Annual rainfall maps for the Horizons-Manawatu Region

NIWA Client Report: WLG2008 / 69
November 2008

NIWA Project: ELF09201 / HZLC60

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Prepared for

Horizons Regional Council

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1. Introduction

Horizons Regional Council (HRC) contracted NIWA (through the Envirolink fund – see appendix) to produce four maps of the annual rainfall for the Horizons-Manawatu Region (see location map, Figure 1). The four maps are the mean and median annual rainfall total (in millimeters) for the two overlapping 30-year periods 1971–2000 and 1978–2007. Geographic Information Systems (GIS) raster data grids at 500m spatial resolution (from which the maps are derived) have also been provided to HRC.

The period 1971–2000 was chosen because it is the latest climate "normal" period (the next normal period will be 1981–2010). As this period does not include recent years (which include some years with anomalously high and low rainfalls), the "most recent" 30-year period was also analysed and mapped, being the years 1978–2007.

This report briefly describes the spatial interpolation method used to produce the GIS data grids (and hence maps). Significantly, the interpolations used all the available annual rainfall data currently archived in the NIWA National Climate Database (clidb) for New Zealand plus additional annual rainfall data (not housed in clidb) supplied by HRC (see Figure 1).

2. Spatial interpolation method

The underlying usefulness of spatial interpolation methods is directly related to the quality and quantity of the surface observations. In New Zealand there is an excellent and extensive network of currently-open climate stations that record rainfall totals every day. The majority of these rainfall data are stored in the National Climate Database (clidb), an Oracle relational database. This is maintained by the National Institute of Water and Atmospheric Research (NIWA) in Wellington.

The two most successful methods used for the spatial interpolation of climate variables from surface observations covering large areas and encompassing complex terrain are kriging (including cokriging) and splines (Hutchinson and Gessler, 1994). Other methods such as inverse distance weighting, trend surface analysis (including linear and polynomial regression), and nearest neighbour tend to produce greater prediction errors in these situations, particularly those methods that do not include elevation information (Hutchinson and Bischof, 1983; Laslett *et al.*, 1987, Phillips *et al.*, 1992).

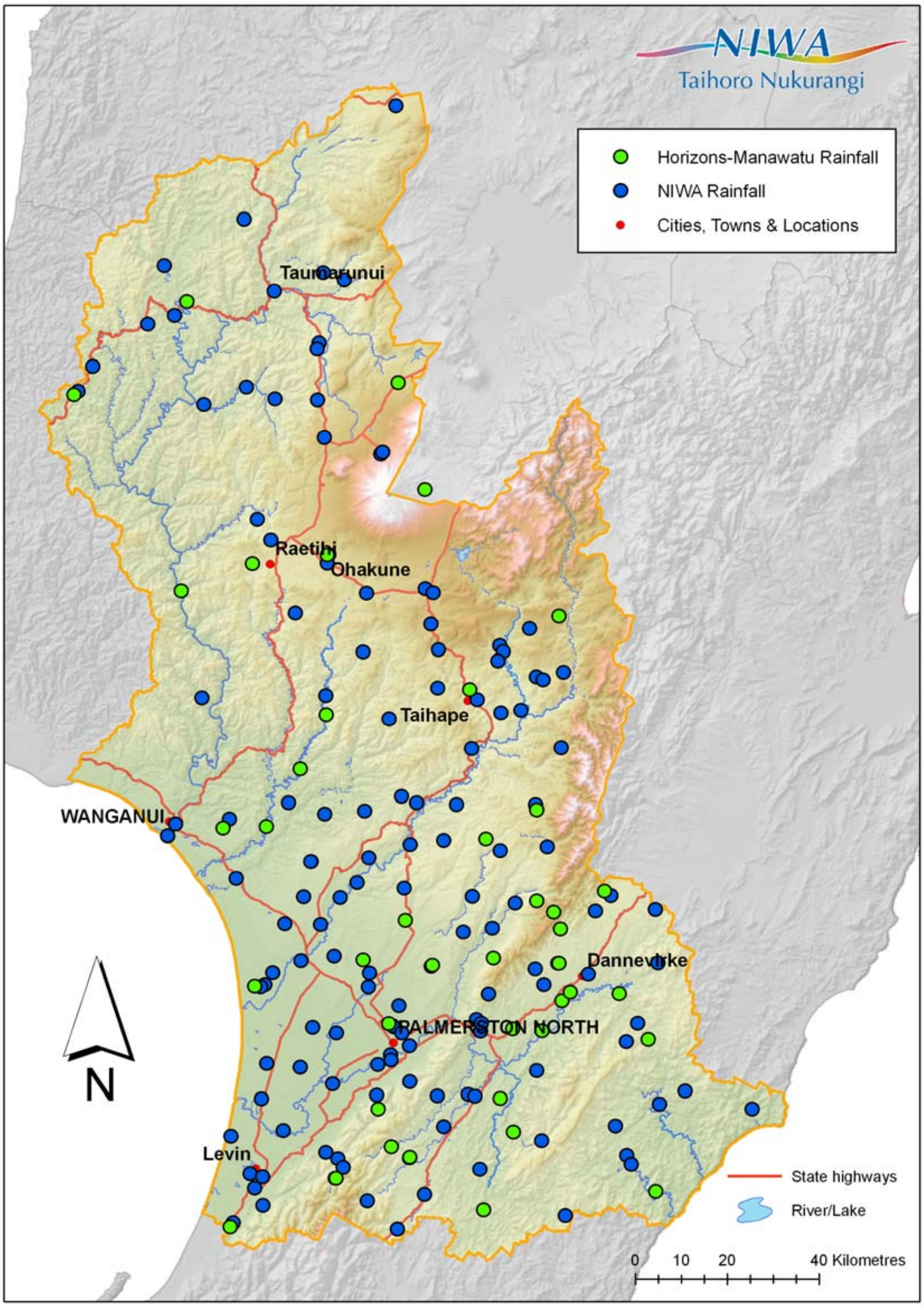

Figure 1: Extent of the Horizons-Manawatu region and the location of rainfall observations sites (data held in the NIWA climate database = blue circles; data held by Horizons Regional Council = green circles) used in the analysis.

Kriging and splines have many similarities (Matheron, 1981), and when the kriging variogram is well chosen, the prediction errors from both methods are similar (Seaman and Hutchinson, 1985; Laslett *et al*., 1987). A significant advantage of thin plate smoothing splines over kriging, however, is in their efficiency. Kriged surfaces are defined by minimizing the variance of the error of estimation, which normally depends on a preliminary variogram analysis. The accuracy of the fitted variogram model is a function of the correct selection of the variogram parameters and of the nugget variance in particular, which has a direct impact on the error properties of the fitted surface. The selection of these parameters often requires several trials, and the estimates are not always reliable (Hutchinson and Gessler, 1994).

A thin-plate smoothing spline works by fitting a surface to the data with some error allowed at each data point, so the surface can be smoother than if the data were fitted exactly. Each station is omitted in turn from the estimation of the fitted surface and the mean error is found. This is repeated for a range of values of a smoothing parameter, then the value that minimises the mean error is taken to give the optimum smoothing. This process is called minimizing the generalised cross validation (GCV). It can be automated once the order of the derivative, which controls the surface roughness, has been chosen.

The density of the observation network is the primary deficiency for interpolation methods. In lowland areas with relatively uncomplicated terrain (i.e. where the majority of the population reside) there is an abundance of rainfall data. On the other hand, rainfall observations in areas of mountainous terrain are often sparse and records are often relatively short with many missing values. This is not uncommon for many areas around the world (and is also the case for the Horizons-Manawatu Region, see Figure 1). Interpolation of rainfalls into these areas based on data from lower elevation stations sometimes several kilometres away can cause significant discrepancies.

In this study, we have chosen a thin plate smoothing spline model, which has been shown to perform well for the interpolation of New Zealand climate data (Sansom and Thompson, 2003; Tait *et al*., 2006; Tait and Turner, 2005; and Zheng and Basher, 1995). The software used was ANUSPLIN version 4.3 (Hutchinson, 2008).

Most meteorological variables, including rainfall, are affected by orography. Thus it makes sense to interpolate rainfall using a spline model with two position variables and an orographic variable such as elevation. The broad spatial pattern is determined by the two position variables, while the inclusion of elevation modifies the broad pattern to give more precise representations of the higher resolution variability.

Hutchinson (1995) used a trivariate thin plate smoothing spline (latitude, longitude, and elevation) to interpolate mean annual rainfall (and other meteorological variables) across Australia. A trivariate spline, which allows the relationship between rainfall and elevation to vary spatially, was deemed more appropriate for a continent-wide interpolation, compared with a trivariate partial spline (includes a single linear dependence upon elevation), which is more suited to small-scale applications.

To improve the interpolations further, we used a digitised version of a hand-drawn map of the mean annual rainfall for the period 1951–80, instead of elevation, in the trivariate spline model. The hypothesis was based on the observation that the 1951–80 map showed more realistic rainfall totals in the mountains (based on short-term observations, some high resolution NWP model runs, and observed river flows) than those produced from the elevation-based spline model. Last, we assigned a relative variance to each rainfall observation site, based on the inverse of the number of complete years of data. This relative variance weights stations with long records more strongly in the interpolation than stations with short records. Note that only sites with three or more years of data were included in the analysis.

Using this modelling approach, Figure 2 shows the median annual rainfall map for all of New Zealand and includes details of an interpolation error analysis performed at the observation sites. Note that this analysis is based on data sourced from clidb only. It can be seen that the mean prediction standard error over all the observation sites is 147.9 mm (note – at low elevation locations where there is a dense network of observation sites, the error is closer to the minimum value of 132.6 mm). The model prediction standard error is a combination of the variance of the data values and the model standard error estimate of the interpolated values.

Confidence intervals of the calculated spline values can be estimated by multiplying the prediction standard error by 1.96, the 95 percent two-sided confidence interval of the standard normal distribution.

3. Annual rainfall maps for the Horizons-Manawatu Region

Using annual rainfall data sourced from clidb and HRC, spline interpolations were performed on four datasets: the mean and median annual rainfall for the two periods 1971–2000 and 1978–2007. The GIS-formated output grids (provided to HRC) have a spatial resolution of 500m and are projected onto the New Zealand Map Grid. Figures 3–6 show the rainfall maps associated with these four data grids.

Taihoro Nukurangi

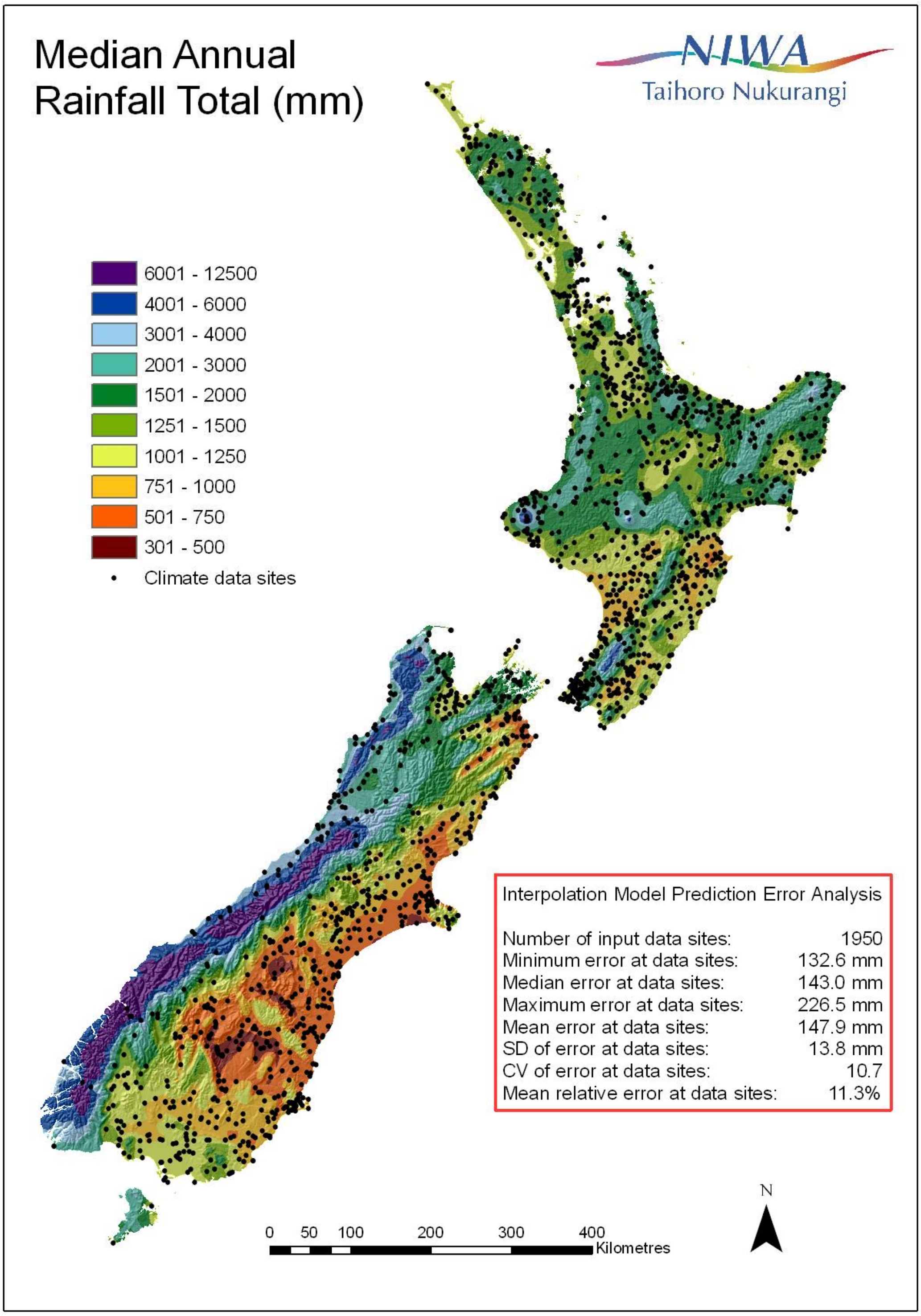

Figure 2: Interpolated median annual rainfall (based on the period 1971–2000) for all of New Zealand and an analysis of the interpolation error at the observation sites.

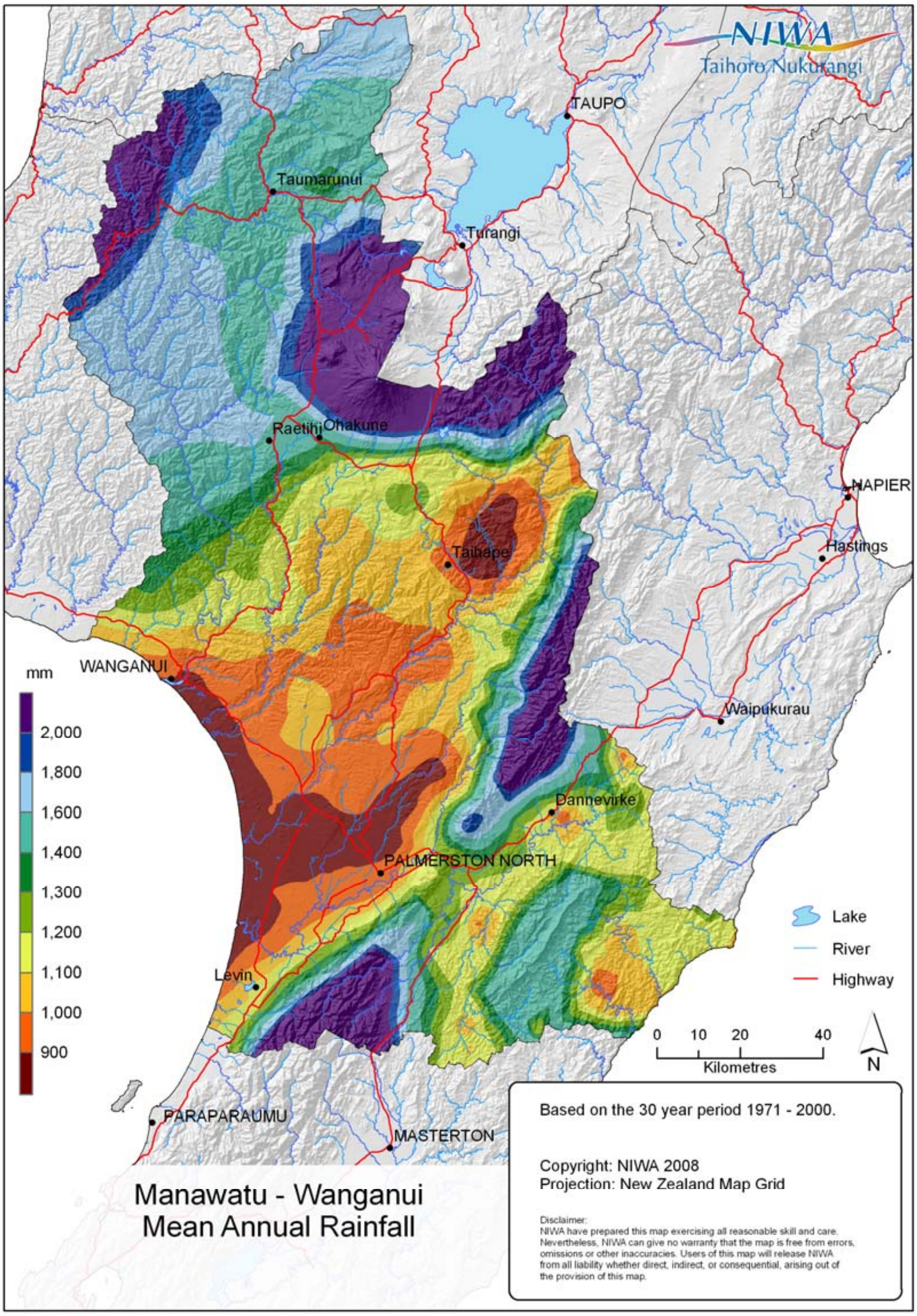

Figure 3: Interpolated mean annual rainfall (based on the period 1971–2000) for the Horizons-Manawatu region.

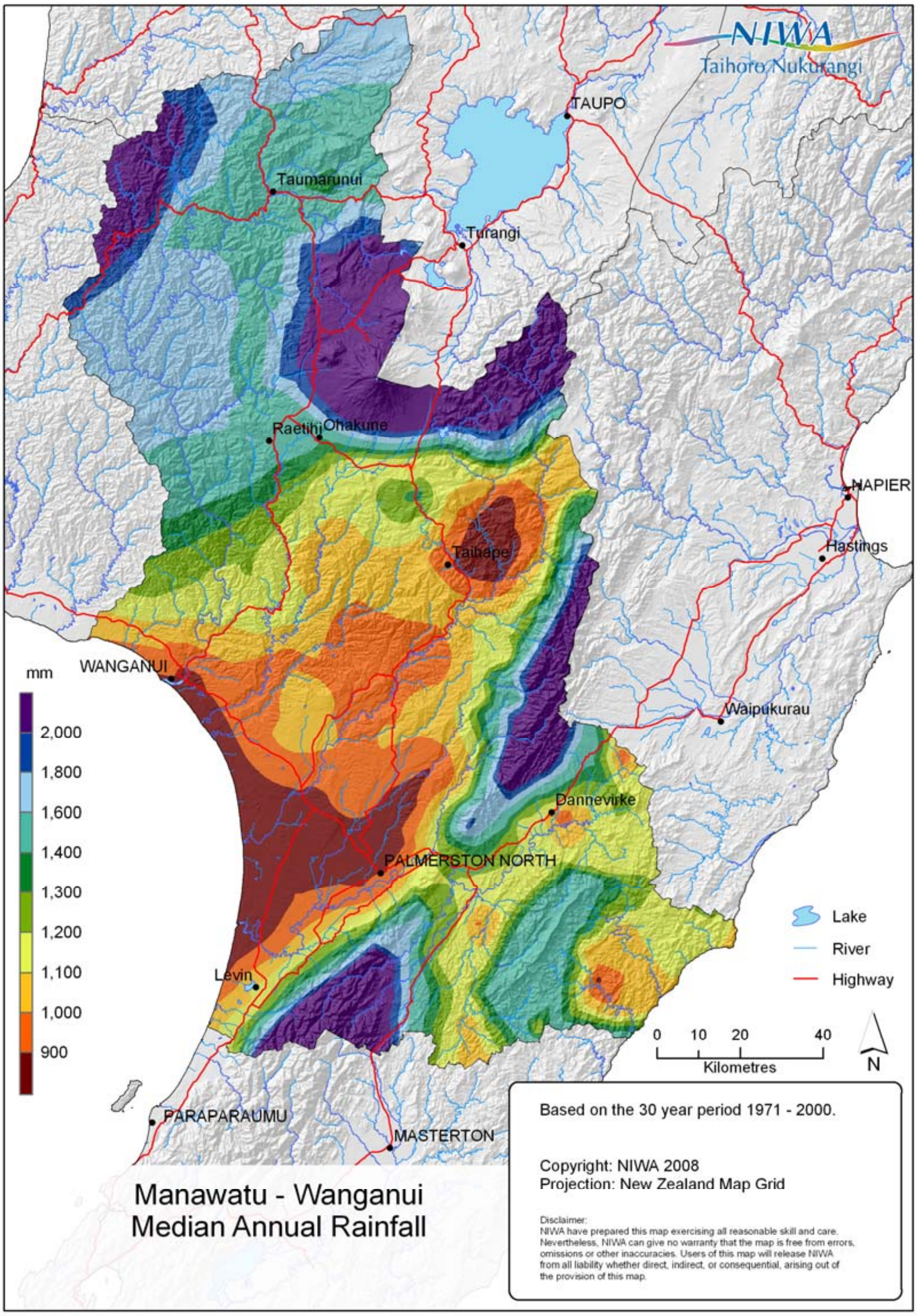

Figure 4: Interpolated median annual rainfall (based on the period 1971–2000) for the Horizons-Manawatu region.

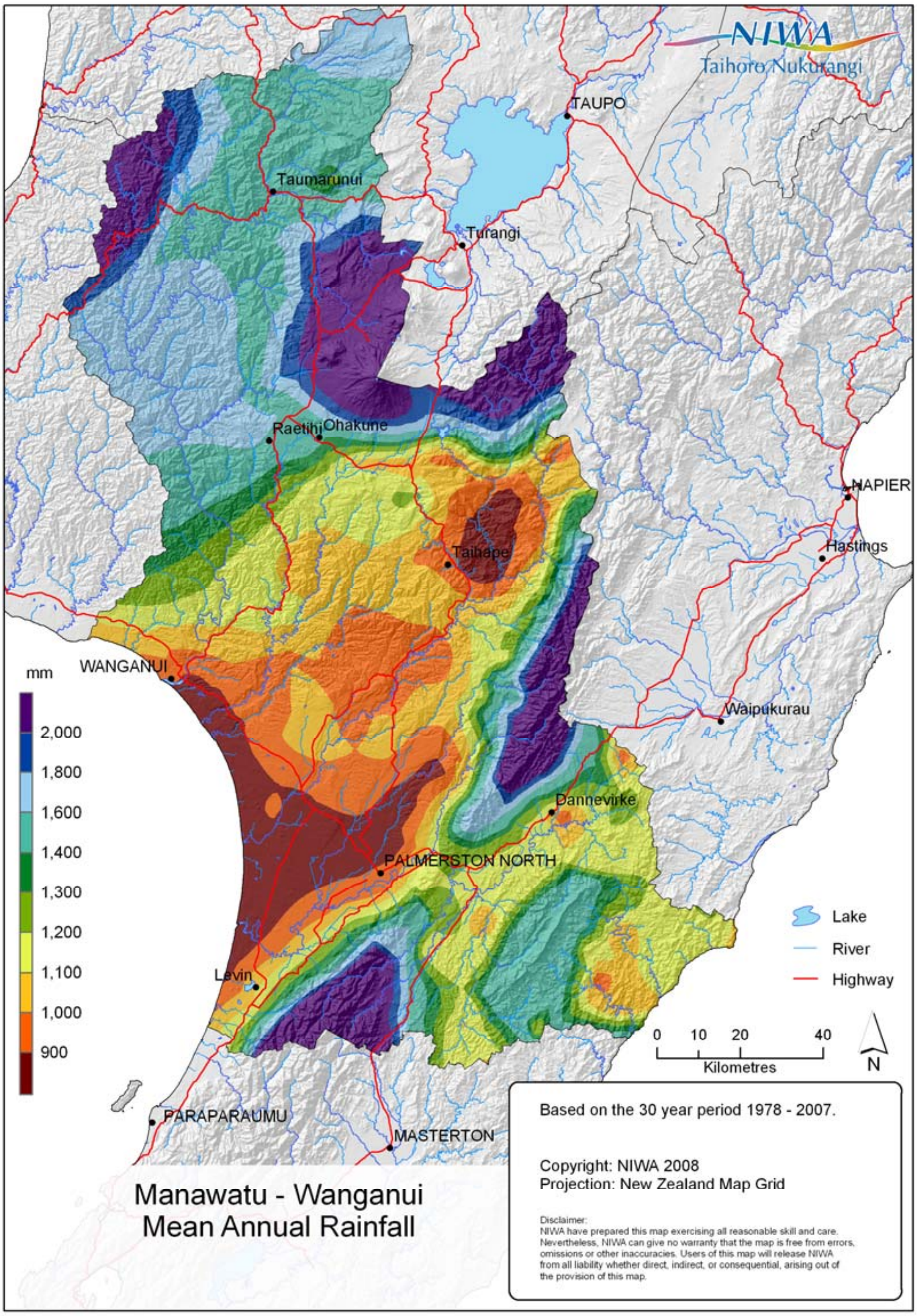

Figure 5: Interpolated mean annual rainfall (based on the period 1978–2007) for the Horizons-Manawatu region.

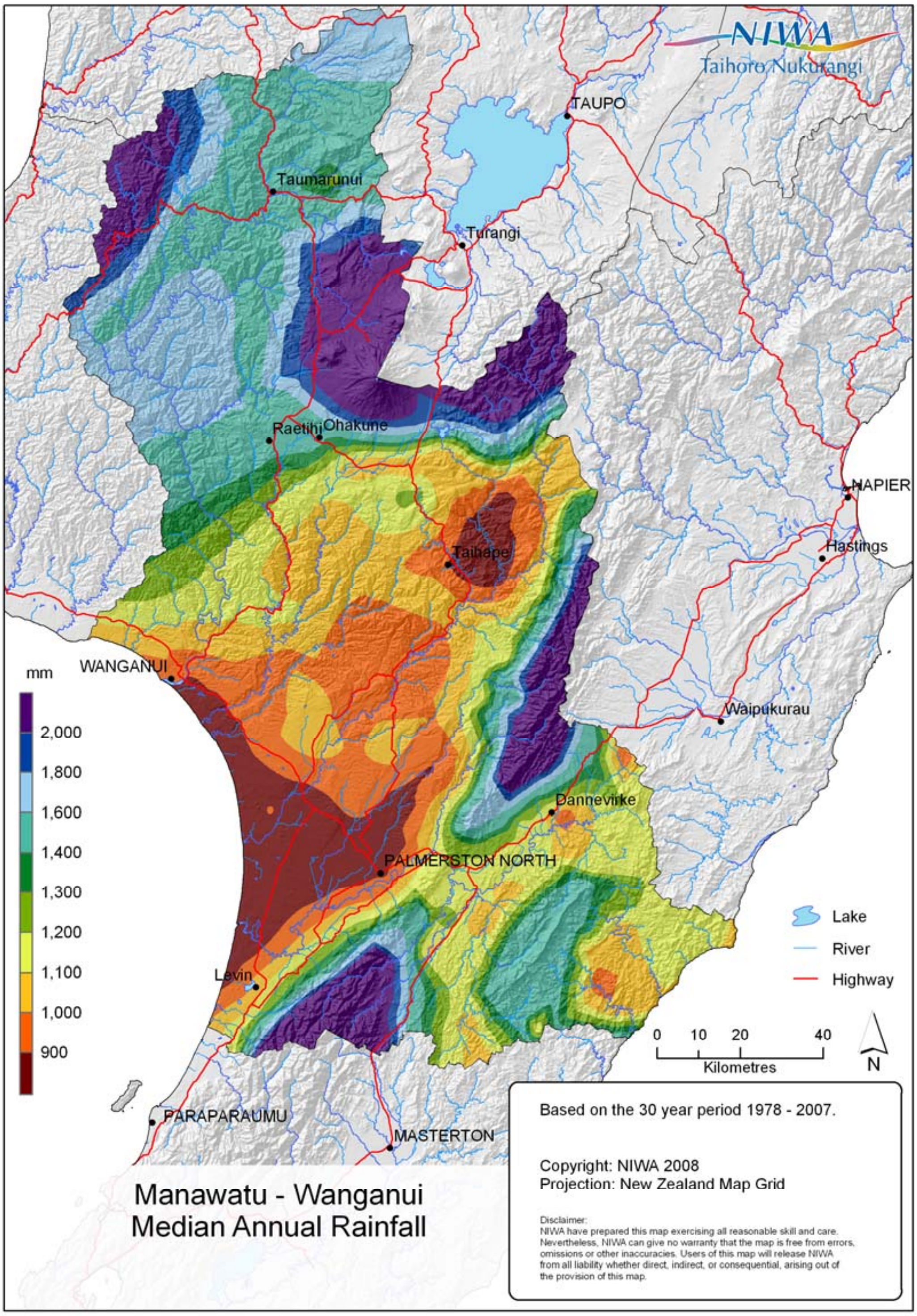

Figure 6: Interpolated median annual rainfall (based on the period 1978–2007) for the Horizons-Manawatu region.

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5. Appendix – Envirolink Fund Contract

Foundation for RESEARCH SCIENCE & TECHNOLOGY
Tūāpapa Rangahau Pūtaiao

Envirolink application for small advice grants
(up to $5,000 excluding GST)

Regional Council Advice number: 605-HZLC60 Date: 1/07/08

Regional Council: Horizons Regional Council

Advice requested by: Raelene Hurndell

Phone number: 69522927 Email address: raelene.hurndell@horizons.govt.nz

Proposed research organisation: Andrew Tait of NIWA

Type of ecosystem involved: Freshwater

Please answer all questions so that your application can be fully considered.

1. Please give a short description that outlines the environmental management issue you are seeking advice on.

Horizons is seeking the development of a detailed and accurate isohyetal rainfall map for the region and a subsequent spatial analysis tool that will allow the rainfall data to be queried at 'farm scale'.

2. How will the advice allow you to positively address this issue to create benefit for your local community?

Horizons have recently notified the One Plan. The proposed One Plan includes a rule requiring intensive farms in catchments with identified degraded water quality to obtain a resource consent. The resource consent requires nutrient management via a farmer applied resource management strategy (FARM strategy). Rainfall has a strong influence on nutrient balances of farming systems and is a key input to determining the best practice management of nutrients on a farm by farm basis. The maps and spatial analysis tool to be developed by this project will ensure that the most accurate and up-to-date rainfall data is available to consent applicants and Horizons staff.

3. How do you intend to use this advice?

These maps will be used to define rainfall for particular farms for input into nutrient management models such as Overseer. This information will feed into the development of whole farm plans and nutrient management strategies, as described above.The development of whole farm plans and nutrient management strategies has the potential to achieve an on-going improvement of water quality in the region's waterways.

Foundation for Research Science and Technology, PO Box 12-240, Wellington, New Zealand

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TECHNOLOGY
Tūāpapa Rangahau Pūtaiao

Envirolink application form for small advice grants

Please fill out this form if you are applying for the small advice grant. This grant is set up for Regional Councils to obtain an initial expert consultation by a research organisation.

- The Regional Council may prepare this form jointly with the selected research organisation.
- The research organisation confirms eligibility by assessing the grant against the eligibility criteria for small advice grants.
- The grant covers consultation expenses up to $5,000 excluding GST.

Please fill in all queries on this form. The answers to questions one to three may be brief, but must provide enough information to ensure the advice request satisfies the eligibility criteria.

The Regional Council Advice number allows tracking of the advice path. Please use the designated code for your council name and a unique number.

Northland Regional Council — (NLRC)

Gisborne District Council — (GSDC)

Hawkes Bay Regional Council — (HBRC)

Horizons Regional Council — (HZLC)

Nelson City Council - (NLCC)

Marlborough District Council — (MLDC)

Tasman District Council — (TSDC)

West Coast Regional Council — (WCRC)

Environment Southland — (ESRC)

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4. Please choose which service(s) you would like the research organisation to provide.

☐ Seminar ☐ Training ☐ Informal Verbal Consultation

☐ Services ☐ Literature Survey ☐ Collating Research Material

Other (Please specify) Use of the 'best' available rainfall data for the Horizons Region to develop maps of median and mean annual rainfall of the region; and the provision of a spatial analysis layer (GIS) with a brief NIWA Client report detailing the map development process.

Can you attest that this request, to your knowledge, has not been answered in the past by either your council or another council's activities? Yes

This application has been sighted by your Council's Envirolink Coordinator.

Yes

Name of person completing form: Raelene Hurndelll

Please email completed form to the Envirolink contact for your selected research organisation.

To be filled in by research organisation

Approval is contingent upon the request for advice meeting Envirolink criteria and the ability of selected research organisation to fulfil the request.

Approval: Decision not made yet Approval date:

If no, give brief explanation:

Foundation for Research Science and Technology, PO Box 12-240, Wellington, New Zealand