another. Third, the mapping rules were applied to low resolution maps leading to inaccurate boundaries in some locations.

44 The conceptual model assumes that contaminant transport, dilution, and attenuation is controlled, at landscape-scales, by physiographic

characteristics. The choice of the landscape-scale conceptual model partly reflects the amount of water composition data (i.e., the number of sites) that informed both phases of the project (Figure 1). Sites with data describing water composition were sparsely distributed across the region but covered a wide range of physiographic characteristics. Surface water sites, which were later shown to be most consistently linked to the Physiographic Zones, were particularly sparse (Figure 1). The number and density of sites, and their representation of variation in physiographic characteristics, determined the level of detail that could be included in the conceptual model. The sparsity of the data meant that the development phase of the project could only perceive coarse (i.e., landscape scale) variation in water composition and, consequently, the Physiographic Zones only stratify broad-scale variation in water quality risk. This coarseness is reflected in the subdivision of Southland into a relatively small number of zones (i.e., nine).

45 The Physiographic Zones map depicts sharp boundaries between zones, however, in general, landscape-scale variation in the physiographic characteristics is not associated with abrupt transitions. Rather physiographic characteristics of what is conceived of as a landscape unit belonging to one zone, grade into, and are potentially mixed with, those of an adjacent unit. Therefore, the mapped zones and their boundaries are abstract representations of continuously varying physiographic conditions and therefore water quality risk, across the region. The lines representing boundaries on the Physiographic Zone map are, therefore, a cartographic device that represents what is, in reality, an area of transition from one zone to another.

46 An example of the abstract nature of the Physiographic Zone boundaries is the definition of the Alpine Zone. The zones recognise that altitude is a key characteristic of the precipitation source that is mechanistically linked to water composition. Altitude is therefore a significant feature of the map of the Physiographic Zones (Figure 2) with the Alpine Zone being defined by areas having an elevation of greater than 800m. The line that distinguishes the Alpine Zone is therefore representative of the transition to Alpine Zone physiographic characteristics. While 800m may broadly discriminate alpine characteristics (i.e., at landscape scales), at finer scales other factors such as orientation and fine scaled geomorphic features (e.g., ridges and gullies), also determine “alpine conditions”. The boundary of the Alpine Zone is therefore representative of the

transition from lower to higher precipitation source and it should not be interpreted as an absolute boundary. In general, the boundaries of all the Physiographic Zones are representative of transitions and should be regarded as fuzzy boundaries between areas that have different physiographic character and water quality risk.

47 The conceptual model's coarse and abstract description of water quality risk across the Southland Region is analogous to a person's view of variation in physical geography when flying in an aircraft at a very high altitude. At this altitude, broad differences between mountains, hills and lowlands and major features such as lakes and rivers can be perceived. It may also be possible to perceive significant differences between parts of lowland areas that differ with respect to their geological substrate because these would be associated with subtle differences in vegetation. However, just as variation in the region's physical geography can only be broadly resolved when flying at high altitude, the boundaries on the Physiographic Zone map broadly represent transitions between different types of water quality risk.

48 It is noted that soil and geological maps are generally drawn with lines denoting sharply defined and homogeneous physical units. In reality, the characteristics of one soil or geological type grade into, and are potentially mixed with, those of the adjacent type. In this sense, the physical abstraction of cartographic boundaries of the physiographic zones are no different to other maps of physical attributes. However, in the case of the Physiographic Zone map, the units represent homogeneous areas with respect to multiple physical attributes, so the abstract nature of the boundaries is compounded.

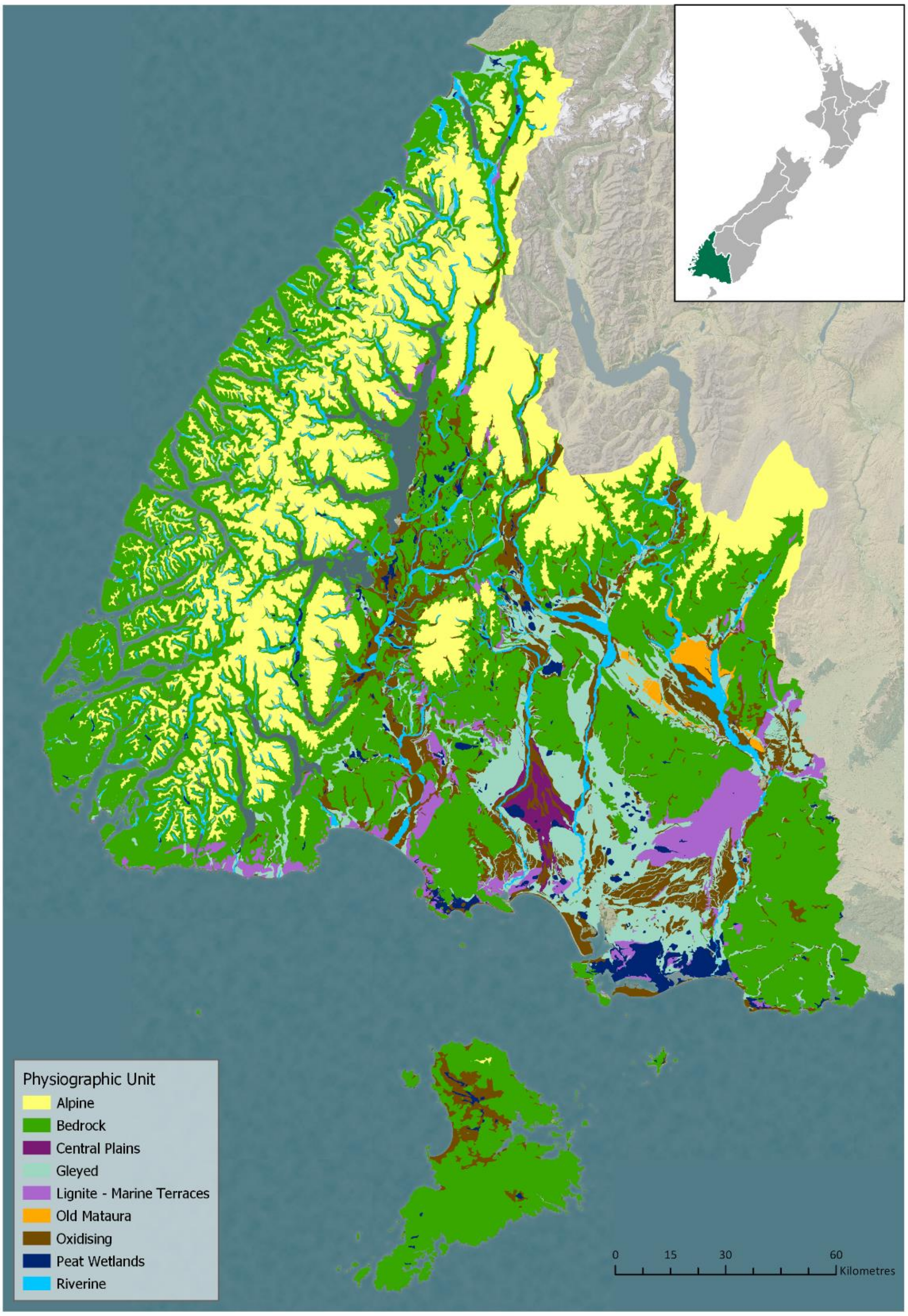

Figure 2. Map of the Physiographic Zones of Southland.

49 The third source of limitation of resolution of water quality risk by the Physiographic Zones is the mapping information that was used to assign all parts of the region to a zone, and to draw the Zone boundaries seen in Figure 2. The Physiographic Zones map was produced by applying criteria, or mapping rules, to multiple component maps, including soil survey maps (with the finest mapping scale being 1:50,000) and

geological maps (1:250,000 scale) and the River Environment Classification (REC), which was derived from 1:50,000 scale topographic maps. These maps were used because they represented comprehensive (i.e., whole region) coverage at the highest resolution available. However, the spatial detail and accuracy of these maps was commensurate with their mapping scales. Lines drawn on maps of 1:50,000 scale or coarser appear inaccurate, at least in some locations, to a person standing in the landscape. This means that although the mapping rules are clear, they are applied to data that in some locations were inaccurate. Therefore, the Physiographic Zones boundaries are inaccurate, at least in some locations, at the scale of individual properties.

50 Returning to the airplane passenger analogy, the accuracy of the boundaries shown on the component maps is analogous to a person's ability to draw lines separating geographic features when flying in an aircraft at a very high altitude. The location of the boundaries shown on these maps would be more highly resolved by a finer scale map just as an aircraft passenger would draw more accurate and highly resolved boundaries between geographic features when flying at a lower level compared to a higher level. This means that some of the boundaries of the mapped zones are inaccurate at the scale of individual properties. These inaccuracies may mean that a Physiographic Zone boundary as indicated on the pSWLP map is inconsistent with mapping rules and the actual conditions on the properties.

51 There is a third general limitation to the ability of the Physiographic Zones to resolve water composition and water quality risk which is related to the use of physiographic characteristics. The physiographic characteristics are inherent or natural aspects of the landscape that determine water composition and water quality risk. The coarse subdivision of the region into nine Zones discriminates broad differences but there is internal variation within individual zones. A key cause of variation between sites or farms belonging to the same Zone are anthropogenic factors that modify the natural conditions and create water quality risks that are in addition to the inherent risks. For example, at the scale of a property, soil compaction by over-treading and other land use activities may have resulted in what was once a well-drained soil becoming compacted and requiring artificial drainage. This would

alter the water quality risk from nitrate loss to groundwater to N, P, S, M loss through artificial drains.

Utility of the Physiographic Zones

52 The Physiographic Zones describe variation in some of the key processes and pathways that determine water quality risk across Southland. Statistical testing has shown there are robust differences in water composition between Zones. In addition, statistical testing has shown that water composition observations are consistent with the mechanistic understanding of processes and pathways that underlies the conceptual model. The framework that has been developed around the Zones provides information for understanding and managing the water quality risks associated with each Zone. This means that knowledge of Zone membership for a property provides a basis for identifying the main types of water quality risk that can be expected.

53 However, users need to be cognisant of three things:

(a) The limitations to resolution of detail and spatial accuracy described above means Zone membership does not describe all sources of water quality risk at the scale of an individual property.

(b) The Physiographic Zone boundaries are indicative of areas where there is a transition from one set of conditions to another. Because the mapped boundaries are abstract, the main water quality risks in these transitional areas will be described by one or both of the Zones that the boundary separates. This means that the main water quality risks at the property scale can be guided by the Physiographic Zones but require “on the ground” judgment and interpretation.

(c) The boundaries of the Physiographic Zones, as described by the mapping rules, will sometimes be inaccurate at the property scale (i.e., by a person standing in the landscape). This means that the main water quality risks at the property scale can be guided by the Physiographic Zones but require “on the ground” judgment and interpretation.

(d) local-scale water quality risks can be modified by land management and land use activities

Use of the Physiographic Zones in decision making

54 I consider the Physiographic Zones are a useful, generalised description of the broad (i.e. landscape-scale) variation in water composition and water quality risk across the Southland region. The Physiographic Zones are, therefore, an appropriate framework for broadly defining the actions that will be taken to manage water quality risk across the region. Based on what is understood about variation in processes and associated water quality risk, it is appropriate that there are differences in management actions and management requirements between properties belonging to different Physiographic Zones.

55 I consider that the Physiographic Zones can provide a basis for directing certain activities away from situations in which they may pose a particular risk, because of dominant flow paths and water quality risks. I also consider the Physiographic Zone information could be used as a starting point for identifying the dominant flow paths and water quality risks that are likely to occur on individual properties given their membership of a Physiographic Zone. In addition, the framework that the Council has developed around mitigation objectives for individual Physiographic Zones is an appropriate starting point for managing water quality risks, either on individual properties or individual Zones.

56 However, any use of the Physiographic Zones needs to be cognisant of the three limitations discussed above. Because of these limitations, I do not consider it would be appropriate to specify actions associated with managing water quality risks for individual properties based purely on that property's membership of a Physiographic Zone (as defined by the map).

57 Relying on the property's membership of a Physiographic Zone may result in inappropriate actions in some circumstances for two reasons. First, the property may be allocated to a Physiographic Zone that is not consistent with its' actual landscape characteristics or water quality risks. This will arise because of the abstract nature of the Physiographic Zone boundaries and the inaccuracy of those boundaries with respect to the mapping rules. Second, there may be water quality risks associated with the property that are different or in addition to the general risks associated with the Physiographic Zone to which it belongs. This will arise because a property may have water quality risk factors other than

those that are generally true of the Physiographic Zone to which it has been allocated.

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Dr Antonius Snelder