Department of Conservation
Te Papa Atawhai

Freshwater Ecosystems of New Zealand

USER GUIDE

Freshwater Ecosystems of New Zealand (FENZ) Geodatabase

VERSION ONE – AUGUST 2010

USER GUIDE

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Department of Conservation

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1. INTRODUCTION

This document provides an introduction to the Freshwater Ecosystems of New Zealand or FENZ database, a set of spatial data layers describing environmental and biological patterns in New Zealand's freshwater ecosystems. These layers were designed as a resource that provides consistent national coverage of information about those ecosystems, including their geographical locations, their physical and biological attributes, and their current condition. The database also includes worked examples of how this resource information can be used to assess the value of different sites to inform management decisions about the long-term protection of natural values, including biodiversity. While protection of these intrinsic values of our freshwaters may incur a degree of economic cost, they are an important contributor to the well-being of all New Zealanders, delivering a broad range of benefits that underpin our economic, social, cultural and spiritual well-being.

The FENZ database grew initially out of work initiated under a whole of government initiative run under the Sustainable Development Programme of Action for Freshwater to identify Waters of National Importance (WONI) for tourism, irrigation, energy generation, industrial uses, recreation, natural heritage and cultural heritage. The Department of Conservation (DOC) was given the task of identifying a candidate list of nationally important aquatic systems for freshwater natural heritage. Following the production of satisfactory results from an initial pilot analysis (Chadderton et al. 2004), the Department commissioned a range of further research (mostly from the National Institute of Water and Atmospheric Research and Landcare Research), to better identify sites with high natural values, with separate projects focussing on lakes, wetlands, and rivers and streams. These sought in particular to develop improved descriptions of biological values, more comprehensive ecosystem classifications, more robust assessments of human impacts, and higher resolution methods for the ranking of sites. This DVD presents many of the data resources and results produced during that research, along with additional relevant data produced for the Department during research on freshwater biodiversity patterns funded under the Terrestrial and Freshwater Biodiversity Information System fund (TFBIS).

A range of documentation is provided with the FENZ Geodatabase. This *FENZ User Guide* is the primary source of information about FENZ. Section Two provides a broad introduction to the database and its purposes; Section Three describes each of the individual components in greater detail, including how they were constructed, the various sources of input data that were used, and guidance on their limitations and appropriate uses. A collection of PDF reprints of published documents is also included both in the primary database source folder (DOC) and in a folder on the FENZ DVD, and this provides a broad range of more detailed background material for those users who want to explore the development and use of these data "in greater detail.

2. AN OVERVIEW OF FENZ

In this section we present an overview of some of the broad concepts and ideas that underlie the development of data presented on the FENZ DVD. It is intended as a broad technical introduction to help end-users understand the types of data contained in FENZ, how they were developed, and how this affects their use and interpretation.

2.1. Environmental data

Environmental data form the base for many of the layers contained in the FENZ Database. Where possible, environmental attributes have been provided for each spatial feature, i.e., each river segment, lake, or wetland. Some of these describe the environment directly at the site, while others describe broader features of the surrounding environment, e.g., the amount of native vegetation or average slope in the upstream catchment, or the distance to the coast.

Values for some of these attributes were derived directly from measurements – examples include satellite based estimates of catchment cover, or measurements of geographic distance or slope. By contrast, other attributes were estimated from models, given the absence of comprehensive measurements at all sites. For example, temperature estimates have been estimated from mathematical surfaces fitted to climate station observations, and river flows have been calculated from hydrological models. Wherever possible, information has been provided about how the data were generated either in the more detailed descriptions provided below or in the references provided at the end of this document.

2.2. Biological data

Comprehensive biological data is only available for a small percentage of New Zealand's freshwater ecosystems, with records for rivers and streams generally being more comprehensive than for lakes and wetlands. However, even in our riverine ecosystems, records from one of our biggest freshwater biological databases, the New Zealand Freshwater Fish Database, sample only a little more than 1% of the half million or so river and stream segments in the river network database. Similarly, a compilation of macroinvertebrate samples of New Zealand rivers and streams samples less than 0.5% of the total number of river and stream segments. Particularly for the rivers and streams, this problem has been addressed using environment-based species distribution models. These build a model of the relationship between species occurrence and environment at the sample sites, and this model is then used to predict the probability of capture for each species across the entire river network. This works well for many species that, as a consequence of their good dispersal ability, are geographically widespread (e.g., diadromous fish). However, for other species (e.g., many non-diadromous fish species), both environmental and geographical effects are important in determining their distributions. Here a model based solely on the environment identifies the conditions preferred by the species, but will predict occurrences in catchments outside its known geographic range – for these species we account for the geographic restriction by only making predictions for those catchments in which the species is known to occur. More details of these methods and their use as tools to understand the distributions of species can be found in Leathwick et al. (2008a), Elith & Leathwick (2009), and the references that they contain.

2.3. Classifications

Classifications are an integral part of the FENZ Database and play a critical role in grouping together rivers and streams, lakes, or wetlands that have similar ecological character. Ideally, these classifications would be defined using comprehensive biological data for all sites, but that is clearly impractical, given our relative lack of survey data. Two approaches can be used to overcome this difficulty. First, we could use modelled biological data for all sites (see previous section) to define a classification of the expected biological character of all sites. However this approach is not only time-consuming, it is also hampered by our lack of robust knowledge about where many species occurred historically.

An alternative approach is to use the environmental factors that are important drivers of biological patterns, particularly if we focus on those aspects of the environment that are less affected by human activities. By grouping together lakes or rivers and streams using this approach we can define groups of sites that share similar environmental character, and if we use the major drivers of biological patterns to define the classification, then we can have reasonably confidence that these groups of sites will also have similar biological character.

Use of classifications in this way can have significant practical advantages. In particular, it gives us a useful way to compare and contrast sites, for example, if we wanted to design a monitoring scheme that reports on the average conditions for a particular group of functionally related streams (lowland hill-country) or lakes (shallow, coastal). Similarly it can be used to indicate where a particularly monitoring method should or should not be used, where results of a particular management intervention can be realistically applied, or how far the findings of an intensive site-based study can be extrapolated to other sites.

Two of these classifications (rivers and streams, lakes) are also hierarchical in that they provide varying levels of classification detail. For example, the river and stream classification can be used at a 20-group level for making national summaries, or can be used at 100, 200 or 300 group levels of classification if finer levels of subdivision are required for regional or local analyses. By contrast, the wetlands classification has a single level of detail, separating wetlands into eight classes on the basis of their hydrological and nutrient status.

Further information on the use of environmental classifications in aquatic environments can be found in Snelder & Biggs (2002), Leathwick et al. (2010), and the references that they contain.

2.4. Human pressures and their impacts

Estimating human impacts on biological integrity across a wide range of conditions and for large numbers of sites was one of the most challenging parts of the WONI project. Lack of spatially comprehensive, quantitative data was again problematic, as is the manner in which a range of factors generally act in combination, i.e., intensive human use of a landscape is usually reflected in all of these factors being present, and this makes it difficult to isolate the impacts of any one of them. Given these difficulties, we adopted an expert opinion-based approach, built around identifying for each of the three broad environment types (i) the major human drivers of change, (ii) their likely impacts on biological integrity, and (iii) how these effects could be combined to derive an overall condition score. Each of the individual pressure factors had to be able to be measured or estimated for all sites, and these estimates were then used to calculate the likely impact on biodiversity using a consensus-defined response curve. These estimates of biodiversity decline were then combined into a single index, values for which varied from 1 (pristine) to 0 (totally degraded). More details of the methods used to estimate pressures are provided in the second part of this user guide, and in contract reports provided on the DVD (Leathwick & Julian 2007; Ausseil et al. 2008; deWinton et al. 2008).

2.5. Conservation rankings

Calculating the conservation value of sites is a complex process that can be addressed in a variety of ways depending on the objectives, and rankings calculated for one purpose may be of only marginal value for a contrasting purpose.

One common requirement in conservation management is for rankings that identify the minimum set of sites, often referred to as planning units, that will adequately represent the biological values of a particular landscape, e.g., as when identifying a set of sites requiring protection for conservation purposes. Here the objective is to identify the most efficient set of reserves that protects the full range of values, given some threshold level of protection to be applied in total across the landscape, and these will generally contain the best remaining examples of a full range of ecosystems. By contrast, a regional council or other land-managing authority might be interested in a more straight forward ranking, in which it simply wishes to identify all those sites in which freshwater ecosystems have been retained in good condition so that limitations can be placed on particular landuses. In this case, the assessment is based much more on the inherent values and condition of a site as a discrete entity, i.e., regardless of how its biological values compare with those of other sites, or how frequently its values occur elsewhere across the landscape.

One of the first steps in assessing the conservation value of a site is establishing the biological values that are present. Where only a few sites are to be assessed, this can often be achieved by assembling available biological data, perhaps augmented by field survey; alternatively, and in particular where assessments are required for large numbers of sites, an environment-based classification can be used as a surrogate to capture variation in biological values, e.g., the classification of rivers and streams described above. A second challenge in calculating the importance of sites is assessing the degree to which biological values have been affected by human pressures, this being complicated by both the range of human factors affecting freshwater ecosystems, and our frequent lack of quantitative information describing their impacts. Given these difficulties, the rankings presented here for rivers and streams, lakes, and wetlands, are all based on assessment of the impacts of a range of remotely assessed factors, with these impacts described using qualitative curves based on expert opinion as described in Section 2.4.

Having assembled the required information about biological values and human impacts for some set of sites, decisions must then be made about how to calculate rankings. Where one simply wishes to identify all sites that have high biological values to minimise further loss, then a scoring based approach is likely to work well, and this might consider factors such as the size and buffering of sites, the diversity of biological values that they contain, and their degree of human modification. Once all candidate sites have been ranked in this way, all those having scores exceeding some critical threshold can be flagged as having "high" value. Additional information describing the level of protection currently provided to each ecosystem might also be useful. Combining information about condition, protection, and the likely timing of any development would then enable the most urgent priorities for management attention, i.e. good condition sites that support ecosystems with low levels of protection in the surrounding landscape, and particularly those in environments with high development pressure.

The required approach becomes much more complex when the objective is to identify a minimum set ranking that identifies a set of sites that will most efficiently provide representative protection for a full range of the biological values of a landscape. Here the ranking of a candidate site depends not only on its biological attributes, but also on how those relate to the values represented by other sites that have already been chosen. The objective in this case is to identify a set of sites that together protect the full range of biological values in a landscape, and for any one particular biological value (e.g., small alpine lakes) a wide choice of candidate sites might be selected in an interchangeable fashion with little effect on the overall outcome. In this case, the allocation of a low ranking to a particular site cannot be used to reliably indicate that it does not contain biological values that are of low quality — some low ranked sites will undoubtedly be in poor condition, but others may still be in excellent condition. In the latter case the low ranking simply reflects that another comparable site offers a more efficient option for protection of the particular biological values that they share in common. Conversely, some sites that are in a poor condition are likely to be highly ranked, and here their high ranking indicates that they are the best choice possible to provide protection for an ecosystem type that has been severely degraded throughout its range. In summary, the rankings allocated in a minimum set process will reflect not only the inherent biological values of sites, but also how those values complement the values of other high ranking sites; while they will generally identify good condition examples of a full range of ecosystems, not all good condition sites will necessarily be highly ranked; conversely, some poor condition sites may be highly ranked where a particular ecosystem has been highly impacted.

Particularly in freshwater ecosystems, connectivity is also important, reflecting the functional importance of longitudinal connections along river systems (Abell et al. 2007), which frequently also involves wetlands and/or lakes. Given these effects, it is clearly much more efficient to protect a catchment that contains a range of ecosystems, rather than to protect a particular ecosystem in one sub-catchment, a second in an unconnected sub-catchment, and a third in yet another location. In the minimum set rankings described below, particular techniques have been used to encourage the identification of catchments (or sets of sub-catchments) in which multiple river and stream ecosystems can be protected within one river system. We have also experimented with extending this approach to include connectivity effects between rivers and streams, lakes, and wetlands — this approach shows considerable promise for its ability to identify catchments that contain high values across all three habitat types, often with minimal reduction in outcomes compared to when those habitats are assessed individually. Further reading on the use of connectivity considerations when protecting freshwater ecosystems can be found in Abell et al. (2007), Linke et al. (2007), Moilanen et al. (2008), and Leathwick et al. (2010).

2.6. Data accuracy and reliability

Users of the FENZ Database layers need to be aware that any extensive spatial data describing environmental and ecological patterns will contain uncertainties and inaccuracies — these are particularly unavoidable when trying to assemble consistent information about such spatially dispersed features as rivers and streams, lakes and wetlands. The following material is intended as a summary of the likely accuracy and reliability of the different FENZ components; users should also consult the reports referenced for the various data components in Section Two for more detailed accounts of their likely reliability.

Spatial accuracy

Establishing the spatial locations of lakes was relatively straightforward, given the ready availability of the digital spatial data describing lake locations that was compiled for the production of New Zealand's 1:50 000 topographic map series. In using this data, we imposed a lower size limit of 1 ha for inclusion of a lake in the working database, and assigned each of the retained lakes a unique numeric identifier. A small number of lakes were subsequently removed when it became apparent that they had also been included as areas of more open water in our wetlands layer.

Our description of the spatial locations of rivers and streams was drawn directly from the existing River Environment Classification (REC — Snelder & Biggs 2002), i.e., the majority of our riverine spatial data are delivered using the REC network topology, although with substantial numbers of REC flow-lines in lakes removed by overlay against the lake spatial data. We highlight in particular that the REC topology was derived by automatic analysis of digital elevation data based on national 20m contour data, rather than from the topographic map stream lines. While use of this relatively coarse resolution elevation data generally provided good identification of stream flow lines in hill-country, it is less satisfactory at detecting smaller streams in flatter areas, e.g., alluvial flood plains. Users should therefore be wary of over-relying on the positions of small streams in these low-gradient landscapes, using the spatial data with a degree of caution, backed by field knowledge where required.

The locations of wetlands were the hardest to map as they are often situated on the ecotones between terrestrial and fully aquatic systems, often have varying water levels, and can be difficult to differentiate from other vegetated areas when their identification is based on use of aerial photographs and/or remote sensed imagery. In addition, extensive drainage of these systems is still ongoing, so that some wetlands that we identified will have either been reduced in size or no longer exist. Conversely, we are also aware that the approach used failed to identify a small number of wetlands. Given these difficulties, we provide this information with the explicit acknowledgement that further field checking is required to improve its quality.

Environmental and biological attribute data

A broad mix of techniques were used to generate the environmental and biological attribute data associated with each of the aquatic features contained in the FENZ database—the particular method used frequently influences the reliability that is associated with each data component. Estimation of a number of important environmental descriptors, e.g., river and stream gradients, catchment cover, lake area, was relatively straight-forward using standard and widely available spatial data and analysis tools, and should have minimal error. Obtaining estimates for other parameters was facilitated by the intensive research effort that has been invested in the estimation of attributes such as river and stream flow and its variability, and nutrient loads – however, the modelled nature of these estimates makes them slightly less certain than directly measured variables. Although lakes are far fewer in number than either rivers or wetlands, environmental (and biological) data are available for only around 10% of them, and this was generally biased towards larger, lowland lakes; the absence of comprehensive lake depth data was particularly limiting and estimation of lake depths based on the surrounding topography was not always reliable. Identification of the effective contributing catchment for wetlands that are predominantly rain-fed was sometimes difficult.

In broad terms, much more biological data was available for rivers and streams than for either lakes or wetlands. However, even in the rivers and streams, biological descriptions were only available for a subset of river and stream segments, and this necessitated the use of environment-based interpolation techniques to estimate the biological character for the vast majority of segments for which no field data were available. The statistical techniques used to carry out this interpolation generally worked very well, particularly for the more widespread species. Source documents referenced below provide estimates of prediction accuracy for each species, along with estimates of the prediction error. Insufficient biological sample data was available to support the use of these techniques for lakes and wetlands. Biological description in this case is limited to the allocation of each lake or wetland to a classification group as described in the detailed sections on lakes and wetlands in Section Three.

Estimation of human impacts

As already indicated above, estimation of human impacts on the integrity of our freshwater ecosystems was hampered by our lack of up to date and robust descriptions of human induced changes in the physical environment and how these impact on biological values. Estimating human impacts on rivers and streams was facilitated by national data describing catchment clearance, nutrient inputs, the presence of dams, and the distributions of introduced fish, but making inferences about the impacts of these factors was a more uncertain process. Inferences about river impacts from human activities in the catchment are often stronger than for wetlands and lakes due to the way in which the longitudinal connectivity that is a feature of river systems homogenises human impacts with progression downstream.

Estimation of human impacts on wetlands was also heavily reliant on the use of remote sensed data, and while this might be reasonably reliable for some wetlands (e.g., riverine) that have strong hydrological linkages with their surrounding catchments, it will be less reliable for those systems (e.g., mires) where that linkage is weak and rainfall provides the major input of freshwater.

Describing human impacts on lake integrity was complicated by a general lack of relevant data, the nature of the drivers that bring about lake degradation, and the nature of lake responses. For example, introduction of alien plants and fish is one of the main causes of lake degradation, but these introductions tend to be highly chaotic in nature, and are not readily predicted from the broader environment (e.g., as could be done for native species in rivers). In addition, the responses of lakes to both introduced pest species and elevated inputs of nutrients from human land-uses is often highly non-linear – a lake may appear to have a high degree of resilience for a time, but then undergo a catastrophic collapse of its macrophytes, transitioning to an algal dominated system. Last, some lakes (e.g., peat lakes) can be relatively weakly connected to their surrounding landscapes, either because of minimal water flows from the surrounding catchment or because of strong buffering of inputs by the immediately surrounding vegetation.

Ecological classifications

The varying amounts of data available across the different realms results in quite different levels of reliability in the classifications contained in the FENZ database. The river and stream classification is the most data-defined of the three classifications, with extensive biological data used to identify, weight and transform the available environmental predictors; the resulting classification has been effectively tuned to maximise its discrimination of biological pattern. By contrast, insufficient biological data was available for either the lakes or wetlands, where two contrasting approaches were used. The variables used to define the lake classification were selected by an expert group, but once defined, there was no way of verifying the ability of this classification to act as a surrogate for biological patterns; it is best regarded therefore as a working hypothesis of lake groupings, and ideally we would replace it with a more explicitly tuned classification if/when more extensive data becomes available. For the wetlands we used a totally different approach, relying on a published classification that has wide acceptance within New Zealand's wetland community because of the collegial approach used in its definition. However, while no effort was required to define the classification, considerable effort was required to allocate each of the wetlands identified on the ground into its most likely classification group. Given this approach, reliability issues centre not so much on the nature of the classification, but around the reliability with which particular sites have been correctly placed within a classification group.

Rankings

Turning to the rankings, those of rivers and streams are likely to be more stable and reliable than those for lakes and wetlands. This is because of the robustness of the underlying river classification, including robust estimation of inter-group similarities, and the relatively straight forward estimation of current river and stream condition. The analyses themselves were straightforward, without complications caused by small numbers of planning units, or extreme variation in their extents. By contrast, the lake rankings were more difficult to calculate, given the nature of the lake classification, the difficulty in estimating current condition, and the very wide variation in the sizes of the individual lakes. Particularly in lowland areas with many degraded lakes, these rankings should be used with caution, and estimates should be verified in the field before any decisions are based upon them. Calculating rankings for some regions was also complicated by the very small number of lakes. Calculating rankings for the wetlands was of intermediate difficulty, and was facilitated by their greater number than for lakes, the relatively simple classification structure, and the generally reasonable estimation of human pressures. As already stated above, users also need to be aware of the particular assumptions and intent of these rankings, ensuring that those are consistent with their own intended use.

In summary, while this description of data uncertainties may seem somewhat pessimistic to users not experienced in working with spatial data, we do not regard them as invalidating the utility of these layers. Our philosophy is that spatial data will always contain errors, regardless of how much effort has been expended on their grooming. The key questions do not revolve around how to obtain error-free data, so much as understanding the likely sources of error and uncertainty, and how those should influence the subsequent use of the data. We would encourage users to view this data as a step towards a more data-defined view of New Zealand's freshwater ecosystems, and one that will hopefully become more valuable over time as its use leads to its progressive improvement. We are most confident in the use of the FENZ database as a broad-scale, national to regional framework that provides a context or framework for structured analysis and decision making. Its use at more local scales should be surrounded by greater caution, as it is here that uncertainties and errors are most likely to become significant. However, we are also confident in the ability of the data to provide starting point descriptions that will be useful for many applications, provided that use of the data is backed up by field verification where important decisions are to be made.

3. THE FENZ DATA LAYERS AND THEIR USES

The FENZ Database consists predominantly of a set of spatial data layers generated and stored in a geographic information system or GIS, with each of these data layers containing a set of geographic features. For example the river and stream network is represented using a series of line strings or poly-lines that are connected to allow the tracing along river networks in either an upstream or downstream direction. By contrast, the lakes and wetlands are represented using polygons, each of which describes a lake, a wetland, or an area within a wetland having a particular type of vegetation. Each of these layers also has an attached set of data describing the attributes or characteristics of these spatial features.

Together, these layers provide a facility for displaying, manipulating and analysing data. Some users may want to use the data layers predominantly as a digital map tool that allows the viewing of information describing particular places of interest. Example projects are provided on the DVD that can be used in this way, using either the proprietary software ArcGis or the free map viewer, ArcReader, which can be downloaded from www.esri.com. Others will be interested in using more extended options that allow the generation of queries or the calculation of new data, but this will require analytical software of one form or another, e.g., ArcGis.

3.1. River and stream data layers

Six river and stream spatial datalayers are provided in the FENZ Database, with five of these using the REC flow lines to describe river and stream locations – together these describe for each river segment (a section of river or stream between two adjacent confluences) the physical environment, human pressures, the predicted occurrence of native and introduced fish, predicted occurrence of aquatic macro-invertebrates, and membership in a river and stream classification. All five of these layers are based on the spatial data topology developed for the River Environment Classification (REC) of Snelder & Biggs (2002). The sixth river and stream layer differs in that it describes human pressures and conservation rankings for 3rd-order catchment or sub-catchment planning units represented as polygons. All catchments of third order or less are enclosed within a single polygon – catchments that are larger than 3rd order are broken into their 3rd (and higher) order sub-catchments and their main stem.

River predictors

The **River predictors** dataset ("River_and_stream_predictors" in "Rivers.gdb") contains an extended set of environmental attribute data that was assembled to support the development of the FENZ river and stream classification; it is provided here as a resource that describes environmental conditions across all New Zealand's rivers and streams. It contains all the constituent variables used to define the river and stream classification, along with a smaller number of supplementary variables, as described in the metadata. Variables were chosen and/or developed for their likely functional relevance to the distributions of freshwater biota – a description of the rationale used for many of them is contained in the methods section of Leathwick et al. (2005), which also demonstrates their use to predict the distributions of native fish species. They have since been used in analyses of the distributions of other species groups, including aquatic macro-invertebrates (Leathwick, Julian & Smith 2009), and whio (A. Whitehead, unpublished data).

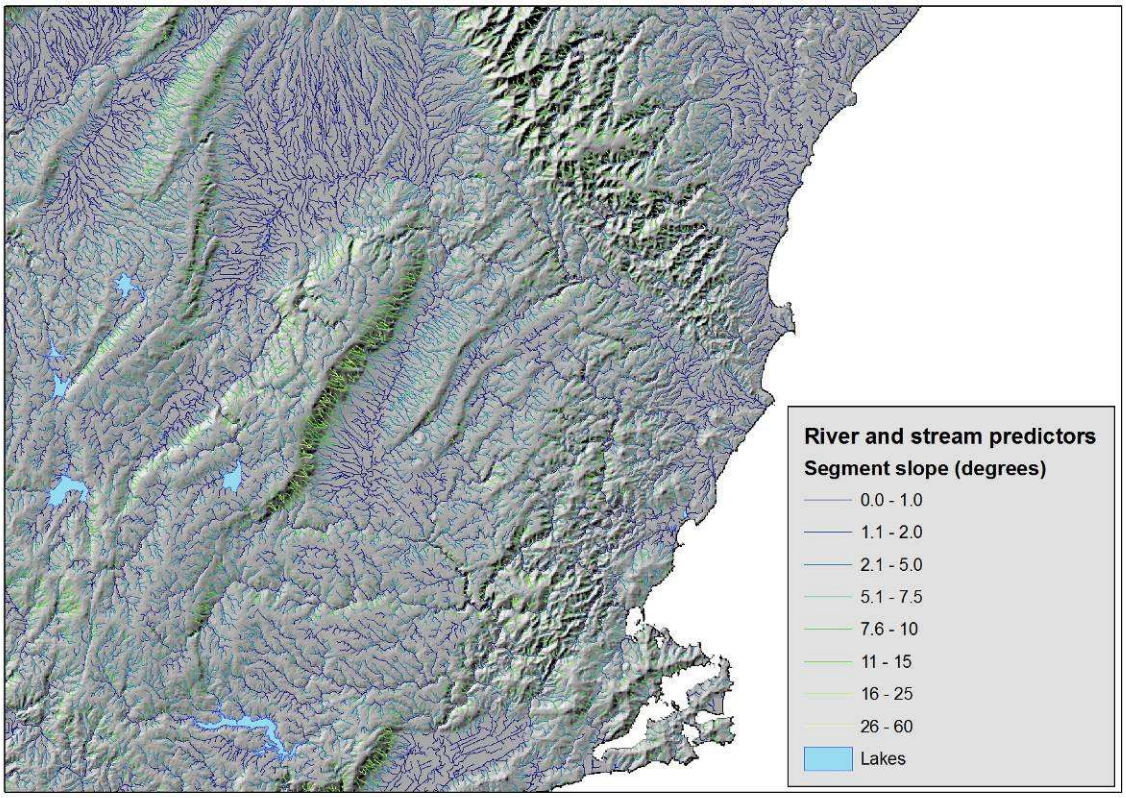

Figure 1. An example of a segment-scale river and stream environmental variable, the segment slope or gradient.

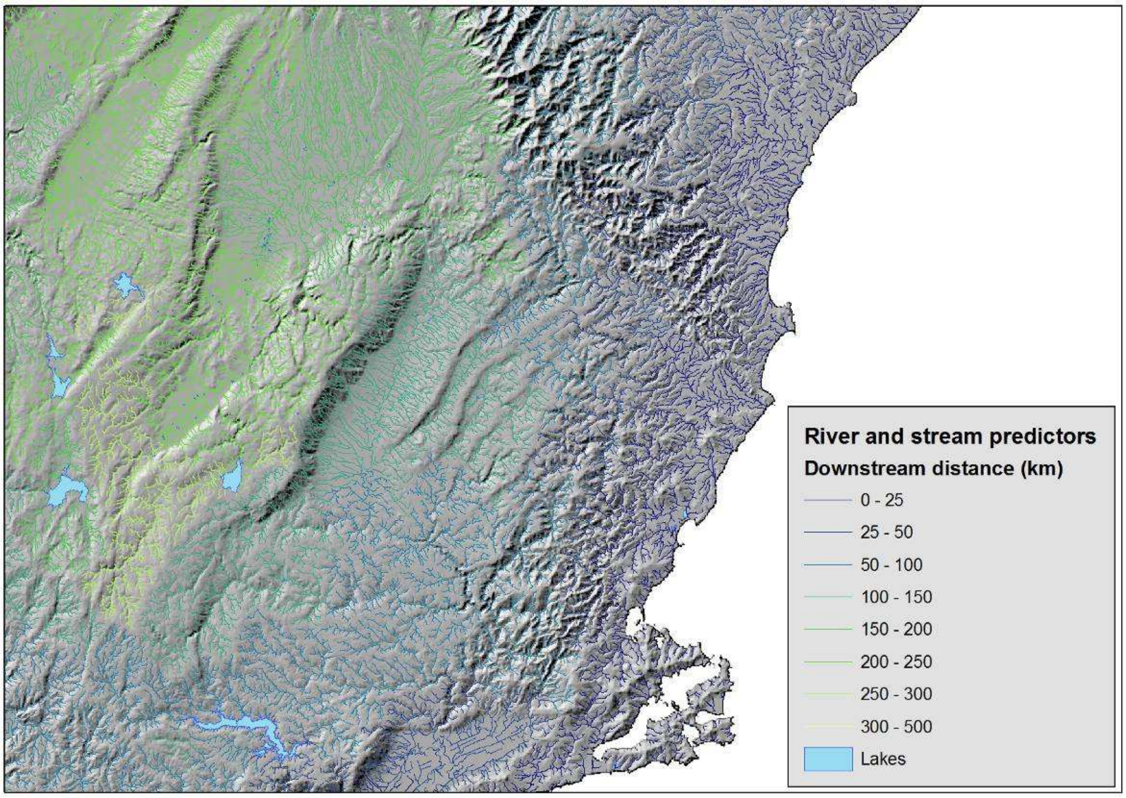

Figure 2. An example of a downstream river and stream environmental variable, the downstream distance to the sea.

Variables are grouped according to the spatial scale at which they were calculated, as indicated by the beginning letters of each variable name. Names beginning with "Seg" were calculated at a segment scale, and include estimates of the river flow, the stream gradient (Fig. 1), the amount of shading, and the modeled nitrogen load. Variable names beginning with "DS" describe conditions between the segment and the coast, including the distance along the river network from the midpoint of each segment to the sea (Fig. 2), the downstream gradient, and the maximum downstream slope. Variables beginning with "US" describe conditions in the upstream catchment, including the average slope (Fig. 3), the average frequency of major rainfall events, and the proportional cover of native vegetation, wetlands, pasture and glaciers. Two reach-scale variables describe the mean sediment size and habitat type, modeled from field sampling of these attributes in samples stored in the New Zealand Freshwater Fish Database (see Leathwick et al. 2008c).

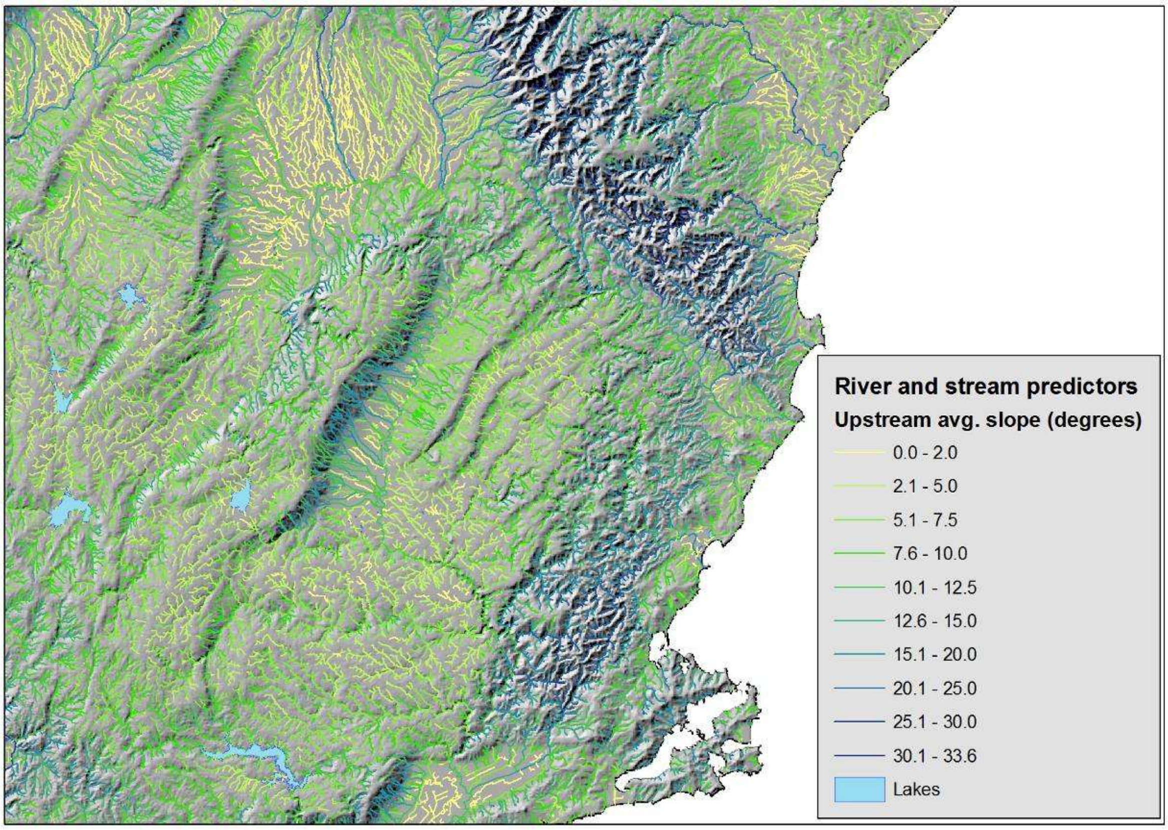

Figure 3. An example of an upstream or catchment-scale river and stream environmental variable, the average upstream slope.

Predicted species distributions

Predictions of species occurrence have been produced for all rivers and streams across New Zealand for both fish and macro-invertebrates ("Predicted_fish_distributions" and "Predicted_invertebrate_distributions" in "Rivers.gdb"). Estimates were produced by combining field sample data with environmental predictors contained in the "river_and_stream_predictors" layer, using a separate statistical model for each species to describe the relationship between its average occurrence and environment at the sample sites. This model was then used to make predictions across all river and stream segments. Fish sample data were drawn from the New Zealand Freshwater Fish Database (n = 13363) and invertebrate samples (n = 2668) were drawn from a collection of stream invertebrate community samples, collected mostly by regional councils. Values provided in the fish and invertebrate spatial layers for each river segment describe expected probabilities of capture for each species (e.g., Figs. 4 & 5) when using standard sampling methods.

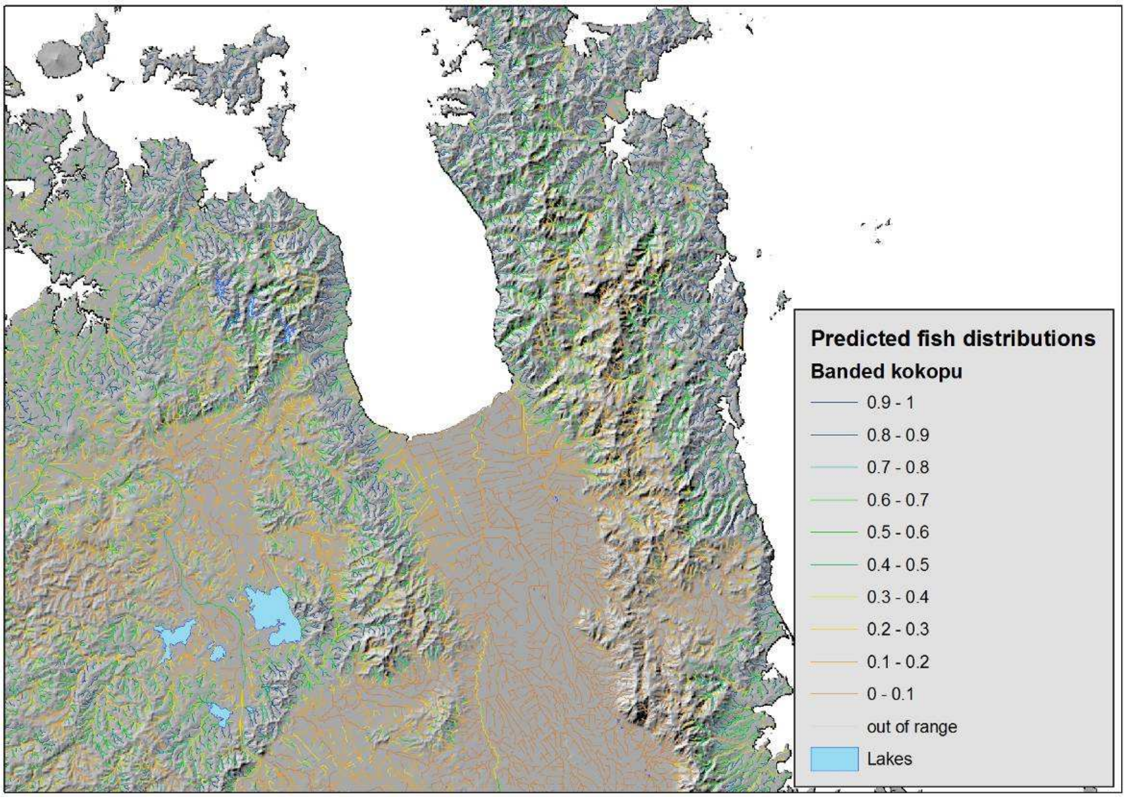

Figure 4. Predicted probabilities of capture for banded kokopu based on data from 13,363 fish sample sites, extrapolated to all river and stream segments using an environment-based model.

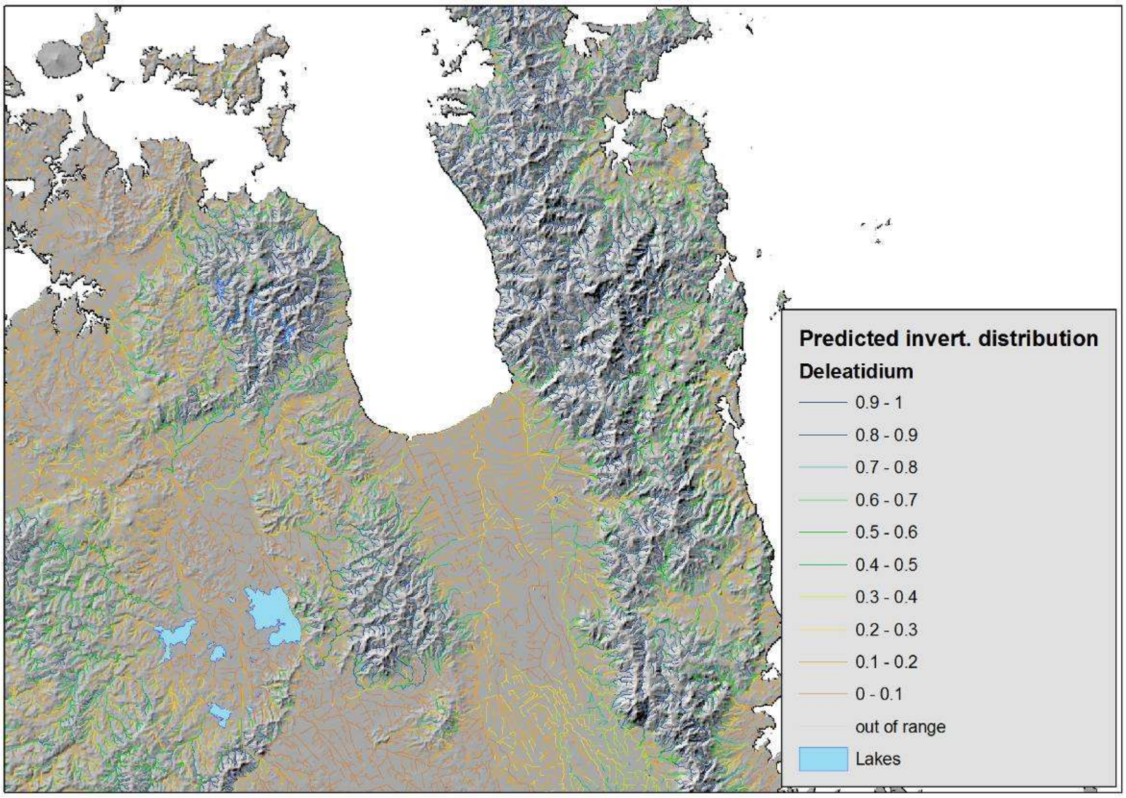

Figure 5. Predicted probabilities of capture for Deleatidium spp. based on data from 2670 invertebrate sample sites, extrapolated to all river and stream segments using an environment-based model.

Two sets of predictions are provided for fish species with patchy geographic ranges, one indicating the potential range based on environment, i.e., with no geographic limitations, and the second using the same probabilities, but with values set to a null for all catchments from which the species is known to be absent. Further documentation, including information about the reliability of these predictions, is contained in Leathwick et al. (2008b) and Leathwick, Julian & Smith (2009).

Also provided in this layer is a ten-group diadromous fish classification defined using a multivariate classification analysis of the predicted distributions of 15 native diadromous species (Fig. 6). A detailed description of this classification is provided in Leathwick et al. (2009) along with suggestions on its use to guide the restoration of diadromous fish communities.

These predictions provide a useful interpretative layer both for the FENZ river and stream classification and the WONI rankings; they have also been used to rank sites based directly on their biological values, with the objective of identifying sets of locations likely to support a full range of fish species (Moilanen, Leathwick & Elith 2008; Leathwick & Julian 2009).

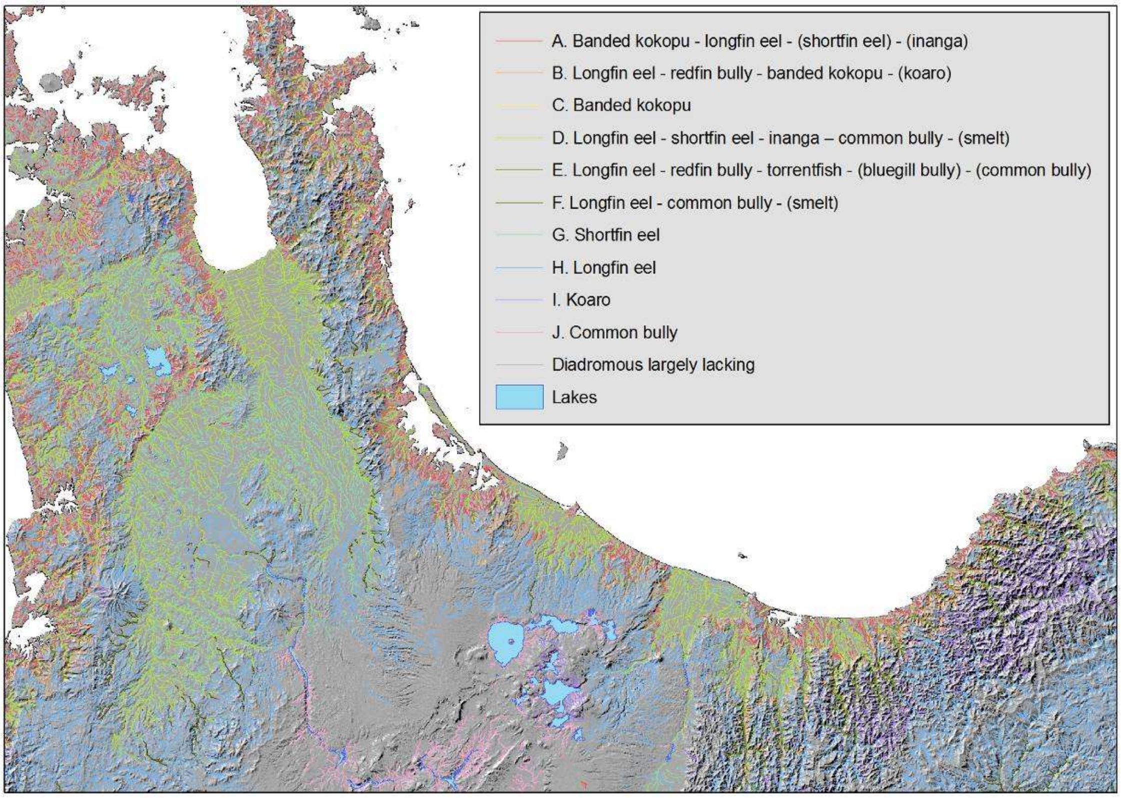

Figure 6. Distribution of diadromous fish communities for part of the central North Island and Waikato.

River and stream classification

The **FENZ River and Stream Classification** (**“**River_and_stream_classification” in “Rivers.gdb”) groups together river segments having similar environmental conditions, regardless of their geographical location. It was produced by combining environmental data contained in the river predictors layer with the two biological datasets described in the previous section – native freshwater fish and fresh-water macro-invertebrates. In this case, the biological data were used to guide the selection, weighting and transformation of environmental variables to use in defining the classification (Leathwick et al. 2008c, Leathwick et al. in press), substantially improving the biological discrimination of the resulting environmental groups. Classification results are supplied at four levels of detail containing 20, 100, 200 and 300 groups respectively (Figs. 7 & 8).

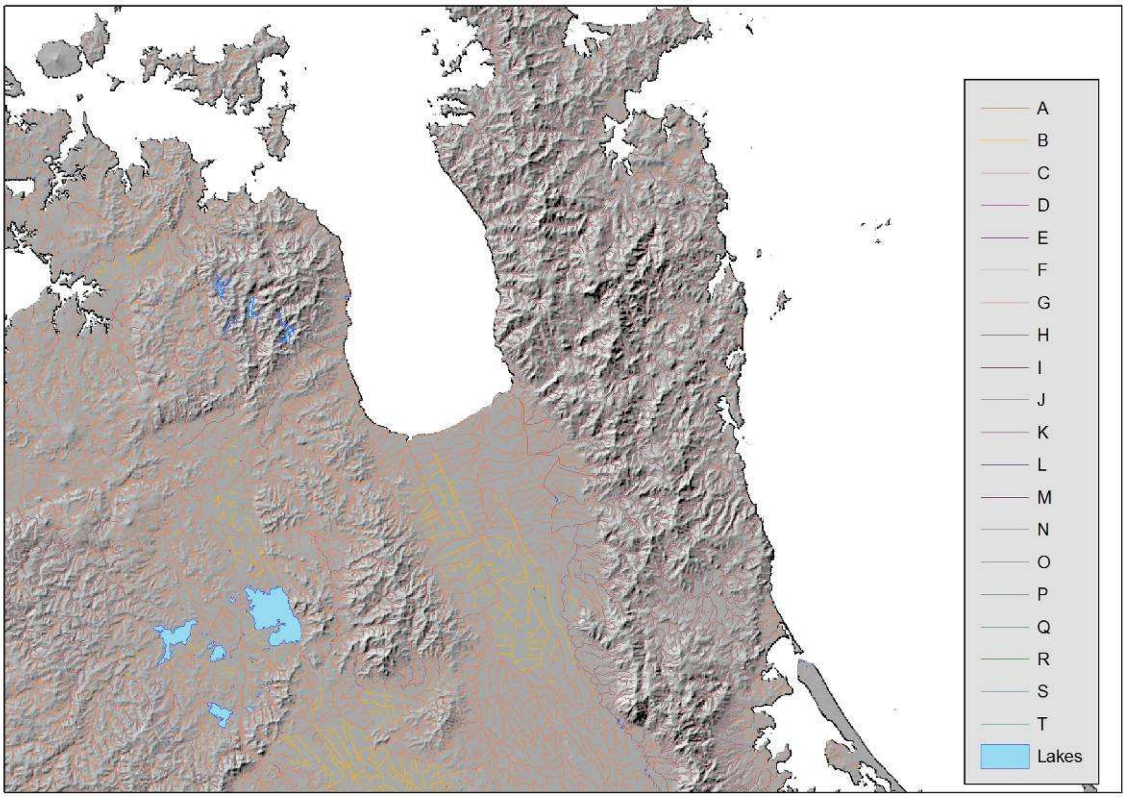

Figure 7. Membership of river and stream segments in classification groups at a 20-group level of classification. Note that only three groups occur within this restricted geographic area at this coarse level of classification detail.

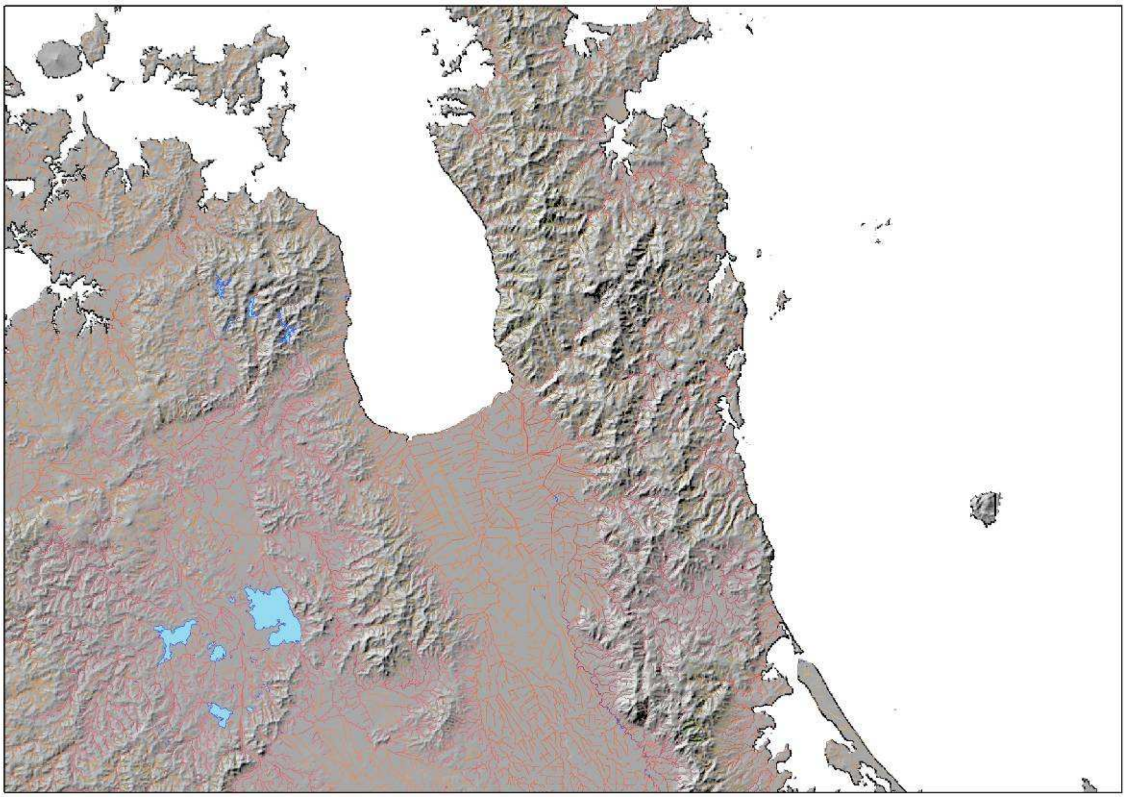

Figure 8. Membership of river and stream segments in classification groups at a 200-group level of classification. Note the expanded number of groups (compared to Fig. 7) occurring at this finer level of classification detail

Mean values for the underlying environmental variables used to define the classification are contained in tables stored both in the file geodatabase and in a spreadsheet contained on the DVD. Initial documentation of the classification groups is contained in a NIWA client report (Leathwick et al. 2008c); further documentation will be produced in due course.

The classification has a wide range of potential uses, including providing a framework for designing monitoring networks or for summarizing and reporting current status and trend, indicating groups of rivers and streams across which particular standards might be imposed, or as input to processes used for identifying representative sites for protection, e.g., the river and stream rankings described below.

River pressures

The **River pressures** dataset (**"**River_and_stream_pressures" in "Rivers.gdb") describes spatial variation in human pressures on riverine biodiversity, estimated using the best nationally available datasets. Individual factors considered include the estimated distributions of introduced fish, information on the distributions of mines and dams, satellite based estimates of natural vegetation cover in the upstream catchment (Fig. 9), estimates of the extent of impervious cover based on topographic map data, and modeled nitrogen inputs to rivers and streams. The likely impacts of these factors on indigenous biodiversity were estimated using expert-based judgment, formalized in mathematical response curves; the individual components were then combined into a single estimate of ecological integrity (Leathwick & Julian 2007). Both the individual pressure factors and two combined indices of pressure (e.g., Fig. 10) are contained in the river and stream pressures layer.

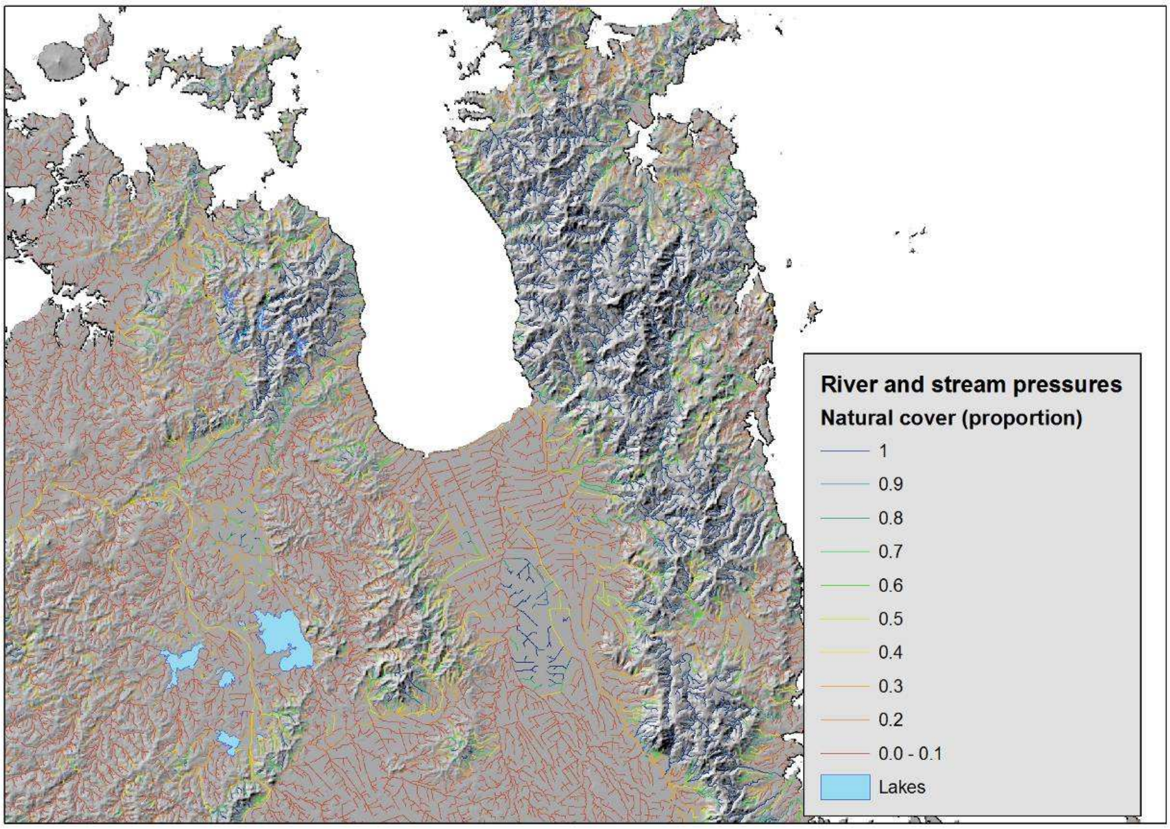

Figure 9. Variation in the upstream extent of natural vegetation cover.

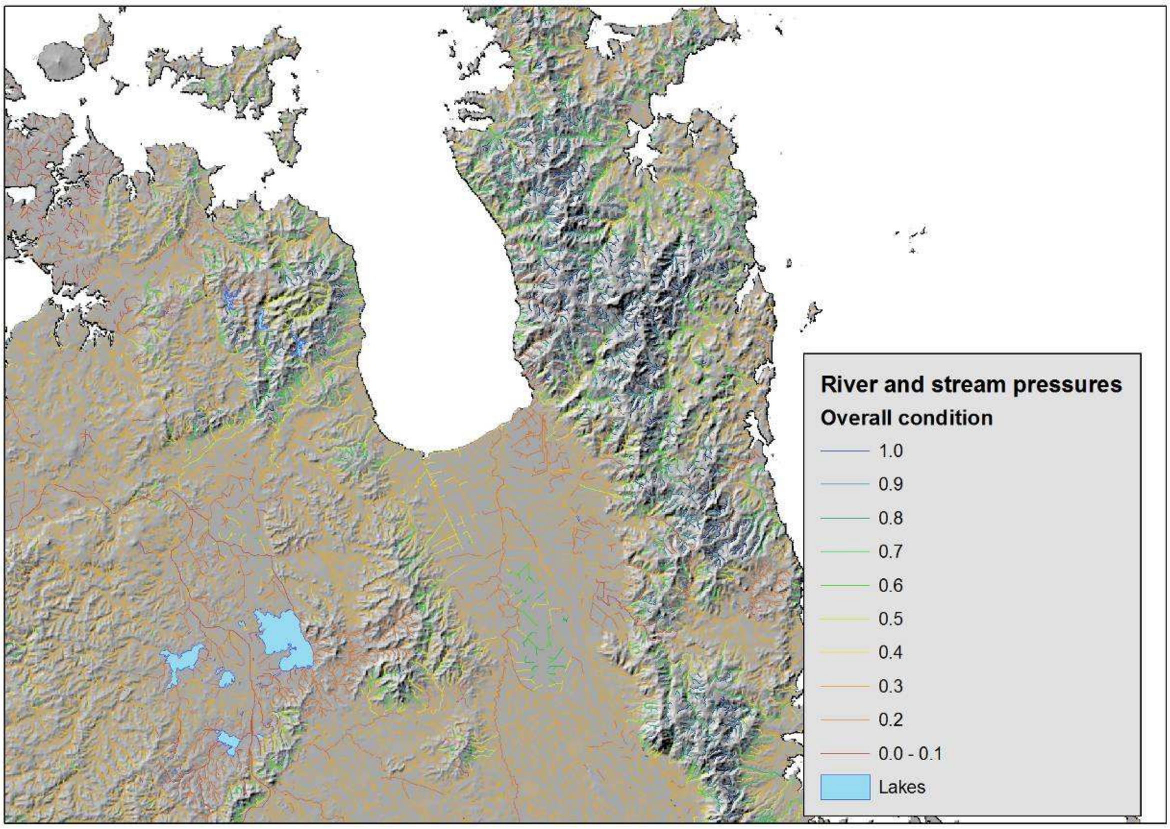

Figure 10. Variation in the overall index of human pressure based on equation 1 in Leathwick & Julian (2007).

River and stream rankings

All of the **rankings of importance** provided for rivers and streams are minimum set rankings, i.e., they order sites according to their ability to provide representative protection of a full range of ecosystems, after taking account of both human pressures and the desirability of maintaining upstream-downstream connections. Rather than working with individual river and stream segments, rankings were calculated for sets of small planning units, created by breaking all rivers larger than third order into their third (or higher)-order sub-catchments and their main stem; streams smaller than third order were treated as individual planning units without sub-division (Fig. 11). All rankings were calculated using the spatial conservation prioritization software, Zonation (Moilanen & Kujala, 2008), following the approach described in Leathwick et al. (2010), but with higher resolution input layers. These described the distributions of FENZ classification groups at a 200 group level of detail at a spatial resolution of 100 m. Additional grid layers described the distribution of planning units and human pressures.

Zonation starts by assuming that all planning units are available for protection, and then proceeds in a backwards stepwise fashion, at each step removing the planning unit making the lowest contribution to overall conservation outcomes. In carrying out this removal process it attempts to protect good quality examples of each ecosystem type, including those that are rare. This process also takes account of similarities between the ecosystem groups, allowing a degree of substitution between sites when protecting closely related ecosystems, but insuring the protection of distinctive ecosystems with no close relatives (see Leathwick et al. 2010 for details).

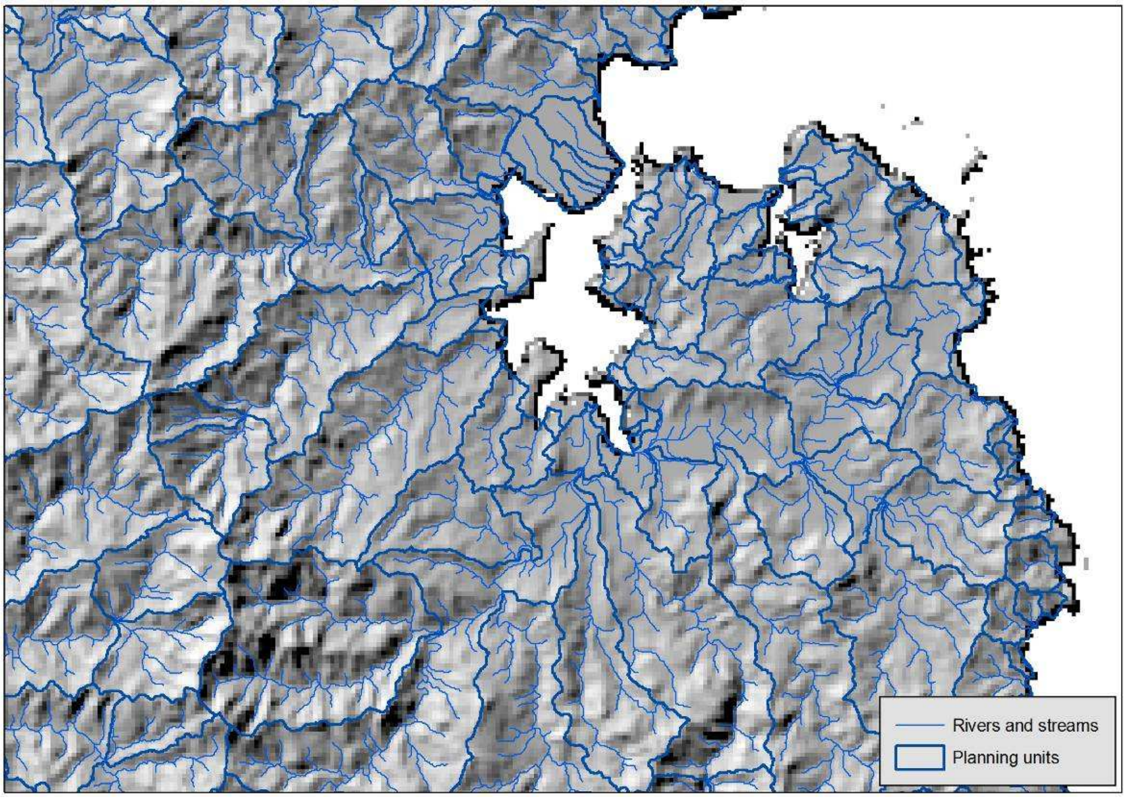

Figure 11. Third order catchment-based planning units, as used for calculating river and stream rankings.

Three sets of rankings are presented for each planning unit, two of which were calculated at a national scale, with the third calculated separately within WONI biogeographic units (Leathwick, Collier & Chadderton 2007). All analyses used pressure and connectivity constraints; the pressure information (taken from the river pressures datalayer) reduces the value of a planning unit according to the degree of human influence, while the connectivity constraints reduce the 'value' of each planning unit as it's upstream or downstream neighbors are removed. Both upstream and downstream constraints were used for the majority of rivers, reflecting the need both for the protection of the headwaters of high value sites, and the maintenance of fish passage to/from the sea. However, requirements for downstream connectivity were relaxed for inland river and stream segments where diadromous fish are largely absent. Results indicate the relative priority or rank of each planning unit, with low ranks identifying those planning units having the highest individual contributions to biodiversity protection. A second variable in the database contains values that indicate the proportion of all rivers and streams that would be protected, if protection was implemented in strict order of priority (Fig. 12). For example, the top 10% of all sites nationally have values in the range 0–10, while the top 20% of sites have scores in the range from 0–20.

In the second national analysis an additional layer was used to identify those planning units having 80% or more of their extent protected – planning units with less than 80% protection were removed first, and only when all of these had been ranked, were the protected planning units removed (Fig. 13). Scores in the range from 0-21.1 therefore indicate the relative ranking within planning units having 80% or greater protection, i.e. the conservation estate, these planning units making up 21.1% of the total extent of all planning units. By contrast, scores in the range from 21.1–31.1 indicate those planning units with less than 80% protection that are most strongly complementary to those units that are already protected.

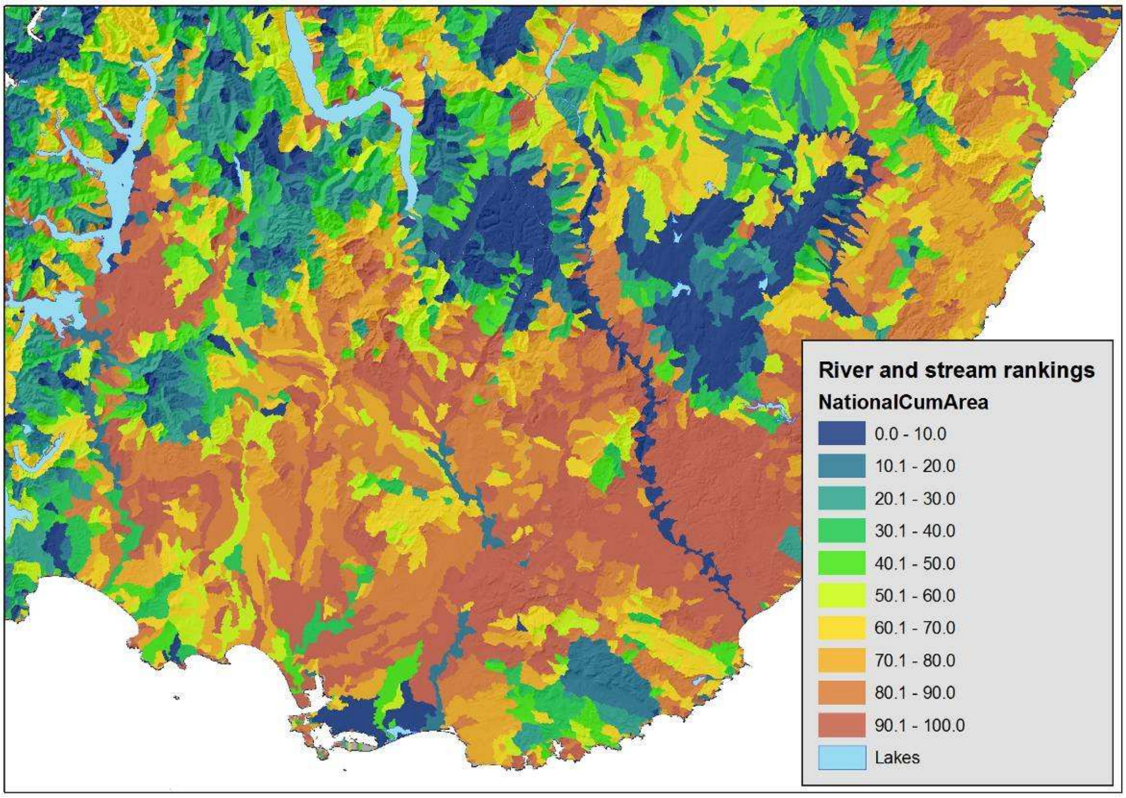

Figure 12. National "minimum-set" rankings for 3rd-order planning units, taking account of human pressures and the need for maintenance of upstream-downstream connectivity.

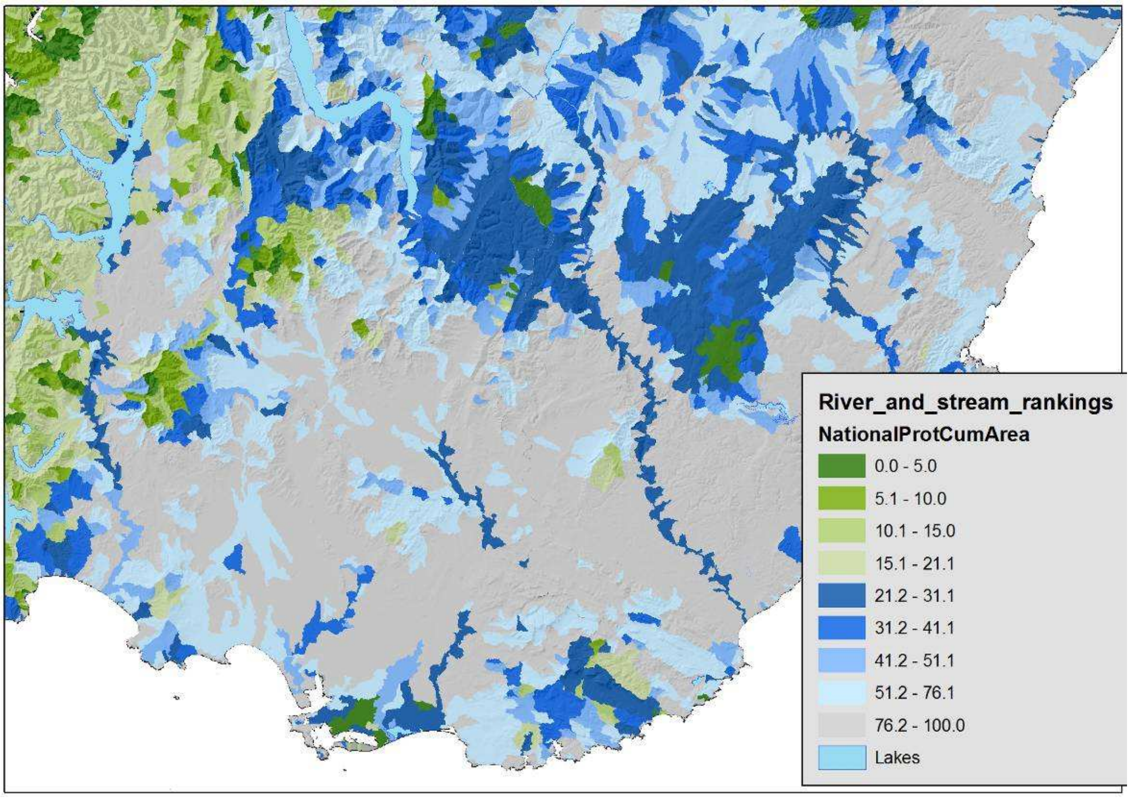

Figure 13. National "minimum-set" rankings calculated as in Fig. 12, but with all planning units having 80% or more of their area protected held back until all "non-protected" planning units had been removed.

Results from the regional analyses (Fig. 14), indicate the ranking within the context of each FENZ biogeographic unit, so that ranks can be used to identify within unit priorities, but are not comparable between units – the national rankings should be used to compare planning units in different biogeographic units.

Additional variables are also included in the river and stream ranking layer that provide alternative perspectives on the importance and/or current status of planning units, and have particular value when the objective is to calculate standalone estimates of the values of individual sites, i.e., independent of their similarities to other sites. For example, the variable "PressureSum" describes the average overall score for human pressures within each planning unit, and can be readily used to identify those planning units retaining freshwater ecosystems that are likely to be in good condition. By contrast, the variable "SpatialProtection" describes the proportion of each planning unit that has formal protection, i.e., conservation land, QEII and Nga Whenua Rahui covenants, and Regional Council reserves (Fig. 15). The variable "RiverProtectedness" further develops this concept, but from an ecosystem perspective, describing the average degree of formal protection provided nationally to the river and stream classification groups (100 group level of detail) occurring in each planning unit (Fig. 16). This calculation was performed by calculating the proportional extent of each ecosystem type occurring in each planning unit, and then averaging their degree of formal protection nationally, weighted by their extent in the planning unit. For example, a planning unit might have 50% of its total stream length belonging in type A.1 and 50% in type C.2; if the percentage protection of the total national occurrence of these two types is 10% and 40% respectively, then the average protectedness of the planning unit would be 30%, calculated as (0.5 * 10%) + (0.5 * 40%). Thus, planning units with low values are dominated by ecosystem groups having very low levels of protection nationally. A summary of the average value for the individual human pressure components in each planning unit is also included in this layer.

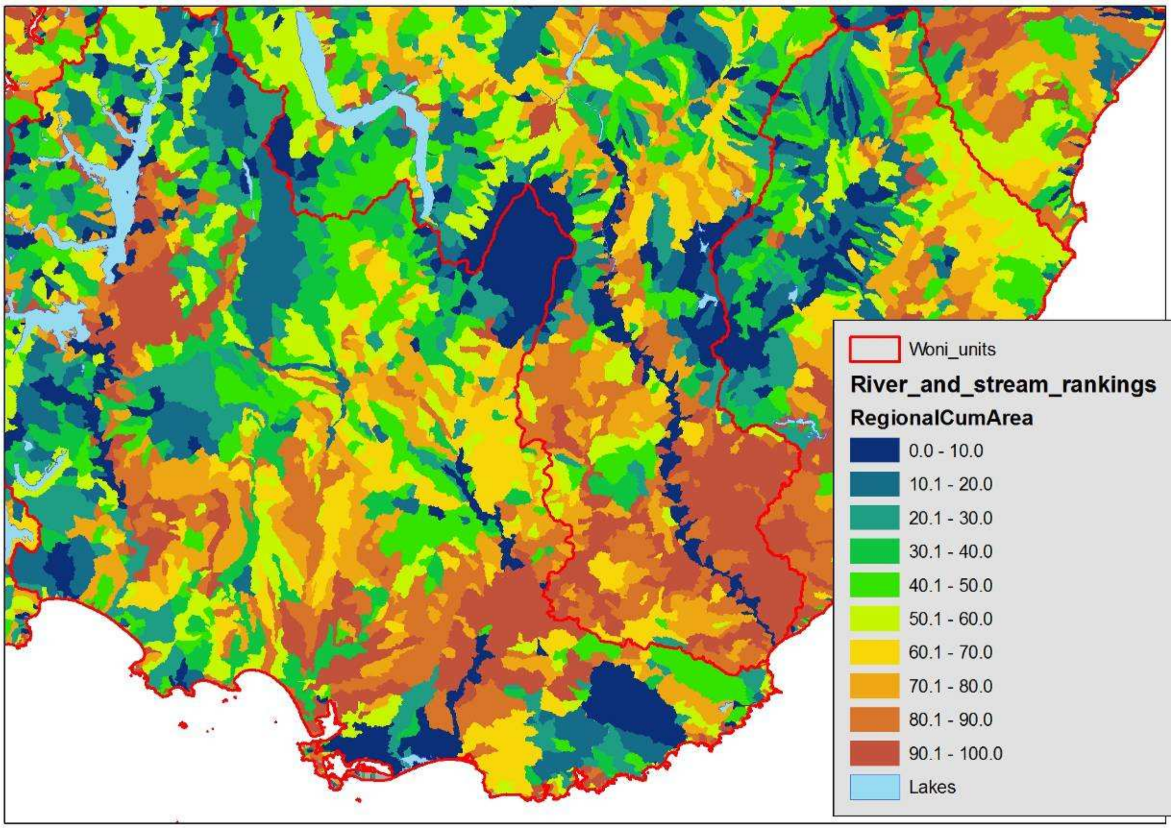

Figure 14. Regional "minimum-set" rankings, calculated as in Figure 12, but using a series of analyses, each of which was confined within a biogeographic unit, the boundaries of which are shown in red.

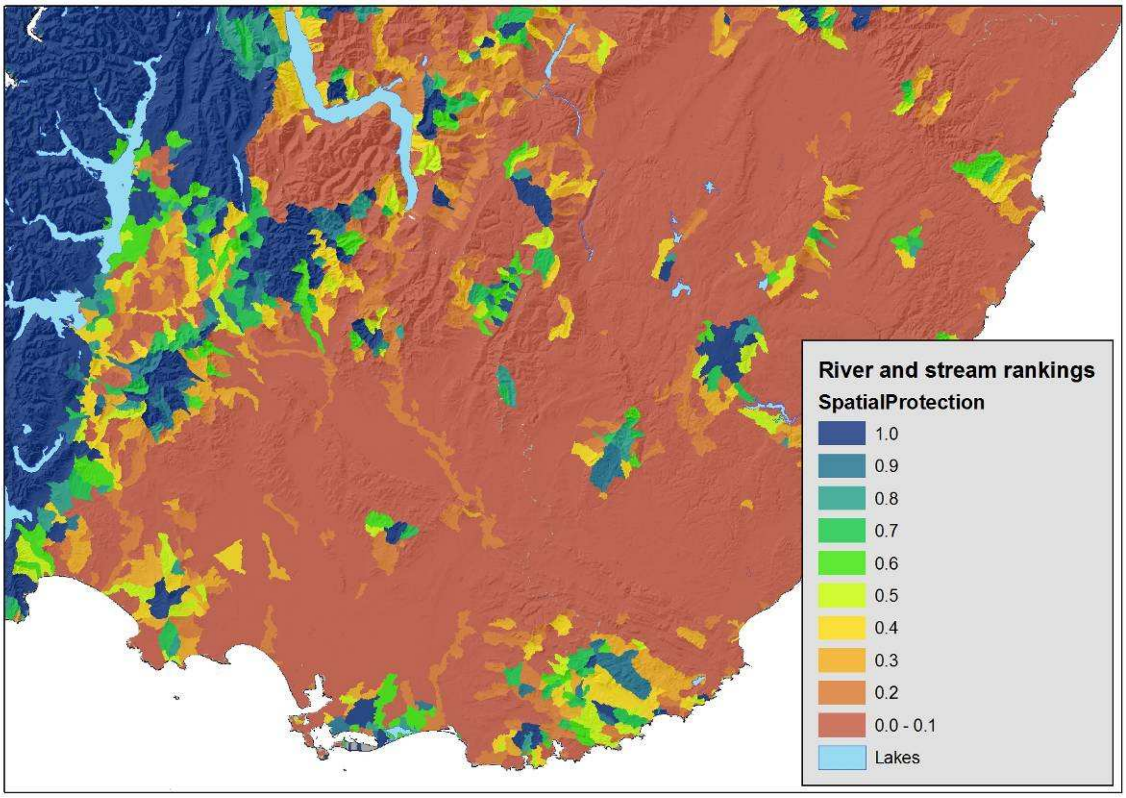

Figure 15. Spatial variation in geographic protection across planning units.

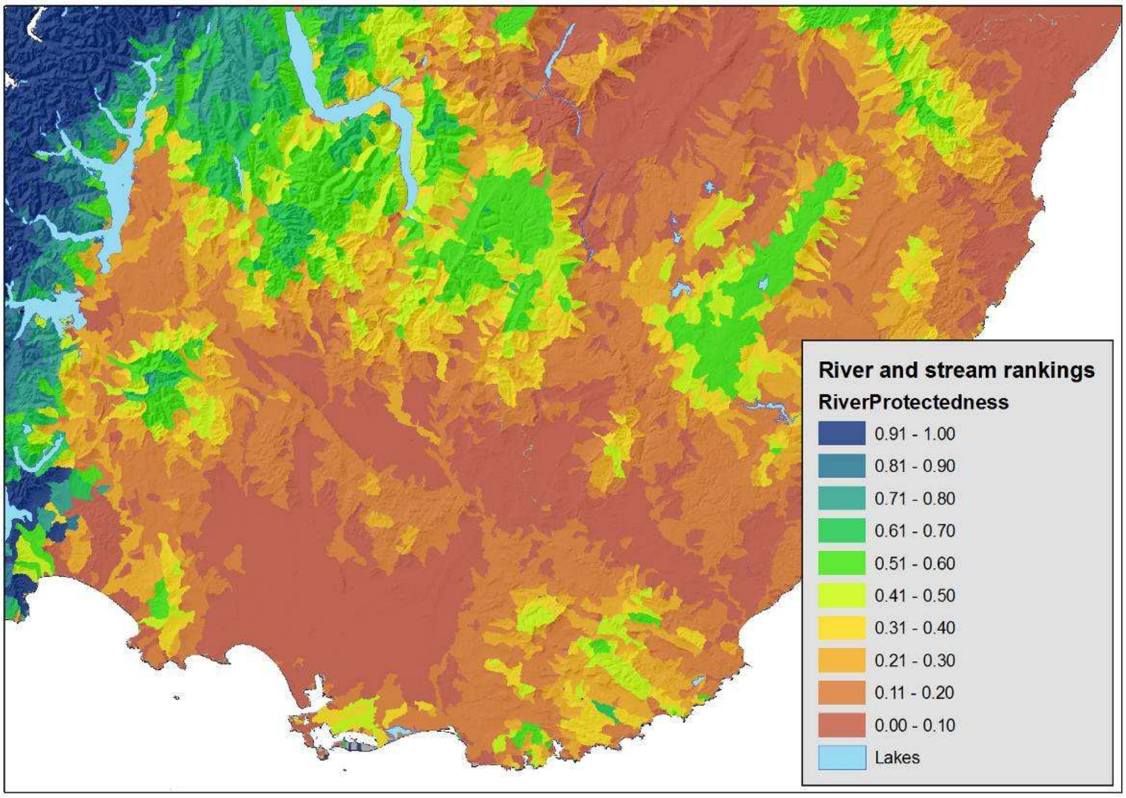

Figure 16. Spatial variation in the "protectedness" of planning units, based on the national-level protection provided to the river classification groups they contain at a 100-group level of classification – see text for explanation.

3.2. Lake data layers

Spatial data produced as part of the lakes component of WONI is not as fully developed as for rivers and streams, reflecting the lower availability of resource data describing the environments and biological attributes of our lakes. The first of three lake layers contains an environmental classification and base resource data, the second describes human pressures and lake rankings, and the third delineates and describes lake catchments.

Lake classification

The **lakes environment classification** (**"**Lake_classification" in "Lakes.gdb") used a series of lake and catchment scale variables to discriminate variation in the natural and existing character of New Zealand's lakes (Snelder 2006). Lack of comprehensive biological data prevented use of the "trained-classification" approach used with rivers and streams, so this classification was constructed using expert knowledge to guide the selection and weighting of the defining environmental variables. An initial 'primary' classification was constructed first, using six environmental variables, and recognising seven classification groups nationally (Fig. 17). Using this primary classification as a starting point, two more detailed multi-level classifications were created, one focusing on natural values, and the second taking greater account of human pressures – see Snelder (2006) for details. Both of these classifications are provided at four levels of classification detail to allow use for applications requiring different numbers of groups. Additional variables at the lake scale include descriptions of the known (or estimated) maximum depth, December air temperature and solar radiation, average summer wind, the fetch (or wind exposure) and the estimated residence time. Catchment-scale variables include descriptions of the cover of *Nothofagus* forests, peat soils, glaciers, pasture, and urban areas, the average hardness and phosphorus concentration of surface rocks, and the average annual temperature.

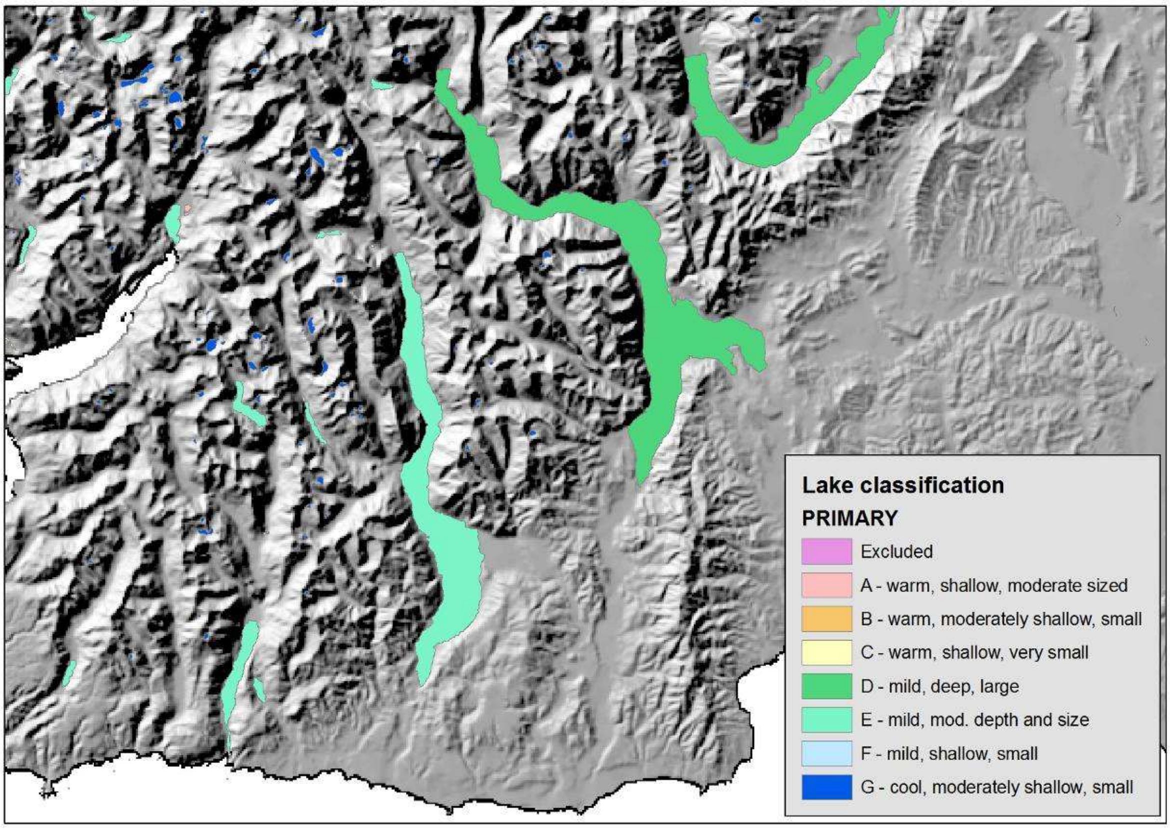

Figure 17. The seven-group primary lake classification for part of western Southland.

This dataset initially contained 3820 lakes with an area greater than 1 ha, but a number of these (226) have since been relocated into the wetland classification. The same classification process has been re-applied to a reduced set of lakes (n = 3594), but final documentation is still to be prepared for this product.

Lake pressures and rankings

Estimates of the effects of **human pressures on lakes** (**"**Lake_pressures_and_rankings" in "Lakes.gdb") were calculated using a similar approach to that used for rivers and streams. Individual terms describe the loss of native catchment vegetation cover, the estimated nitrogen load, the development of impervious surfaces in the catchment, the presence of introduced macrophytes and fish, and the impacts of flow alteration by dams; values for the individual terms are contained in the pressures and rankings data layer. Values are combined into two indices of integrity using the same approach as for rivers and streams, as described in de Winton et al. (2009). However, full implementation was hindered by a lack of information for all lakes on the presence of invasive macrophytes; this latter component was therefore excluded when calculating final lake pressures to use in deriving rankings.

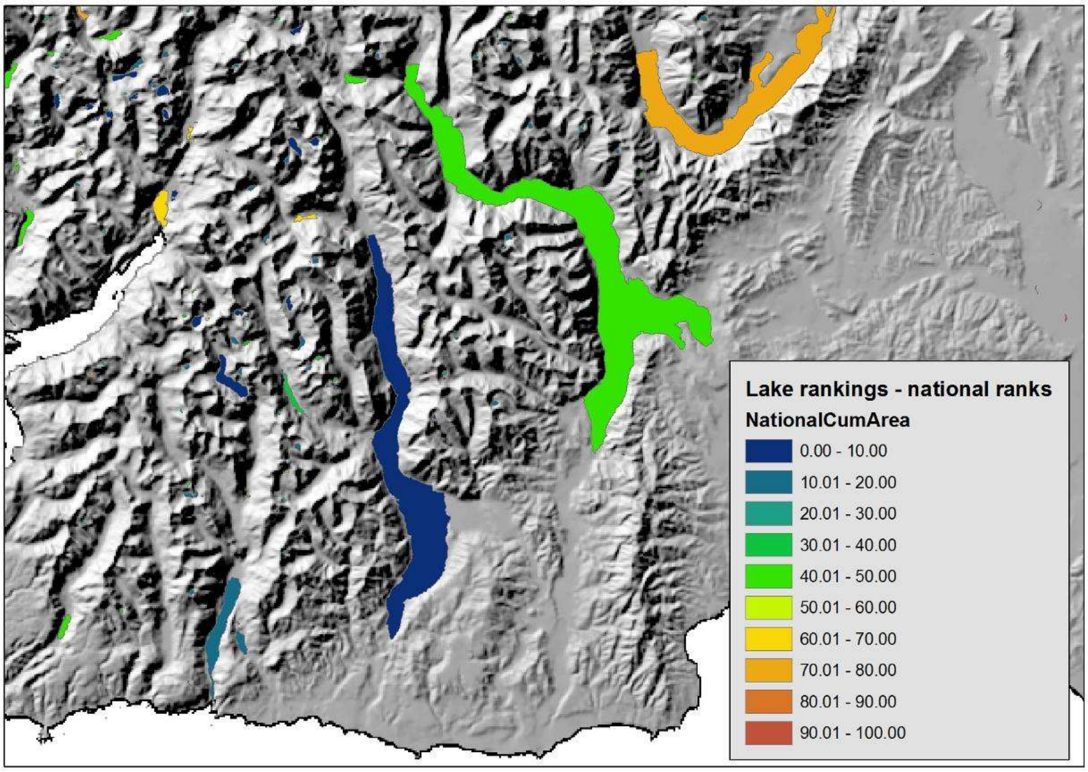

Figure 18. National "minimum-set" rankings for lakes in western Southland, taking account of human pressures.

Lake rankings were calculated with Zonation using a similar approach to that used for rivers, with each lake treated as a separate planning unit – human pressures were also included, as described below, but connectivity constraints were omitted. Three minimum set rankings were calculated using Zonation for all lakes using the "Natural4" level of classification, which contains 67 lake types. The first two sets of rankings were calculated from national analyses, with the first ranking all sites irrespective of their current status (Fig. 18), and the second using a protection mask to identify those planning units with 80% of their area protected – these were held back until all unprotected lakes had been removed (Fig. 19) as described for the river ranking analyses.

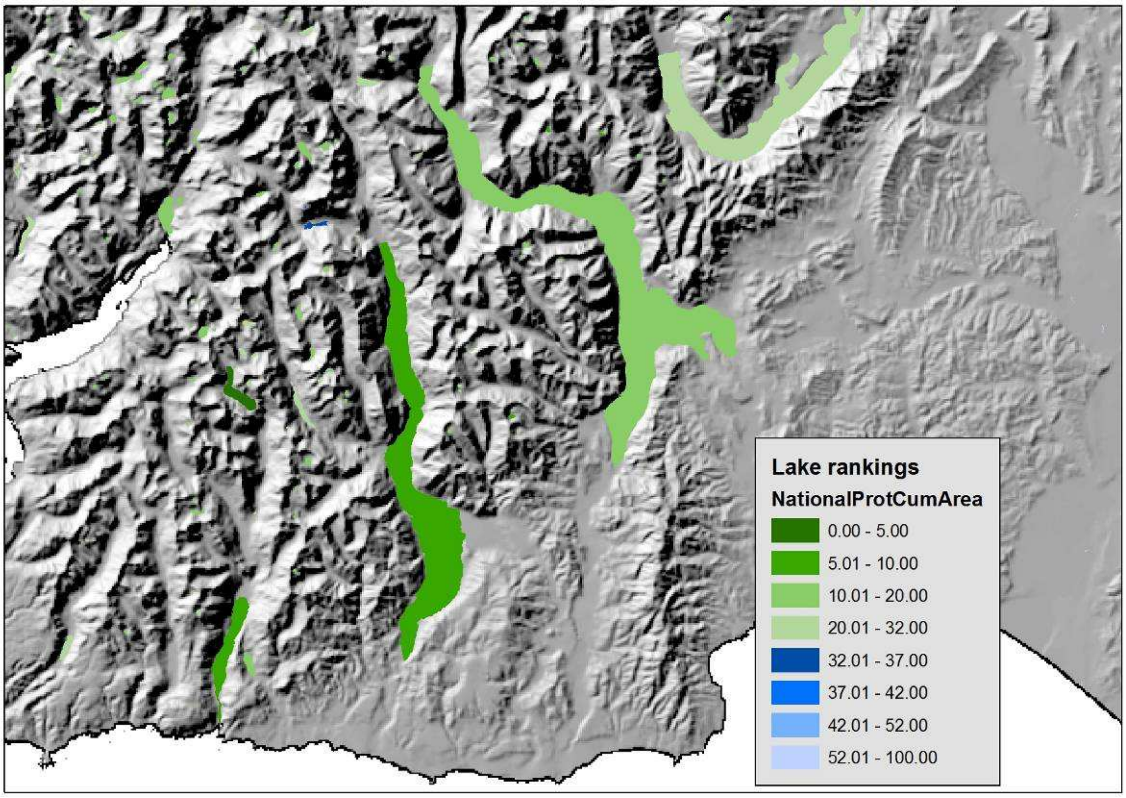

Figure 19. National "minimum-set" rankings for lakes in western Southland calculated as in Fig. 18, but with all planning units having 80% or more of their area protected held back until all "non-protected" planning units had been removed.

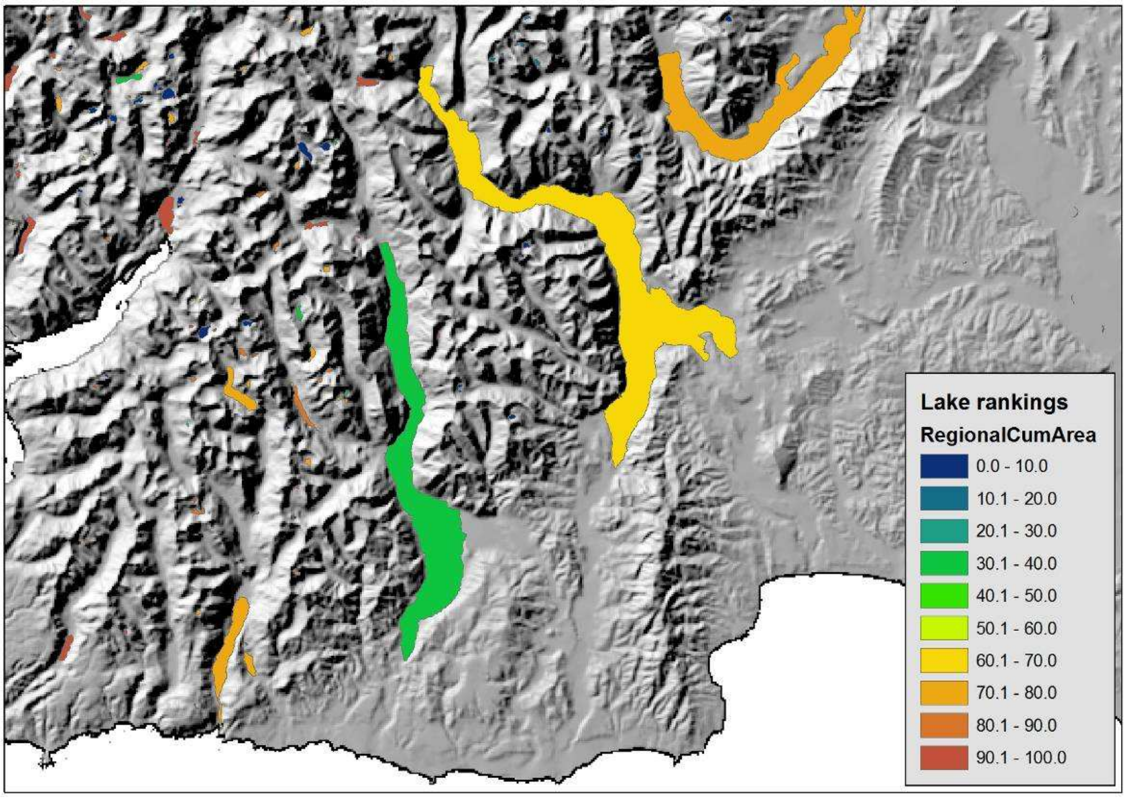

Figure 20. Regional scale "minimum-set" rankings for lakes in western Southland, calculated separately within each biogeographic unit.

The third set of rankings was calculated from analyses run separately for each WONI biogeographic unit (Fig. 20) (Leathwick, Collier & Chadderton 2007). Note that some lakes of around 1 ha or less in size were unable to be represented by the 100 m resolution grid classification layers and have therefore not been ranked. Results for each of the Zonation rankings are presented both as integer ranks (e.g., "NationalRank") and with values that indicate the proportion of all lakes that would be protected, if protection was implemented in strict order of priority (e.g., "NationalCumArea").

Lake catchments

The lake catchments layer contains the working dataset that was used in the calculation of the catchment-scale variables associated with each lake. The polygon record for each lake delineates the surrounding catchment as determined by analysis of a digital elevation model, along with the various environmental attributes describing average conditions within this catchment.

3.3. Wetland data layers

All of the wetland layers were produced by Anne-Galle Ausseil of Landcare Research, Palmerston North, and her report (Ausseil et al. 2008) should be consulted for a more detailed account of this work. Results from the working wetland spatial layers and associated data files have been extracted into four geodatabase layers as follows.

Wetland classification

Rather than defining a new classification to describe biological patterns in wetlands, we adopted the existing, semi-hierarchical classification system defined in Johnson & Gerbeaux (2004), which focuses on palustrine and inland saline wetlands. This classification recognises nine classes of palustrine wetlands: bog, fen, swamp, marsh, seepage, shallow water, ephemeral wetland, pakihi/gumland, and saltmarsh. Six of those nine classes: bog, fen, swamp, marsh, seepage, and pakihi/gumland, were retained along with the inland saline wetland class, occurrences of which are easily identified from soil data. Of the classes that were not mapped, saltmarshes were not considered here as they are part of estuarine habitats. Similarly, mapping of the shallow water class would have required information on the depth of standing water that is not available, and as this class generally occurs around the margins of lakes, rivers and estuaries, it could be included in estuarine, lacustrine or riverine assessments. Ephemeral wetlands are season-dependent habitats that cannot be consistently delineated with remote tools. This class has a very limited areal extent in New Zealand, and can arguably be merged with marshes (Johnson & Rogers 2003); although it should be separated in the future as it holds a high proportion of threatened plant taxa. The basis for separation between marsh and swamp (as well as between fen and bogs) has been debated by wetland scientists in New Zealand but Johnson & Gerbeaux (2004) considered that there were sufficient differences in terms of hydrology, soil and vegetation characteristics to justify retaining these classes.

Wetland classes are governed by a distinctive combination of environmental features including the site substrate, water regime and chemistry (Johnson & Gerbeaux, 2004). Information about these environmental attributes was derived from the FSL ("Fundamental Soil Layer") of the New Zealand Land Resource Inventory (NZLRI). A digital elevation model (DEM) was used to generate slope information. Use of these data to predict the expected wetland type was complicated by the manner in which these features combine to influence wetland character. Instead of using a simple classification tree, a fuzzy logic, rule-based system was used to predict the expected classification membership at each wetland. That is the environmental attributes of each wetland location were used to calculate a probability score between 0 and 1 for each wetland class based on rules determined using expert knowledge (Ausseil et al. 2008; Ausseil et al. 2010).

For example, seepages, pakihi/gumland and inland saline wetlands were distinguished by varying combinations of slope and soil type. Similarly, swamp/marsh and bog/fen were differentiated based on the pH class, peat content, fertility, and the nearby presence of a lake of river. Swamps and marshes were further distinguished by drainage class, and bogs and fens were distinguished using the pH class, the peat content and/or the presence of red tussock. Protocols used for predicting the historical extent of wetlands were similar to those used for current wetlands, but the rules used did not include consideration of the presence of a lake, river, and sub-catchment area, as these clues are site-specific and could only be applied to the prediction of current wetlands. Field surveys in the Otago region were used to check the validity of the classification; results are reported in Ausseil et al. (2008) and Ausseil et al. (2010).

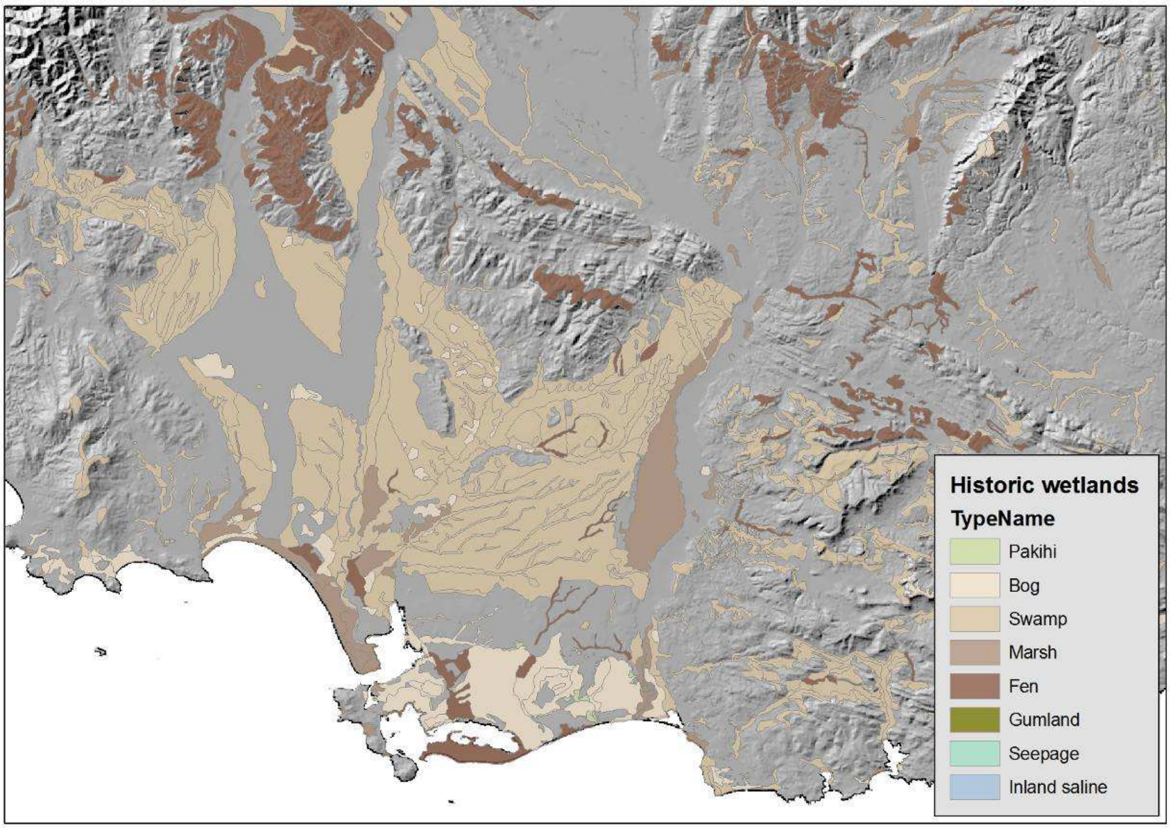

Figure 21. The estimated historic distribution of wetlands in lowland parts of Southland.

The "***historic_wetlands_typology***" layer (Fig. 21) describes the estimated *historic distribution* of wetlands, including predictions of their expected historic composition, based on information stored in the New Zealand Land Resource Inventory as described above. The predominant means of identifying historic wetlands was based around identification of those NZLRI land units where the land use capability (LUC) was primarily limited by wetness (peaty and gleyed soils mainly). This was augmented by additional information about land units dominated by other limiting factors such as nutrients, climate and erosion, but which also contained poorly drained/wetland areas (e.g. pakihis, seepages or alpine bogs). As a consequence of the inherent inaccuracy of these underlying data layers in some parts of New Zealand (particularly montane areas — see Leathwick et al 2002), the reliability of this layer is not as high as for the current wetland layer. In particular, some of the "wetland" polygons, while known to contain wetland habitats, may not be poorly drained across their entire extent. Note that unique site numbers have not been allocated for historic wetlands, because of the difficulty in identifying discrete units in those landscapes with formerly extensive wetland cover.

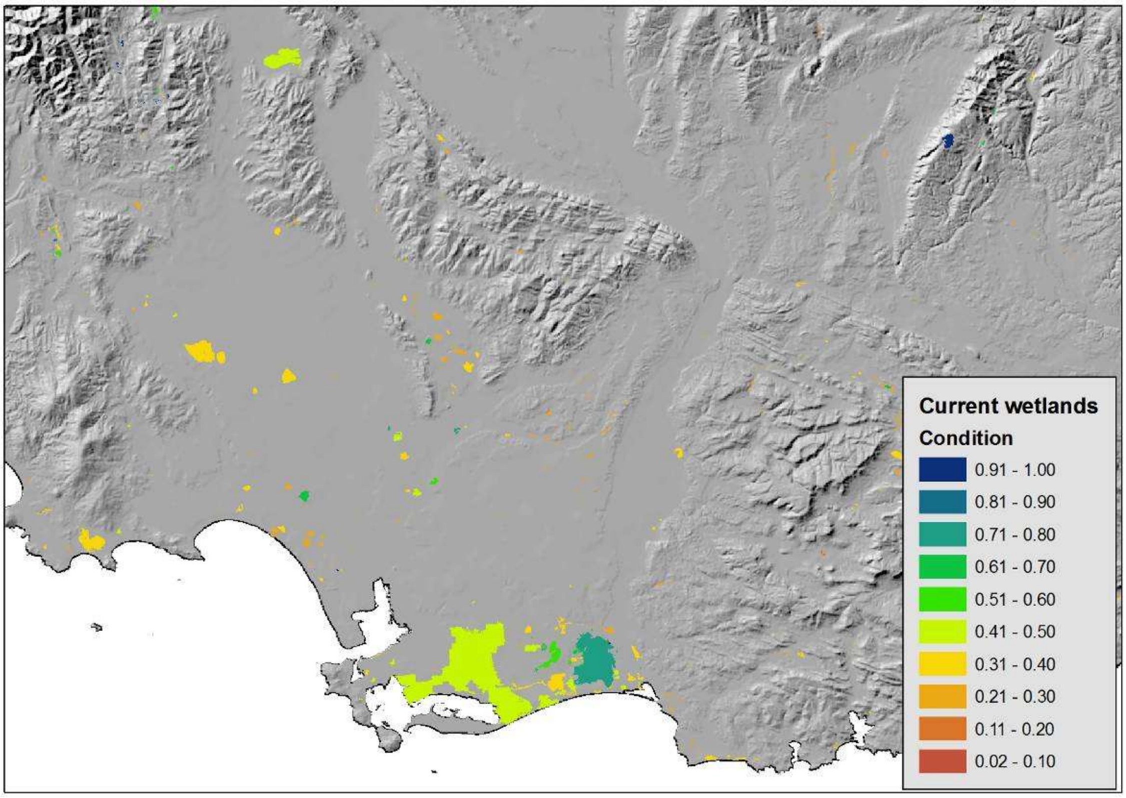

Figure 22. Estimated human pressures on current wetlands in lowland parts of Southland.

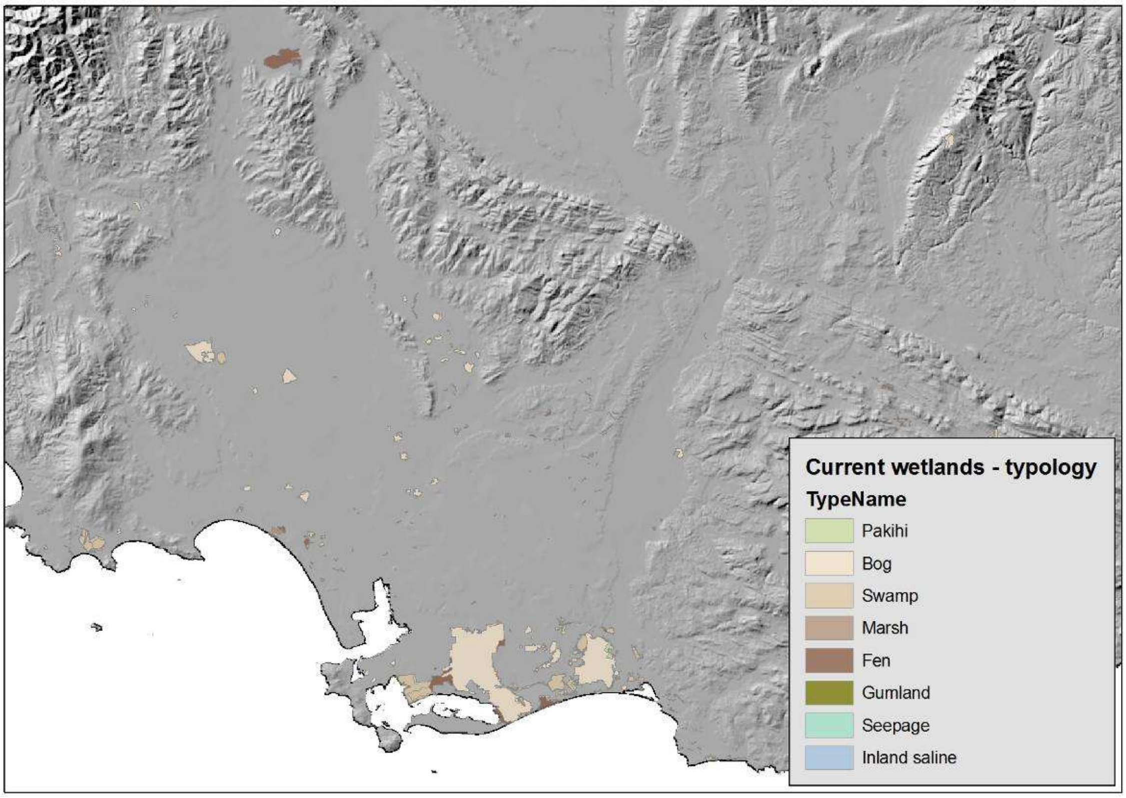

Figure 23. Estimated current wetland types for lowland parts of Southland.

The "***current_wetlands_sites***" layer describes the current extent of wetlands, this being constructed by combining several existing databases, including satellite descriptions of landcover (LCDB2), topographic maps, existing survey data (from regional councils and others), QEII covenant maps, DOC surveys, and a 15 m digital elevation model. Candidate polygons were checked against recent Landsat imagery. Human pressures were also estimated for each current wetland (Fig. 22), these being calculated within three contexts, the contributing catchment, a 30 m buffer around the wetland, and within the wetland itself. Pressure factors considered included the amount of natural vegetation cover, the impervious cover (roads, buildings, etc.), introduced fish richness, the woody weed cover, artificial drainage, and a surrogate measure of land-use pressure based on modeled nitrogen inputs. Pressure measures were transformed into an index of ecological integrity that ranged from 0 (totally degraded) and 1 (pristine).

The ***current_wetland_typology*** layer describes the distribution of the wetland types within each current wetland (Fig. 23), constructed as described above. Only limited field checking has been carried out of this mapping, and further verification is required before these allocations can be relied on with confidence.

Two versions of minimum set rankings are presented for each site (in the "current_wetland_sites" layer) using varying combinations of information about their composition, pressure (integrity), and loss compared to historic extent. The first set of rankings (variable = "Ranking") are those derived by Ausseil et al. (2008) for each WONI region, using a complementarity-based algorithm within the software package "R". They are contained in the variable "Rank" and consist of integer values with low values indicating sites with the highest rankings. Users should be aware that because of the manner in which wetland extent was handled in the calculation of these rankings, they essentially sort wetlands into a sequence from largest to smallest size, with relatively weak consideration of wetland condition and composition.

Because of this difficulty, updated minimum set rankings were calculated using Zonation, as described above for rivers and streams and for lakes, using 100 m grid layers describing the distribution of each wetland type, along with a layer describing spatial variation in human pressures; no connectivity constraints were used. Three sets of Zonation rankings were calculated for each wetland, with the first two calculated nationally, and the third calculated within biogeographic units. As with the rivers and streams and lakes, results for the Zonation rankings are presented both as integer ranks (e.g., "NationalRank") and with values (e.g., "NationalCumArea") that indicate the proportion of all wetlands that would be protected, if protection was implemented in strict order of priority. The first national ranking used just information about the distribution of wetland types and human pressures (Fig. 24). The second also used information about existing protection, with all wetland sites having 80% or more of their extent protected held back until all unprotected wetlands had been removed (Fig. 25) as described for rivers and streams. A third set of rankings were calculated using information about the distribution of wetland types and human pressures, but were calculated within each biogeographic unit (Fig. 26).

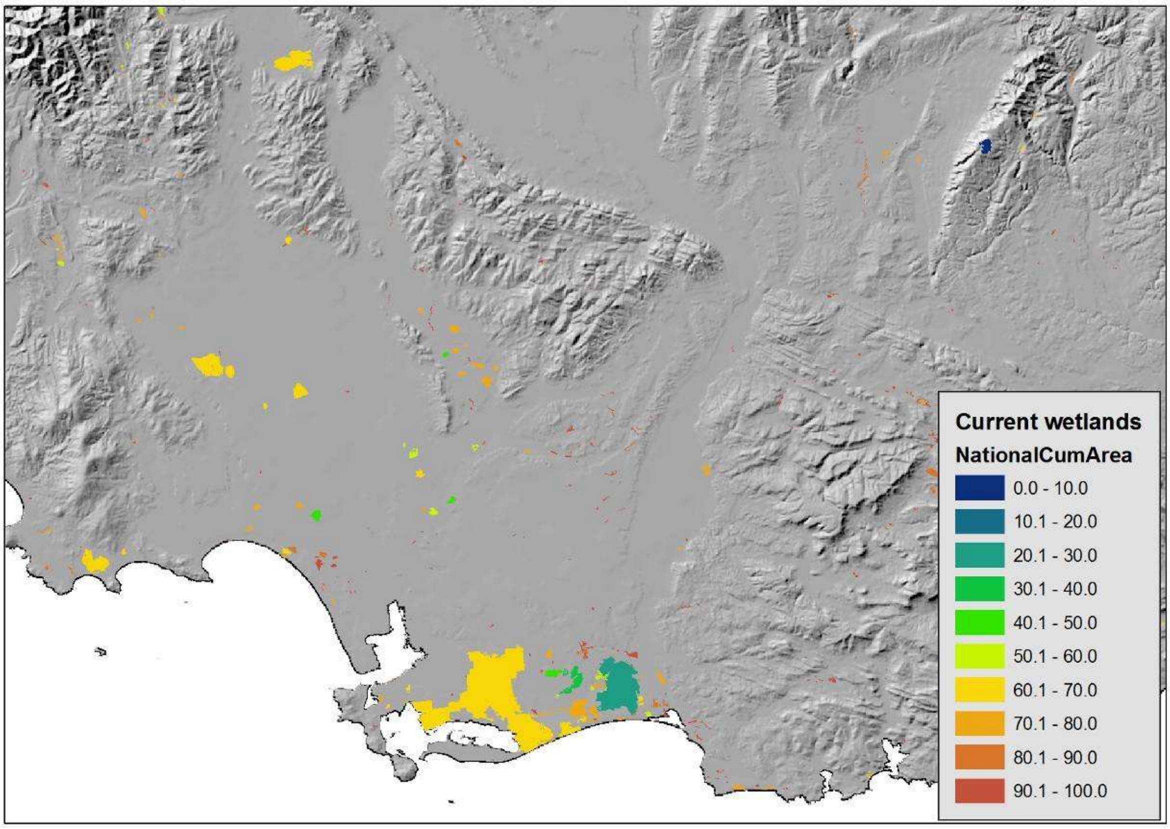

Figure 24. National "minimum-set" rankings for wetlands in lowland parts of Southland.

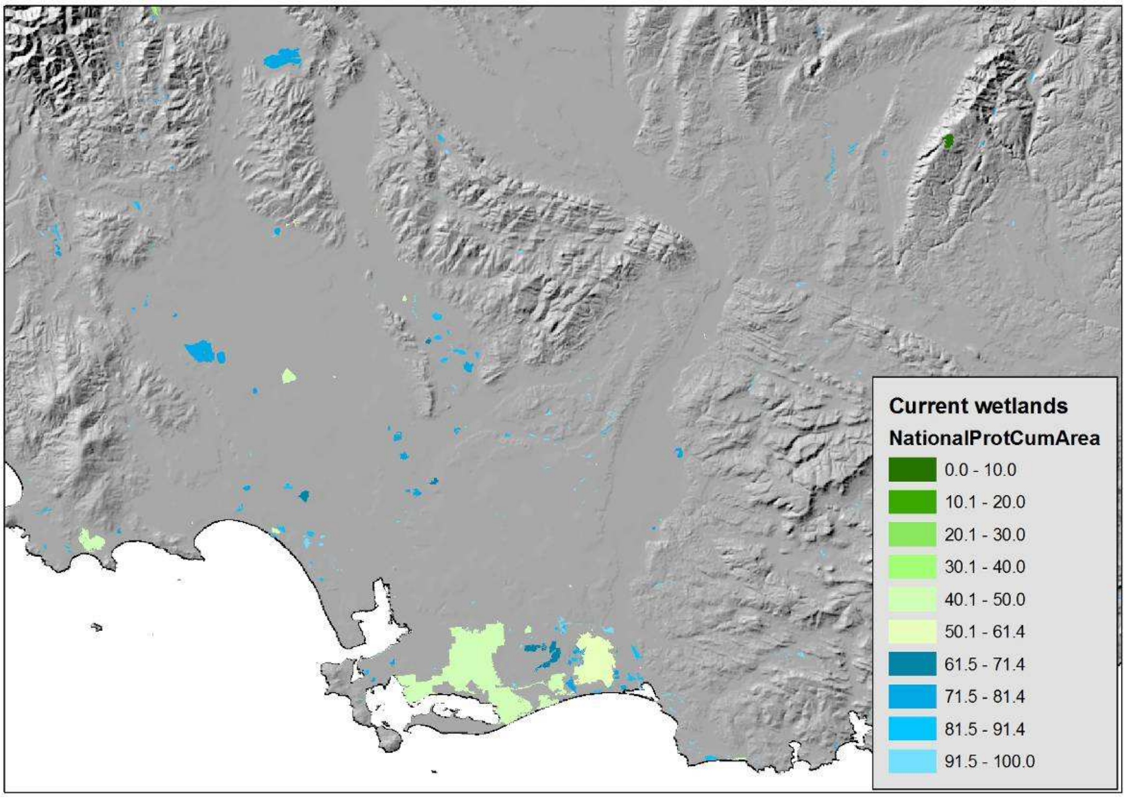

Figure 25. National "minimum-set" rankings for wetlands in lowland parts of Southland calculated as in Fig. 23, but with all planning units having 80% or more of their area protected (shown in green) held back until all "non-protected" planning units (shown in blue) had been removed.

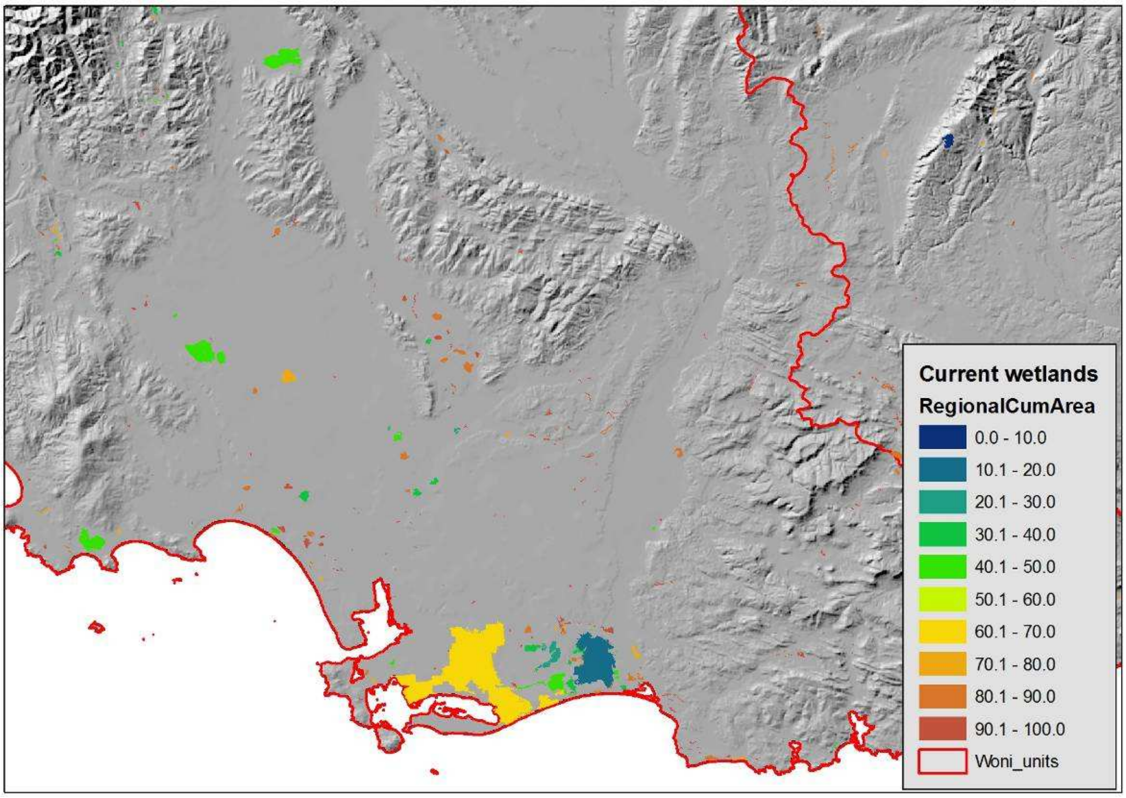

Figure 26. Regional scale "minimum-set" rankings for wetlands in lowland parts of Southland, calculated separately within each biogeographic unit.

3.4. Supporting datalayers

Several supporting data-layers are included in the FENZ Database, with six of these stored in the ***Catchment_and_biogeographic_unit*** geodatabase. The first of these delineates catchments across the whole of NZ and can be used, for example, to calculate whole-of-catchment averages for rankings or other variables. Three layers delineate catchment or sub-catchment-based planning units of progressively larger sizes, i.e., at third, fourth, and fifth stream -orders. These were constructed by merging adjacent river and stream segments depending on their order. For example, the third-order planning unit layer was constructed by breaking all rivers and streams of greater than third order into their third-order sub-catchments, along with their main stem; higher order sub-catchments are also delineated if these are of lower order than the main stem. Catchments of third or lower order are retained as individual entities. These layers can be used for a variety of analysis purposes where it is desirable to group together adjacent river segments; for example, the third order planning unit layer was used to group together adjacent river and stream segments when calculating the Zonation rankings presented in the Rivers geodatabase, substantially speeding up the analysis, and facilitating the description of upstream-downstream linkages. The remaining two layers contained in this geodatabase delineate the two classification levels of the WONI biogeographic classification (Leathwick, Collier & Chadderton 2007), i.e., provinces and units.

ArcGis layer files

A number of ArcGis layer files are also provided on the FENZ Database DVD and these can be used to load the various spatial data layers with preset symbologies – in some cases they also load aliases for extended variable names that are not otherwise stored permanently with the individual data layers. When loading these into ArcMap on a new system, users will generally have to reset the source on the layer properties tab after loading it into ArcMap. To do this, double-click the newly-loaded layer, navigate to the "Source" tab on the Layer Properties dialogue, and using the "Set Data Source…" button (lower-right), identify the new location for the data layer. The layer file will then have to be re-saved to make this change permanent.

3.5. Current uses of freshwater resource data and rankings

Although the primary driver for the WONI products was to identify freshwater sites that are nationally important for their biodiversity values, the data layers described above can be used to support a wide range of conservation related management actions. Other anticipated uses include:

- Assessing the degree to which current protected areas achieve the goals of providing representative protection specified in the New Zealand Biodiversity Strategy;
- Identifying priority sites that require protection, given both their ability to complement those values that are already protected, and their degree of modification and/or vulnerability;
- Identifying priority sites for restoration and setting realistic goals and objectives for the subsequent management of these sites;
- Providing a framework within which to both plan the monitoring of condition and to subsequently interpret results of that monitoring;
- Estimating the likely species composition of sites that have been severely degraded by human activity, e.g., in support of prosecutions following unlawful discharges;
- Assisting Regional Councils in setting flow guidelines or discharge conditions for rivers and streams, and assisting in the enforcement of those activities;
- Identifying sites to be searched for potential new records of threatened species, or identifying potential sites for translocation;
- Predicting risks for the spread of new organisms (pest fish, didymo), taking into account both the requirements of these species, and the values that would be threatened by their invasion.

3.6. A beginning rather than a completion

While the collection of data contained on this DVD might seem extensive, we are profoundly aware that it indicates the beginning rather than the completion of a task. The preparation of this material has provided a strong learning experience, highlighting a range of ways in which we could further improve or extend both the range and reliability of datalayers that are available in support of more informed conservation and resource management. In particular, we have identified a range of new data products that could be usefully added in due course. However, having postponed the release of the data on several occasions to enable the incorporation of such new and/or improved material, we eventually realised that release was also a strong priority – the current DVD therefore contains not so much a final set of layers, as a set that we hope will be augmented and improved over time, both by ourselves, and by other management and research agencies.

4. ACKNOWLEDGMENTS

FENZ is the result of the work of many people over several years and this user guide cannot convey the full depth of information underlying the development of these products. It would not have been possible without the generation of digital spatial representations of New Zealand's environment by several Government agencies in the last 5-10 years and the many local government agencies who supplied their regional records of freshwater biota and environments. This work is part of the Natural Heritage Management System Programme of the Department of Conservation. The insights of Theo Stephens and Kevin Collier were pivotal in the genesis of the work and ongoing support from them and other freshwater scientists made the production of FENZ possible.

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6. APPENDIX I – FENZ ATTRIBUTE DATA DEFINITIONS

The following tables provide metadata for the attributes of the larger data tables contained in the FENZ geodatabase. Attributes of several smaller tables not listed here are contained in the relevant metadata stored in the FENZ Geodatabase.

6.1. River predictors

Field	**Description**
NZREACH	The unique identifier associated with each REC segment
SegJanAirT	Summer (January) air temperature (degrees C) – used in the absence of robust estimates of water temperature
SegMinTNorm	Average minimum daily air temperature (degrees C) normalised with respect to SegJanAirT – negative values indicate strongly seasonal climates and positive values indicate weakly seasonal climates
SegFlow	Mean annual flow (m^3/sec), derived from hydrological models, provided by Jochen Schmidt, NIWA, 2006
SegLowFlow	Mean annual 7-day low flow (m^3/sec), derived from hydrological models, provided by Jochen Schmidt, NIWA, 2006 – see http://wrenz.niwa.co.nz/webmodel/ for details.
SegFlow4th	4^{th} root transformed mean annual 7-day low flow, i.e., (low flow + 1)$^{0.25}$, accommodates the strong skew in distribution of values when fitting statistical models, values are approximately linearly related to flow velocity
SegFlowVariability	Ratio of annual low flow/annual mean flow – indicates long-term stability of flow through the year
SegSlope	Segment slope (degrees), derived from GIS calculation using length and difference between upstream and downstream elevation for each segment
SegSlopeSqrt	Square-root transformed segment slope (slope +1)$^{0.5}$
SegRipShade	Riparian shading (proportion), the likely degree of riparian shading derived by using national, satellite image-based vegetation classification to identify riparian shading in each segment, with the degree of shading then estimated from river size and expected vegetation height
SegHisShade	Estimated shade assuming complete vegetation cover as could be expected during pre-human conditions
SegRipNative	Proportion of native riparian vegetation within a 100 m buffer of the river, calculated using landcover information contained in version one of the Landcover Database (LCDB)
SegCluesN	Nitrogen concentration (ppb) as estimated from CLUES, a leaching model combined with a regionally-based regression model, implemented within a catchment framework (Woods *et al.*, 2006)
SegCluesLogN	Log_{10} transformed values of nitrogen concentration
DSDist2Coast	Distance to coast (km), from mid-point of each river segment, recomputed in Hamilton and differing from the original REC estimates of downstream distance that were computed from the upstream end; change made so values indicate average distance from a segment to the coast, rather than the maximum
DSAvgSlope	Average slope (degrees), from mid-point of each river segment to the coast, differing from the original REC estimates of downstream slope that were computed from the upstream end; change made so values indicate average slope from within a segment

DSAvgSlopeSqrt	Square root transformed values of DSAvgSlope , i.e. $(\text{slope}+1)^{0.5}$.
DSMaxLocalSlope	Maximum downstream slope (degrees), local slopes at 100m intervals along each river segment where calculated and maximum value encountered recorded. Each segment was traversed downstream from its mid-point to the coast to identify the maximum downstream value encountered
DSDam	Presence of downstream obstruction (mostly dams) are indicated by a '1', absence by a '0'.
USAvgTNorm	Average air temperature (degrees C) in the upstream catchment, normalised with respect to SegJanAirT, with negative values indicating colder (higher elevation) headwaters than average, given the segment temperature, and positive values indicating warmer temperatures
USDaysRain	Days/year with rainfall greater than 25 mm in the upstream catchment to indicate the likely frequency of elevated flows, rainday frequencies were provided by Brett Mullan (NIWA) and were derived by averaging across estimated daily rainfalls over the 10 year period from 1990 to 2000 – indicates short-term stability of flow through the year
USAvgSlope	Average slope in the upstream catchment (degrees), describes catchment-driven modification of flow variability
USCalcium	Calcium concentrations in surface rocks using values derived from the underlying LENZ layers – refer LENZ documentation for details
USHardness	Average hardness (induration) of surface rocks using values derived from the underlying LENZ layers – refer LENZ documentation for details
USPhosporus	Phosphorus concentrations in surface rocks using values derived from the underlying LENZ layers – refer LENZ documentation for details
USPeat	Flow-weighted area of peat in upstream catchment (proportion)
USLake	Lake buffering in the upstream catchment, computed as described in the original REC manual
USWetland	Flow-weighted area of wetland in upstream catchment (proportion)
USIndigFor	Flow-weighted area of indigenous forest in upstream catchment (proportion), computed using cover estimates from LCDB1
USNative	Flow-weighted area of indigenous vegetation in upstream catchment (proportion), computed using cover estimates from LCDB1
USPasture	Flow-weighted area of pasture in upstream catchment (proportion), computed using cover estimates from LCDB1
USGlacier	Flow-weighted area of glacial cover in upstream catchment (proportion), computed using cover estimates from LCDB1
ReachSed	Weighted average of proportional cover of bed sediment using categories of: 1–mud; 2–sand; 3–fine gravel; 4–coarse gravel; 5–cobble; 6–boulder; 7–bedrock, predicted from a boosted regression tree model – details of model fitting are provided in Leathwick et al. (2008)
ReachHab	Weighted average of proportional cover of local habitat using categories of: 1–still; 2–backwater; 3–pool; 4–run; 5–riffle; 6–rapid; 7–cascade, predicted from a boosted regression tree model – details of model fitting are provided in Leathwick et al. (2008)
Shape_Length	Segment shape length in metres as computed by ArcGis

6.2. Predicted fish distributions

Field	Description
NZREACH	The unique identifier associated with each REC segment
ANGAUS	Predicted probability of capture for Anguilla australis
ANGDIE	Predicted probability of capture for Anguilla dieffenbachii
CHEFOS	Predicted probability of capture for Cheimarrichthys fosteri
GALARG	Predicted probability of capture for Galaxias argenteus
GALBRE	Predicted probability of capture for Galaxias brevipinnis
GALFAS	Predicted probability of capture for Galaxias fasciatus
GALMAC	Predicted probability of capture for Galaxias maculatus
GALPOS	Predicted probability of capture for Galaxias postvectis
GEOAUS	Predicted probability of capture for Geotria australis
GOBCOT	Predicted probability of capture for Gobiomorphus cotidianus
GOBGOB	Predicted probability of capture for Gobiomorphus gobioides
GOBHUB	Predicted probability of capture for Gobiomorphus hubbsi
GOBHUT	Predicted probability of capture for Gobiomorphus huttoni
RETRET	Predicted probability of capture for Retropinna retropinna
RHORET	Predicted probability of capture for Rhombosolea retiaria
MUGCEP	Predicted probability of capture for Mugil cephalus
GALANO_SPA	Predicted probability of capture for Galaxias anomalus constrained to catchments or sub-catchments with known occurrences
GALCOB_SPA	Predicted probability of capture for Galaxias cobitinis constrained to catchments or sub-catchments with known occurrences
GALDEP_SPA	Predicted probability of capture for Galaxias depressiceps constrained to catchments or sub-catchments with known occurrences
GALDIV_SPA	Predicted probability of capture for Galaxias divergens constrained to catchments or sub-catchments with known occurrences
GALELD_SPA	Predicted probability of capture for Galaxias eldoni constrained to catchments or sub-catchments with known occurrences
GALGOL_SPA	Predicted probability of capture for Galaxias gollumoides constrained to catchments or sub-catchments with known occurrences
GALMAR_SPA	Predicted probability of capture for Galaxias macronasus constrained to catchments or sub-catchments with known occurrences
GALPAU_SPA	Predicted probability of capture for Galaxias paucispondylus constrained to catchments or sub-catchments with known occurrences
GALPRO_SPA	Predicted probability of capture for Galaxias prognathus constrained to catchments or sub-catchments with known occurrences
GALPUL_SPA	Predicted probability of capture for Galaxias pullus constrained to catchments or sub-catchments with known occurrences
GALSPD_SPA	Predicted probability of capture for Galaxias `species D' constrained to catchments or sub-catchments with known occurrences
GALSPN_SPA	Predicted probability of capture for Galaxias `species N' constrained to catchments

	or sub-catchments with known occurrences
GALVUL_SPA	Predicted probability of capture for Gala xias vulgaris constrained to catchments or sub-catchments with known occurrences
GOBBAS_SPA	Predicted probability of capture for Gobiomorphus basalis constrained to catchments or sub-catchments with known occurrences
GOBBRE_SPA	Predicted probability of capture for Gobiomorphus breviceps constrained to catchments or sub-catchments with known occurrences
GALANO_ENV	Predicted probability of capture for Galaxias anomalus based solely on environment
GALCOB_ENV	Predicted probability of capture for Galaxias cobitinis based solely on environment
GALDEP_ENV	Predicted probability of capture for Galaxias depressiceps based solely on environment
GALDIV_ENV	Predicted probability of capture for Galaxias divergens based solely on environment
GALELD_ENV	Predicted probability of capture for Galaxias eldoni based solely on environment
GALGOL_ENV	Predicted probability of capture for Galaxias gollumoides based solely on environment
GALMAR_ENV	Predicted probability of capture for Galaxias macronasus based solely on environment
GALPAU_ENV	Predicted probability of capture for Galaxias paucispondylus based solely on environment
GALPRO_ENV	Predicted probability of capture for Galaxias prognathus based solely on environment
GALPUL_ENV	Predicted probability of capture for Galaxias pullus based solely on environment
GALSPD_ENV	Predicted probability of capture for Galaxias `species D' based solely on environment
GALSPN_ENV	Predicted probability of capture for Galaxias `species N' based solely on environment
GALVUL_ENV	Predicted probability of capture for Galaxias vulgaris based solely on environment
GOBBAS_ENV	Predicted probability of capture for Gobiomorphus basalis based solely on environment
GOBBRE_ENV	Predicted probability of capture for Gobiomorphus breviceps based solely on environment
AMENEB	Predicted probability of capture for Ameiurus nebulosus based solely on environment
AMENEB_RES	Predicted probability of capture for Ameiurus nebulosus constrained to catchments or sub-catchments with known occurrences
CARAUR	Predicted probability of capture for Carassius auratus based solely on environment
CARAUR_RES	Predicted probability of capture for Carassius auratus constrained to catchments or sub-catchments with known occurrences
CYPCAR	Predicted probability of capture for Cyprinus carpio based solely on environment
CYPCAR_RES	Predicted probability of capture for Cyprinus carpio constrained to catchments or sub-catchments with known occurrences
GAMAFF	Predicted probability of capture for Gambusia affinis based solely on environment
GAMAFF_RES	Predicted probability of capture for Gambusia affinis constrained to catchments or sub-catchments with known occurrences
ONCMYK	Predicted probability of capture for Onchorhynchus mykiss based solely on environment

ONCMYK_RES	Predicted probability of capture for Onchorhynchus mykiss constrained to catchments or sub-catchments with known occurrences
ONCTSH	Predicted probability of capture for Onchorhynchus tshawytscha based solely on environment
ONCTSH_RES	Predicted probability of capture for Onchorhynchus tshawytscha constrained to catchments or sub-catchments with known occurrences
SALFON	Predicted probability of capture for Salvelinus fontinalis based solely on environment
SALFON_RES	Predicted probability of capture for Salvelinus fontinalis constrained to catchments or sub-catchments with known occurrences
SALTRU	Predicted probability of capture for Salmo trutta based solely on environment
SALTRU_RES	Predicted probability of capture for Salmo trutta constrained to catchments or sub-catchments with known occurrences
SCAERY	Predicted probability of capture for Scardinius erythrophthalmus based solely on environment
SCAERY_RES	Predicted probability of capture for Scardinius erythrophthalmus constrained to catchments or sub-catchments with known occurrences
SHAPE_Length	Segment length as computed by ArcGis (m)
DiadCommunityGroup	Diadromous community group as described in Leathwick et al. (2009)

6.3. Predicted invertebrate distributions

Attributes for this table are very self explanatory, with a similar structure to those described for predicted fish distributions. However, no spatial restrictions are applied to the predictions, so all are based solely on environment. In addition, more complete field names are used, and so the taxonomic entity in each case can be resolved by referring to Leathwick, Julian & Smith (2009).

6.4. River classification

Field	Description
NZREACH	The unique identifier associated with each REC segment.
LevelOneNumeric	Level One composite classification containing 20 groups – numeric values
LevelOneAlpha	Level One composite GDM classification containing 20 groups – alphanumeric values
LevelTwoNumeric	Level Two composite GDM classification containing 100 groups – numeric values
LevelTwoAlpha	Level Two composite GDM classification containing 100 groups – alphanumeric values
LevelThreeNumeric	Level Three composite GDM classification containing 200 groups – numeric values
LevelThreeAlpha	Level Three composite GDM classification containing 200 groups – alphanumeric values
LevelFourNumeric	Level Four composite GDM classification containing 300 groups – numeric values
LevelFourAlpha	Level Four composite GDM classification containing 300 groups – alphanumeric values
ShapeLength	Shape length as computed by ArcGis (m)

6.5. River pressures

Field	**Description**
NZREACH	The unique identifier associated with each REC segment.
Impervious	Proportional cover of impervious surfaces in the upstream catchment , calculated by D. Brown, DOC, Christchurch. Values for the immediate catchment was calculated and traversed downstream and an area weighted average for the upstream catchment was calculated
Natural_cover	Indigenous vegetation cover in the upstream catchment (proportion), derived from satellite-imagery. Values were traced downstream to calculate upstream catchment average for each segment, with the contributions weighted by their flow
LogNConcentration	Log_{10} nitrogen concentration (ppb), range from -4.1 (very low concentrations) to 3.1 (very high concentrations), based on CLUES, a regionally-based regression model implemented within a catchment framework (Woods et al. 2006)
DownstreamDamEffect	Downstream effects of dams/barriers. Flow weighted calculation of upstream dam effects and their progressive dilution downstream as flow increases with input from undammed tributaries. Dam locations were derived from the New Zealand Dam Inventory, supplemented by records from council databases. It includes dams greater than 3m in height or containing more than 20,000 m^3 of water.
UpstreamDamEffect	Upstream effect of dams/barriers on diadromous species – all segments affected by downstream dams and in which species richness of diadromous fish could be expected to exceed 0.5 species per electric fishing sample are indicated by a value of 1
IndustrialEffect	Industrial site point discharges, with effects reduced downstream as for DamEffectDownstream
CoalEffect	Coal mine point discharges, with effects reduced downstream as for DamEffectDownstream
GeothermalEffect	Human-generated point discharges of geothermal water, with effects reduced downstream as for DamEffectDownstream
MineEffect	Mineral mine point discharges, with effects reduced downstream as for DamEffectDownstream
FishEffect	Summed fish effects as described in Leathwick & Julian (2007) - values were rescaled into a 0-1 range across all river segments.
Ameneb	Predicted probability of capture for *Ameiurus nebulosus* (catfish)
Caraur	Predicted probability of capture for *Carassius auratus* (goldfish)
Cypcar	Predicted probability of capture for *Cyprinus carpio* (koi carp)
Gamaff	Predicted probability of capture for *Gambusia affinis* (mosquito fish)
Oncmyk	Predicted probability of capture for *Oncorhynchus mykiss* (rainbow trout)
Onctsh	Predicted probability of capture for *Oncorhynchus tshawytscha* (Chinook salmon)
Salfon	Predicted probability of capture for *Salvelinus fontinalis* (brook char)
Saltru	Predicted probability of capture for *Salmo trutta* (brown trout)
Scaery	Predicted probability of capture for *Scardinius erythrophthalmus* (rudd)
SumAverage	Pressure indices calculated from individual pressure factors (average) – see Leathwick et al. (2007) for calculation details
SumMinimum	Pressure indices calculated from individual pressure factors (minimum) – see Leathwick et al. (2007) for calculation details

Shape_Length	Segment shape length in metres as computed by ArcGis.

6.6. River ranking

Field	Description
ID	Unique numeric identifier
Nzreach	The unique identifier associated with each REC segment
ExtentHa	The geographic extent of the entire planning unit (ha)
Character	Distinguishes between river planning units and lakes greater than 100 ha in extent
CatchmentOrder	The river order of the planning unit
RiverDSPolyID	The ID of the next downstream planning unit, assuming lakes are to be bypassed
LakeDSPolyID	The ID of the next downstream planning unit, including lake planning units
SpatialProtection	The proportion of the planning unit currently protected in conservation estate, Nga Whenua Rahui and QEII covenants, and Regional Council reserves
RiverProtectedness	The average proportional protection of Level 2 river classification groups contained in the planning unit, weighted by their relative extent - see accompanying documentation for details
PressureSum	Planning unit average human pressure for rivers and streams in the planning unit, calculated using the MinimumSum method of Leathwick et al. (2007)
NaturalCover	The proportional cover of native vegetation, as assessed from natural cover data supplied by Landcare Research
LogNConcentration	Planning unit average nitrogen concentration ($\log_{10}$ transformed ppb) as estimated from CLUES, a regionally-based regression model implemented within a catchment framework (Woods et al. 2006)
Imperviousness	Planning unit average values for imperviousness, i.e., the proportional cover of impervious surfaces in the upstream catchment - see “Impervious” in river pressures layer for details
ExoticFishSum	Planning unit average values for summed fish effects as described in Leathwick et al. (2007) - values were rescaled into a 0-1 range across all river segments, before averages were calculated for each planning unit
UpstreamDamEffect	Planning unit average for upstream barrier effects of dams/barriers on diadromous species - individual segments for which access is blocked are allocated a 1, non-blocked a 0, with values then averaged across the planning unit
DownstreamDamEffect	Planning unit average for downstream effects of known dams/barriers, derived using flow weighted calculation of upstream dam effects and their progressive dilution downstream as flow increases with input from undammed tributaries
CoalMineEffect	Planning unit average for coal mine point discharges, with effects reduced downstream as for DownstreamDamEffect - see Leathwick et al. (2007) for details
OtherMineEffect	Planning unit average for mineral mine point discharges, with effects reduced downstream as for DownstreamDamEffect - see Leathwick et al. (2007) for details
GeothermalEffect	Planning unit average for human-induced geothermal point discharges, with

	effects reduced downstream as for DownstreamDamEffect - see Leathwick et al. (2007) for details
IndustrialEffect	Planning unit average for industrial site point discharges, with effects reduced downstream as for DownstreamDamEffect - see Leathwick et al. (2007) for details
RegionalRank	Regional importance rank calculated using Zonation with pressure and connectivity constraints - low values indicate high ranks, i.e., 1 = first ranked, etc.
RegionalCumArea	The approximate cumulative area protected, expressed as a proportion of the region, if planning units are given protection in their ranked order. Values can be used to identify the planning units required to achieve any given level of protected extent
NationalRank	National importance rank calculated using Zonation with pressure and connectivity constraints - low values indicate high ranks, i.e., 1 = first ranked, etc.
NationalCumArea	The approximate cumulative area protected, expressed as a proportion of New Zealand, if planning units are given protection in their ranked order. Values can be used to identify the planning units required to achieve any given level of protected extent
NationalProtRank	As for NationalRank but with all planning units already having 80% or more protection held back until all other planning units are removed. See accompanying documentation for details
NationalProtCumArea	As for NationalCumArea but with all planning units already having 80% or more protection held back until all other planning units are removed. See accompanying documentation for details.
SHAPE_Length	The perimeter length of the planning unit (m).
SHAPE_Area	The area of the planning unit (m^2).

6.7. Lake classification

Field	Description
LID	Unique lake identifier
Name	Name (where known)
Primary	Primary classification group (A to G)
Natural2	Natural classification level 2 (A.1 to G.3)
Natural3	Natural classification level 3 (A.1.1 to G.3.2)
Natural4	Natural classification level 4 (A.1.1.1 to G.3.2.1)
Natural5	Natural classification level 5 (A.1.1.1.1 to G.3.2.1.)
Current2	Current classification level 2 (A.1 to G.2)
Current3	Current classification level 3 (A.1.1 to G.2.1)
Current4	Current classification level 4 (A.1.1.1 to G.2.1.1)
Current5	Current classification level 4 (A.1.1.1.1 to G.2.1.1.1)
MaxDepth	Maximum lake depth (metres)
LakeArea	Lake area (metres^2)
DecTemp	Estimated December air temperature (degrees)
DecSolrad	Estimated December solar radiation (MJ/metre squared/day)
Fetch	Maximum lake fetch (metres)
SumWind	Estimated summer wind (m/sec)
CatBeech	Estimated catchment cover of forest dominated by *Nothofagus* species (percentage)
CatGlacial	Estimated catchment cover of glaciers (percentage)
CatHard	Average rock hardness in the upstream catchment (1 weak to 5 very strong)
CatPeat	Estimated catchment cover of peat soils (percentage)
CatPhos	Average phosphorus content of rocks in the upstream catchment (1 low to 5 high)
CatSlope	Average slope in the upstream catchment (degrees)
CatAnnTemp	Average annual air temperature in the upstream catchment (degrees)
DirectDistCoast	Shortest distance to the coast (km)
ResidenceTime	Estimated lake residence time (years)
Urban	Cover of built up (urban) sites in the upstream catchment derived from LCDB2_1 (percentage)
Pasture	Cover of high producing exotic grassland in the upstream catchment derived from LCDB2_40 (percentage)
WoniUnit	Woni biogeographic unit (29 total) as identified in Leathwick, Collier & Chadderton (2007)
WoniProvince	Woni biogeographic Province (9 total) as identified in Leathwick, Collier & Chadderton (2007)
RegionalCouncil	Regional Council territory in which the lake occurs
LakeAreaHA	Lake area (ha)

LakePerim	Lake perimeter (metres)
LakeVolume	Lake Volume (metres^3)
LakeElevation	Lake Elevation (metres)
MeanWind	Estimated mean annual wind speed (metres/second)
GeomorphicType	The geomorphic formation typology for the lake according to the classes aeolian (wind-formed, dune), dam, geothermal, glacial, landslide, peat, riverine, shoreline, tectonic, and volcanic- taken from lake atlases by Irwin 1975 (Checklist of New Zealand Lakes), Livingston et al. 1986 (Inventory of New Zealand Lakes Parts I and II), and Viner 1987 (Inland waters of New Zealand).

6.8. Lake pressures and rankings

Field	Description
LID	Unique lake identifier
Name	Name (where known)
Primary	Primary classification group (A to G)
Natural4	Natural classification level 4 (A.1.1.1 to G.3.2.1), reflecting the classification level at which the ranking analysis was conducted
WoniUnit	Woni biogeographic unit (29 total) in which the lake occurs as described in Leathwick, Collier & Chadderton (2007)
RegionalCouncil	Regional Council territory in which the lake occurs
RegionalRank	Regional importance rank calculated using Zonation with pressure constraints within each Woni biogeographic unit - low values indicate high ranks, i.e., 1 = first ranked, etc.
RegionalCumArea	As for RegionalRank, but values indicate the approximate cumulative area that would be protected, expressed as a proportion, if lakes are given protection in their ranked order
NationalRank	National importance rank calculated using Zonation with pressure constraints - low values indicate high ranks, i.e., 1 = first ranked, etc.
NationalCumArea	As for NationalRank, but values indicate the approximate cumulative area that would be protected, expressed as a proportion, if lakes are given protection in their ranked order.
NationalProtRank	As for NationalRank but with all lakes already having 80% or more protection held back until all other lakes are removed. See accompanying documentation for details.
NationalProtCumArea	As for NationalProtRank, but values indicate the approximate cumulative area that would be protected, expressed as a proportion, if lakes are given protection in their ranked order.
NaturalCover	Indigenous vegetation cover removal in the upstream catchment (proportion), derived from satellite-imagery. Values were traced downstream to calculate upstream catchment average for each segment, with the contributions weighted by their areas.
LandusePressure	Nitrogen loading based on CLUES, a regionally-based regression model (Woods et al. 2006).Values of N loading were summed for all inflowing tributaries and standardized (divided) to water residence time (Lake volume/catchment flow).
Impervious	Pressure from impervious surfaces in the upstream catchment measured as proportion of impervious cover (supplied by D. Brown, DOC) and standardized to the catchment area divided by the lake area to take into account lakes with small catchments.
InvasivePlants	Pressure from invasive plants calculated from the maximum AWRAM score of recorded invasive macrophytes from the NIWA LakeSpi database. Multiplied by the clarity proxy and then divided by the depth index (shallow 1, medium 2, deep 3).
InvasiveFish	Pressure of known invasive fish, calculated from invasive fish data from the New Zealand Freshwater Fisheries Database, and invasive fish scores by Wilding and Rowe 2006
DamEffectUpstream	Upstream effect of dams/barriers on diadromous species - all segments affected by downstream dams and in which species richness of diadromous

	fish could be expected to exceed 0.5 species per electric fishing sample are indicated by a value of 1.
DamEffectDownstream	Downstream effects of dams/barriers. Flow weighted calculation of upstream dam effects and their progressive dilution downstream as flow increases with input from undammed tributaries. Dam locations were supplied by Department of Conservation.
SumPressureEQ1a	Estimated pressure calculated using Equation 1 from deWinton et al. (2009) with invasive macrophyte and fish data excluded
SumPressureEQ1b	Estimated pressure calculated using Equation 1 from deWinton et al. (2009) with invasive macrophyte and fish data included where present
SumPressureEQ2a	Estimated pressure calculated using Equation 2 from deWinton et al. (2009) with invasive macrophyte and fish data excluded
SumPressureEQ2b	Estimated pressure calculated using Equation 2 from deWinton et al. (2009) with invasive macrophyte and fish data included where present
LakeAreaHa	Lake area (hectares)
catAreaHa	Lake catchment area (hectares)
ResidenceTime	Estimated lake residence time (years)
NitrogenLoad	Total annual sum of nitrogen loading (kg/year) to the lake as predicted from CLUES model (Woods et al. 2006), summed for all inflows to the lake
PredMacrophyteDepth	Predicted lower depth limit of macrophytes (metres) in the lake modelled using various catchment attributes, See DeWinton et al (2009)
ActualMacrophyteDepth	Actual measured lower depth limits of macrophytes in the lake, where known, from NIWA LakeSpi database
ClarityProxy	Light clarity proxy of the lake taken from either the predicted or known bottom depth limits of macrophytes (in metres)

6.9. Lake catchments

Field	**Description**
LID	Unique lake identifier
Name	Name (where known)
Primary	Primary classification group for the lake (A to G)
LakeAreaHA	Lake Area (hectares)
lkElev	Lake Elevation (metres)
catArea	Total lake catchment area (metre^2)
catPerim	Total lake catchment perimeter (m)
catSlope	Average slope in the upstream catchment (degrees)
catFlow	Mean annual flow (m3/sec), derived from hydrological models, provided by Jochen Schmidt, NIWA, 2006.
catElev	Mean catchment elevation (m)
catAnnTemp	Average annual air temperature in the upstream catchment (degrees)
catDecSolRad	Estimated December solar radiation (MJ/metre squared/day)
catJuneSolRad	Estimated June solar radiation (MJ/metre squared/day)
catPhos	Average phosphorus content of surface rocks in the upstream catchment (1 low to 5 high) – see LENZ documentation for details
catCalc	Average calcium content of surface rocks in the upstream catchment (1 low to 4 high) – see LENZ documentation for details
catHard	Average rock hardness of surface rocks in the upstream catchment (1 weak to 5 very strong) – see LENZ documentation for details
catPsize	Average particle size of surface rocks in the upstream catchment (1 sand to 5 massive) – see LENZ documentation for details
catAlluv	Mean catchment proportional cover of alluvium – derived from LENZ (percentage)
catBeech	Estimated catchment cover of forest dominated by Nothofagus species (percentage)
catGlacial	Estimated catchment cover of glaciers (percentage)
catPeat	Estimated catchment cover of peat soils (percentage)
catImpervious	Area of anthropogenic impervious surface in upstream catchment (proportion), computed using cover estimates from LCDBII by Derek Brown, DOC.
catNatural	Area of indigenous vegetation in upstream catchment (proportion), computed using cover estimates from LCDBII.
catPasture	Area of pasture in upstream catchment (proportion), computed using cover estimates from LCDBII.

6.10. Historic wetlands typology

Field	Description
WLTYPE	Numeric code for wetland type - translated in field 'TypeName'
GENSOI	NZLRI field describing soil attributes in terms of 1:250000 soil units
NZSC	NZLRI field describing NZ Soil Classification
SOILTYPE	NZLRI field describing soil type
TOPROCK	NZLRI field describing surficial geology
BASEROCK	NZLRI field describing underlying geology
DRAIN_CLAS	NZLRI field describing drainage using 1 = very poor; 2 = poor; 3 = imperfect; 4 = moderately well; 5 = well
PH_CLASS	NZLRI field describing pH using 1 = 7.6-8.3; 2 = 6.5-7.5; 3 = 5.8-6.4; 4 = 5.5-5.7; 5 = 4.9-5.4; 6 = 4.5-4.8
VEG	NZLRI field describing vegetation cover
SLOPE	Average slope as determined from EcoSat 15m DEM
ELEV	Average elevation (m) as determined from EcoSat 15m DEM
KAURI	Presence (1) or absence (0) of kauri
P_SWAMP	probability of allocation to 'swamp'
P_MARSH	probability of allocation to 'marsh'
P_BOG	probability of allocation to 'bog'
P_FEN	probability of allocation to 'fen'
P_SEEPAGE	probability of allocation to 'seepage'
P_PAKIHI	probability of allocation to 'pakihi'
P_GUMLAND	probability of allocation to 'gumland'
RIVER	Presence of a river
LAKE	Presence of a lake
PEATCONTEN	Estimated peat content using 1 = pure peat; 2 = mix of peat and mineral soil; 3 = pure mineral soil
FERTILITY	Estimated fertility using 1 = low; 2 = medium, 3 = high
HECTARES	Wetland area (ha)
Sal_class	Salinity using 1 = 0-0.05; 2 = 0.05-0.15; 3 = 0.15-0.3; 4 = 0.3-0.7; 5=0.7-1. Units are in % soluble salts
Red_tussock	Presence of red tussock
Shape_Length	GIS calculated perimeter
Shape_Area	GIS calculated area
TypeName	Text equivalent of 'WLTYPE'

6.11. Current wetlands sites

Field	Description
IDunique	Unique site identifier
Area	Wetland extent across entire site (ha)
Name	Site name
Nzms260	NZMS 260 sheet
Easting	Full NZMG Easting
Northing	Full NZMG Northing
BiogeographicUnit	Woni biogeographic unit number
Condition	Overall index of integrity from completely degraded (0) to pristine (1)
Irreplaceability	See Ausseil et al. 2008
CumulativeEffects	Cumulative conservation effectiveness achieved by protecting this and all higher ranked sites – as calculated by Ausseil et al.
Rank	The conservation rank from high (1) to low (no of sites) – as calculated by Ausseil et al.
CatchmentArea	The extent of the contributing catchment
Source	The source data used in delineating the wetland
NonNaturalnessInSubcat	Proportion of non-natural vegetation in surrounding catchment
NonNaturalnessInBuffer	Proportion of non-natural vegetation in surrounding 30 m buffer
ImperviousnessInWetland AndBuffer	Proportion of impervious cover in the wetland and a surrounding 30 m buffer
ImperviousnessInWetland	Proportion of impervious cover in the wetland
ImperviousnessInBuffer	Proportion of impervious cover in the surrounding 30 m buffer
ImperviousnessInSubcat	Proportion of impervious cover in the surrounding catchment
NriskInSubcat	Nitrate leaching risk in the surrounding catchment
NriskInBuffer	Nitrate leaching risk in the surrounding 30 m buffer
NRiskChoice	Nrisk in subcatch. for marsh, seepage, saline, wetlands with rivers; max(Nrisk subcat or buffer) for swamp; Nrisk in buffer for the others
Pestiness	Introduced fish pestiness score
GorseAndPine	Score for gorse, pine and other woody weeds
Willows	Score for grey willows
CoreToEdgeRatio	Core to edge ratio
Drains	Presence of drains
Idinfo_S	Additional source information
NationalCumArea	National wetland rankings calculated with Zonation and using human pressure estimates - values indicate the approximate cumulative area protected, expressed as a proportion, if wetlands are given protection in their ranked order.
NationalRank	As for NationalCumArea, but with values indicating the ordered rank - low values indicate high ranks, i.e., 1 = first ranked, etc.
NationalProtCumArea	As for NationalCumArea but with all wetlands already having 80% or more

	protection held back until all other wetlands are removed. See accompanying documentation for details.
NationalProtRank	As for NationalCumArea, but with values indicating the ordered rank - low values indicate high ranks, i.e., 1 = first ranked, etc.
RegionalCumArea	Regional wetland rankings calculated with Zonation and using human pressure estimates - values indicate the approximate cumulative area protected, expressed as a proportion, if wetlands are given protection in their ranked order.
RegionalRank	As for RegionalCumArea, but expressed as integer ranks, i.e., 1, 2, 3, 4, etc.
PropProtected	Proportion of site protected either within DOC land, Nga Whenua Rahui, QEII trust, or Regional Council reserve

6.12. Current wetlands typology

Field	**Description**
IDUNIQUE	Unique site identifier
P_SWAMP	probability of allocation to 'swamp'
P_MARSH	probability of allocation to 'marsh'
P_BOG	probability of allocation to 'bog'
P_FEN	probability of allocation to 'fen'
P_SEEPAGE	probability of allocation to 'seepage'
P_PAKIHI	probability of allocation to 'pakihi'
P_GUMLAND	probability of allocation to 'gumland'
WLTYPE	Numeric code for wetland type - translated in field 'TypeName'
SWAMP_VEG	Presence of swamp vegetation
REDTUSS	Presence of red tussock
NZSC	NZLRI field describing NZ Soil Classification
SUBALP_VEG	Presence of sub-alpine vegetation
PH_CLASS	NZLRI field describing pH using 1 = 7.6-8.3; 2 = 6.5-7.5; 3 = 5.8-6.4; 4 = 5.5-5.7; 5 = 4.9-5.4; 6 = 4.5-4.8
DRAIN_CLAS	NZLRI field describing drainage using 1 = very poor; 2 = poor; 3 = imperfect; 4 = moderately well; 5 = well
SOILTYPE	NZLRI field describing soil type
GENSOI	NZLRI field describing soil attributes in terms of 1:250000 soil units - genetic soil units
VEG	NZLRI field describing vegetation cover
VEG2	NZLRI field describing additional vegetation cover
FERTILITY	Estimated fertility using 1 = low; 2 = medium, 3 = high
ELEVATION	Average elevation (m) as determined from EcoSat 15m DEM
SLOPE	Average slope as determined from EcoSat 15m DEM
LAKE2	Presence of a lake
RIVER2	Presence of a river
GUMSOIL	Indicator of gumland soil using 0 = no, 1 = yes
PEATCONTEN	Estimated peat content using 1 = pure peat; 2 = mix of peat and mineral soil; 3 = pure mineral soil
KAURI	Presence (1) or absence (0) of kauri
SUBCATAREA	Area of contributing catchment (ha)
AREAWL	Wetland area (ha)
Sal_class	Salinity using 1 = 0-0.05; 2 = 0.05-0.15; 3 = 0.15-0.3; 4 = 0.3-0.7; 5=0.7-1. Units are in % soluble salts
Shape_Length	GIS calculated perimeter
Shape_Area	GIS calculated area
VegName	Text equivalent of 'WLTYPE'

6.13. Current wetlands catchments

Field	Description
IDunique	Unique site identifier
area	Catchment area (ha)
NextDownID	Unique id of the downstream catchment
Shape_Length	Catchment perimeter - auto GIS added
Shape_Area	Catchment area - auto GIS added