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Kakanui Mountains Wind Resource Study

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1. Executive Summary

This low-resolution wind resource study has been completed for an area of approximately 2,500 km^2 of North Otago over the Kakanui Mountains extending from the Rock and Pillar Range in the southwest to near the Waitaki River to the northeast. The main aim of this study was to quantify the general wind resource over this area and identify possible areas of interest worthy of further investigation. Virtual mast wind climate summaries have been provided for two sites in the modelled region.

The wind maps are based on wind data obtained from simulating the weather regimes affecting the region during the period November 2001 to October 2002 using a mesoscale meteorological model at a resolution of 1000 m. The period November 2001 to October 2002 is considered to be sufficiently representative of the longer-term wind climate in this area for the purposes of this wind resource study.

Mean annual wind speeds at 50 and 75 m above ground level are predicted to be above 11 m/s over some elevated areas on the Kakanui Mountains and Rock and Pillar Range. It is possible that mean wind speeds exceed this where local scale topographic features enhance airflow patterns.

Mean annual wind speeds at 50 and 75 m above ground level are predicted to exceed 8.5 m/s over lower elevated areas to the south of the Kakanui Range. Again, it is likely that mean wind speeds are higher than this where local scale topographic features enhance airflow patterns.

Modelling at 1000 m resolution does not fully resolve all speed-up and slow-down effects due to small-scale topographic features. Locations with favourable topography may experience mean wind speeds 0.5 to 1.0 m/s higher than that indicated on the wind maps and reductions of a similar order are possible in unfavourable locations. High resolution modelling is required to better represent these localised effects.

2. Background

The aim of this study was to assess the general wind resource over and close to the Kakanui Ranges, which are located to the west of Oamaru. Hourly wind data were derived at two respresentative sites to illustrate the wind climates in the area.

3. Methodology

This wind resource assessment used a three-dimensional numerical atmospheric model that was able to simulate the airflow over the region. The model was run at a resolution of 1000 m (i.e. 1000 m separation between grid points). The 50 and 75 m above ground level wind maps were based on hourly wind data obtained from approximately 2500 grid points over the modelled area. This resolution and modelling extent were used to reduce issues associated with boundary conditions due to modelling over such a complex area. At 1000 m resolution, the model is able to account for larger-scale topographic and surface roughness features, providing a general picture of the wind climatology over the region.

The wind maps were based on the weather regimes affecting the eastern parts of the South Island during the one year period from 1 November 2001 to 31 October 2002. This period was selected as being representative of the long term wind climate as discussed in Section 4 below.

4. Long-term Wind Resource

A rigorous analysis of how well the modelled period represents the longer-term wind climate is beyond the scope of this study. With North Otago on the lee side of the Southern Alps during prevailing westerly winds, the resulting airflow patterns at lower elevation are often complicated and distorted by the effects of surrounding and larger scale topography. Higher locations of North Otago, such as on the Kakanui Mountains, are generally very exposed to these westerly component winds. Wind data from two higher level sources were therefore evaluated to provide confidence that the one year period from November 2001 to October 2002 represents the long term wind resource over the modelled region for the purposes of this wind resource analysis. The wind data used in this long term wind climate analysis is summarised in Table 1 below.

Table 1: Sources of wind data used to determine how well the modelled period represents the long term wind climate.

Wind data source	Period	Height above ground level
Invercargill	Nov 1991 – Dec 2004	About 1500 m
NCEP data	Jan 1986 – July 2006	About 1500 m

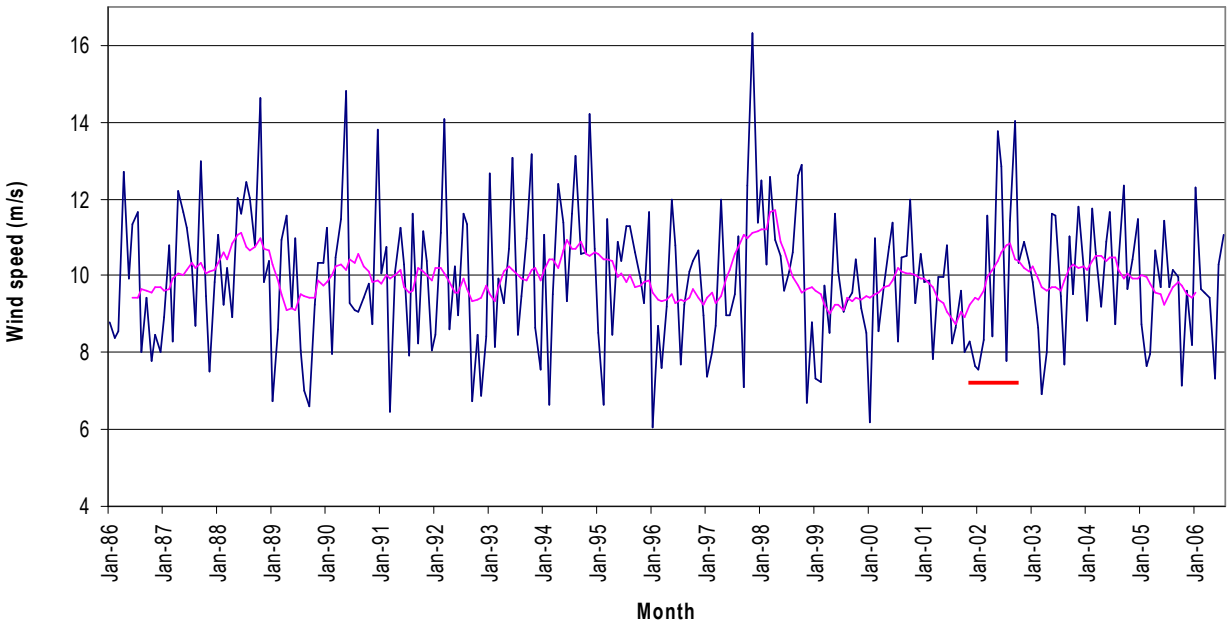
The 20 years of NCEP (National Centers for Environmental Prediction) wind data were obtained from a point near 45.0 S 170.0 E, which is just to the west of the modelled region near Ranfurly. These NCEP data are derived from the six-hourly re-analysis of input data used by global weather prediction models. The Invercargill upper wind data were obtained from six hourly balloon flights.

Table 2 shows that the mean winds speeds for the modelled period are similar to the long term mean wind speed for both data sources. The mean speed for the upper level NCEP data for the modelled period is a little higher than the long term mean and the mean speed for the Invercargill data is the same. The graph in Figure 1 illustrates the time series of wind data for the NCEP data. Analysis of these data provides sufficient evidence that the period from November 2001 to October 2002 is representative of the long-term wind climate for the North Otago region.

Table 2: Mean wind speeds at Invercargill and for the NCEP reference location for relevant time periods.

Period	Mean wind speed at Invercargill (m/s)	Mean wind speed for the NCEP dataset (m/s)
Nov 2001 – Oct 2002	12.0	10.2
All data	12.0	9.9

Figure 1: Monthly mean wind speed and 12-month moving average (pink line) for the NCEP data point near Ranfurly. The modelled period is indicated by the red line segment on the graph.



5. Area and General Wind Climate Description

The region modelled is shown in Figure 3 and covers an area of approximately 2500 km^2 of the North Otago region over the Kakanui Mountains and extending from the Rock and Pillar Range in the southwest to near the Waitaki River to the northeast. The topography of this region and the wider surrounding area is complicated with river valleys and plains surrounded by a number of mountain ranges including the Rock and Pillar Range, St Mary Mountains and Hawkdun Mountains. The topography is less complicated to the east and northeast of the modelled area, including the Waitaki River plain and Pacific Ocean respectively. Figure 4 shows terrain contours within the modelled area and the two virtual mast (VM) wind climate summary locations (VM 1 and VM 2).

While the wind regimes in this region are dominated by the prevailing westerlies, the orographic influences from the Southern Alps shelter and distort the airflow at lower elevations, especially near the coast. At higher elevations there is good exposure to the prevailing westerly component flows, which are likely to be turbulent and gusty during strong wind events. The northwest-southeast orientation of the Kakanui Mountains, suggests that there will be areas of favourable speed-up of westerly winds over elevated ridges. The Kakanui Range is also downstream of a break between the Rock and Pillar and Hawkdun Ranges which may cause channelling of wind flows and hence further enhancement of wind speeds in this area.

Figure 2: Topographic map showing the location of the modelled region.

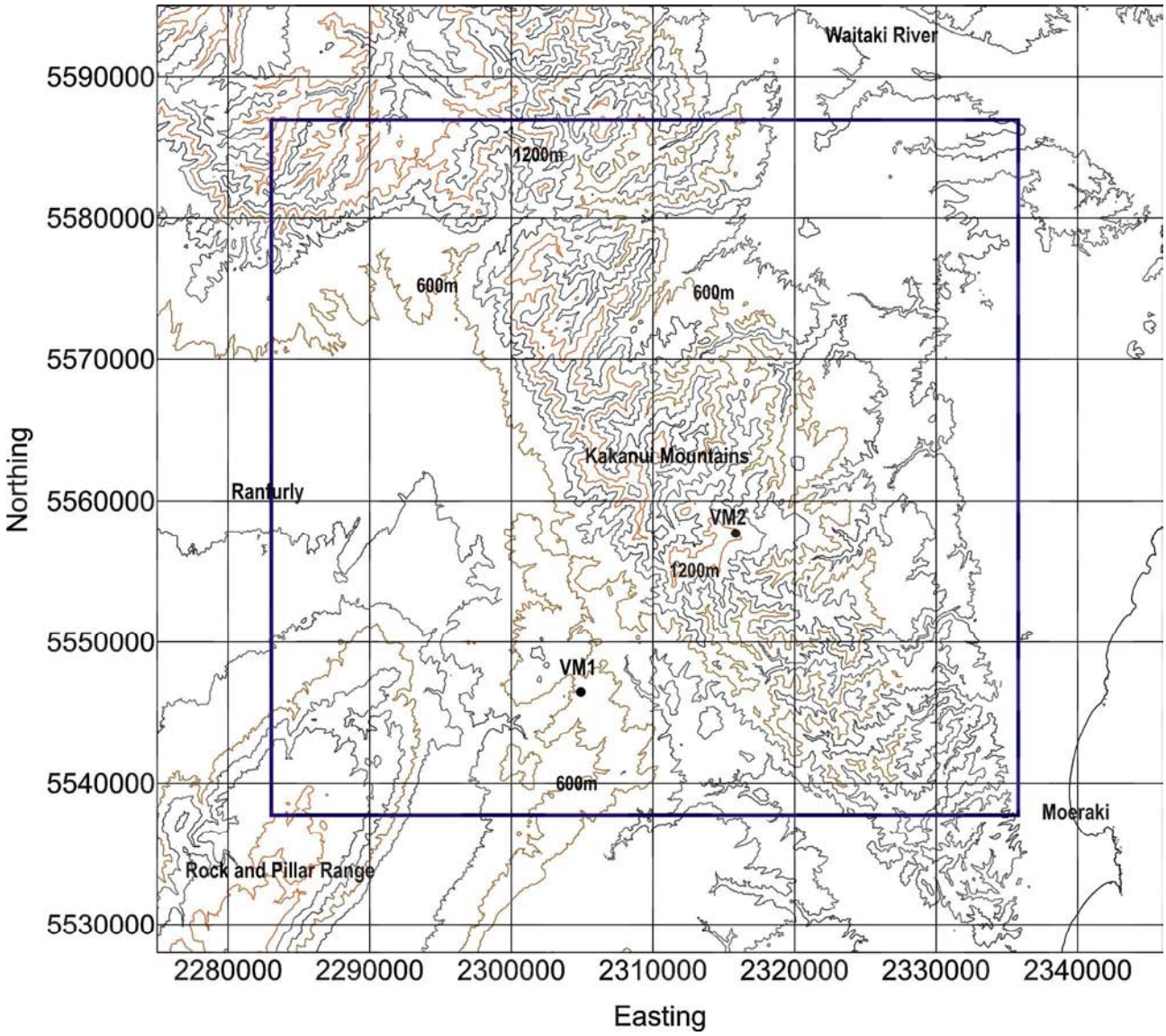


Figure 3: New Zealand Map Grid showing the modelled region within the box and with terrain contours at 200 m intervals. The brown contours are at 600 m (dark) and 1200 m (light).

6. Low Resolution Wind Maps

The wind maps for the Kakanui Mountains area at 50 and 75 m above ground level are shown in Figures 4 and 5. The maps indicate that mean wind speeds are above 12 m/s in places at the 50 and 75 m levels over higher elevations of the Kakanui Mountains. Due to the steepness of the terrain in this area, the model may be propagating these areas of higher mean winds speed further east of the main ridge than in reality. High mean wind speeds are also evident over the Rock and Pillar Range in the southwest of the modelled region. Here, mean wind speeds are predicted to be above 11 m/s at 50 m above ground level in some places.

The modelling results also indicate that a relatively good wind resource exists in the area between the Kakanui Mountains and Rock and Pillar Range at low elevation. A virtual mast wind climate summary site (VM1) has been included for this area, as is shown on the topography and wind maps (Figures 3, 4 and 5). This area, between the towns of Morrison and Kokonga, is elevated above surrounding terrain and is likely to experience channelling of westerly wind flows between the Kakanui Mountains and Rock and Pillar Range. Here mean wind speeds are expected to be generally above 8.5 and 9 m/s at 50 and 75 m above ground level respectively.

The lowest mean wind speeds occur at lower elevations to the west of the Kakanui Mountains in the Ranfurly area, and also to the northeast of the Kakanui Mountains. Here mean wind speeds are expected to be about 6 m/s at the 50 m level.

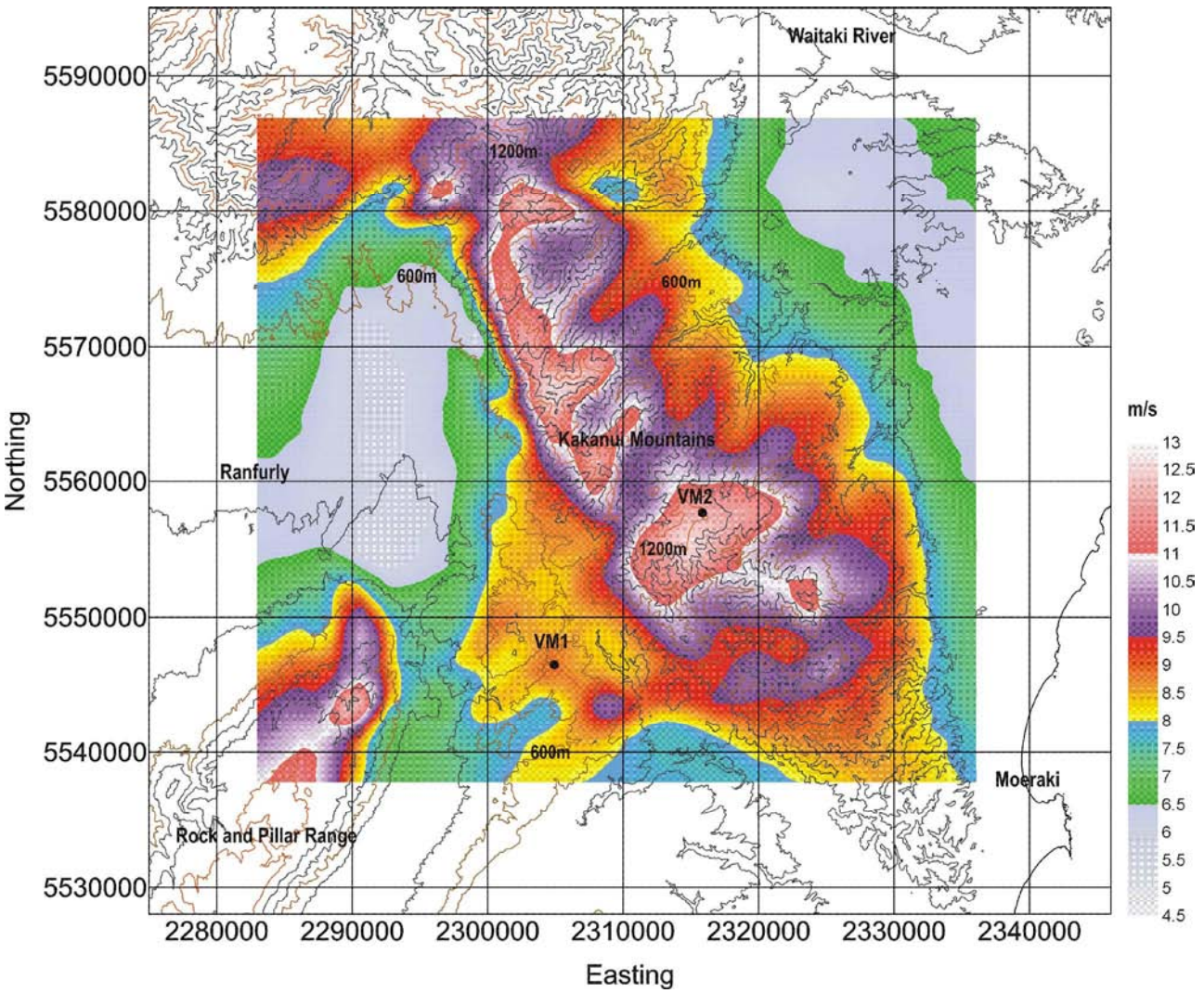


Figure 4: Wind map for the Kakanui Mountains area at 50 m above ground level showing mean wind speed contours at 0.1 m/s intervals. Elevation contours are at 200 m intervals. Brown contours are at 600 m (dark) and 1200 m (light).

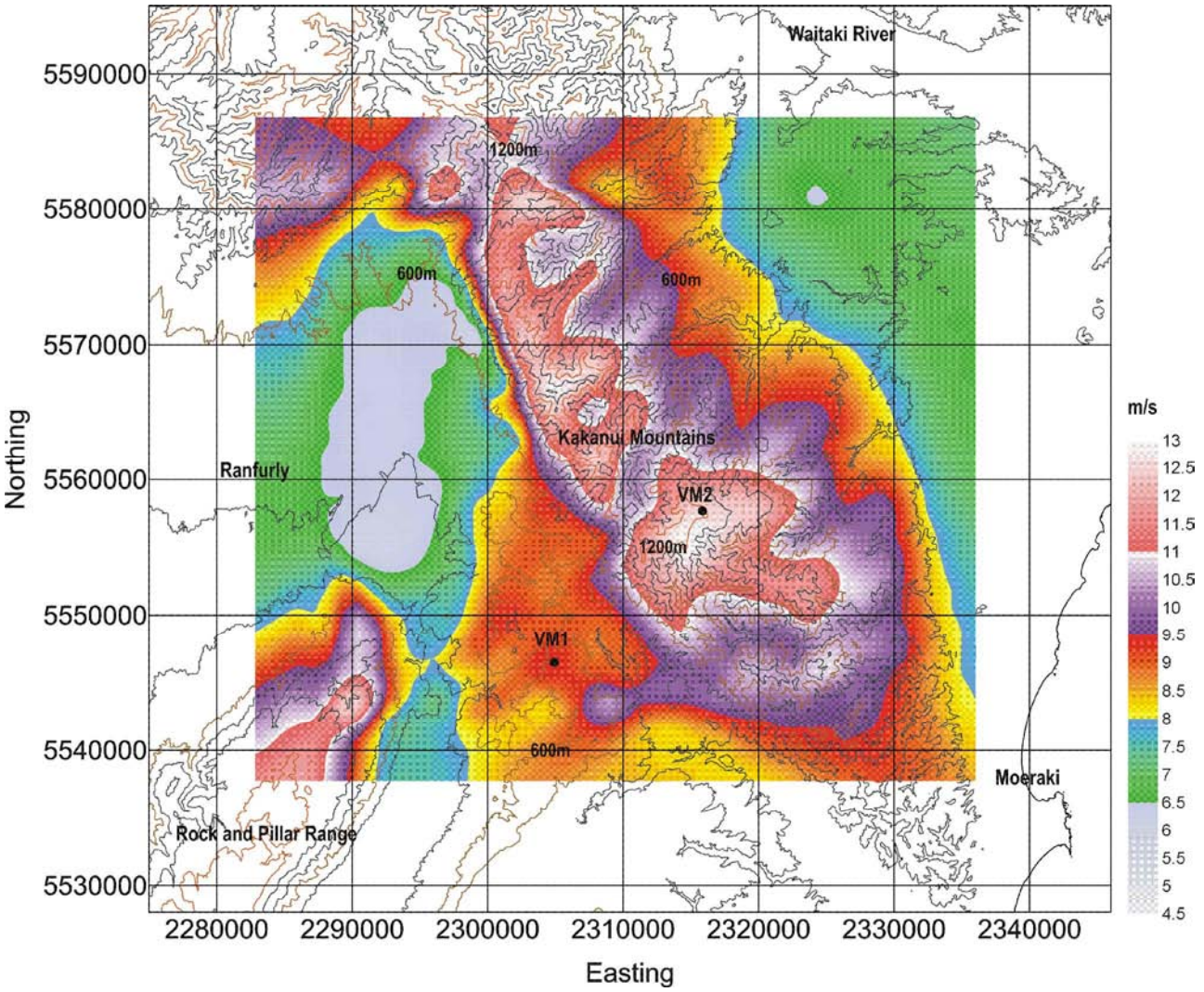


Figure 5: Wind map for the Kakanui Mountains area at 75 m above ground level showing mean wind speed contours at 0.1 m/s intervals. Elevation contours are at 200 m intervals. Brown contours are at 600 m (dark) and 1200 m (light).

The full extent of the modelling has been included in the wind maps above. Although the results look mostly reliable, mean wind speeds within about 5 km of the boundary should be treated with caution. The lobe of higher mean wind speeds to the southeast of virtual mast site 1 (VM1) is where the model is possibly representing channelling of westerly wind regimes, although the modelled mean wind speeds may be slightly over-estimated.

At 1000 m modelling resolution, the speed-up and slow-down effects from smaller-scale topographic features and land surface roughness characteristics will not be fully accounted for by the mesoscale model. Therefore, mean wind speeds at some locations are likely be 0.5 to 1.0 m/s higher than indicated on the maps, particularly in the vicinity of ridge lines and hills, or where local topographic features cause local channelling of airflow. It is difficult to quantify these effects for individual sites due to unique topographic effects and the way the model is representing the topography around such sites. Modelling at higher resolution will better represent such areas.

7. Wind Climate Summaries

Wind climate summaries are given for two sites within the modelled region, including Morrisons (VM 1) which is located between the Kakanui Mountains and Rock and Pillar Range, and Kakanui (VM 2) on the Kakanui Mountains. These sites were selected to represent typical wind climates in the area. Wind rose diagrams and Weibull curves at 50 m above

ground level are provided to illustrate the virtual wind climates. Table 2 shows the overall predicted mean wind speed for the period November 2001 to October 2002 at the two virtual mast sites.

Table 2: Mean wind speed at the virtual mast sites at 50 m above ground level.

Site	50 m mean wind speed (m/s)
Morrisons	8.9
Kakanui	10.0

7.1 Morrisons

The Morrisons virtual mast site is located on elevated terrain to the west of Morrisons between State Highways 85 and 87 near 2305000E, 5546000N. The elevation of this site is about 730 m above mean sea level. This site is considered to be representative of this region, which the model indicates is affected by the speed-up effects from topography and channelling. The mean wind speed for the period November 2001 to October 2002 was 8.9 m/s. The wind rose and Weibull curve diagrams at 50 m above ground level for the Morrisons site are given in Figures 6 and 7.

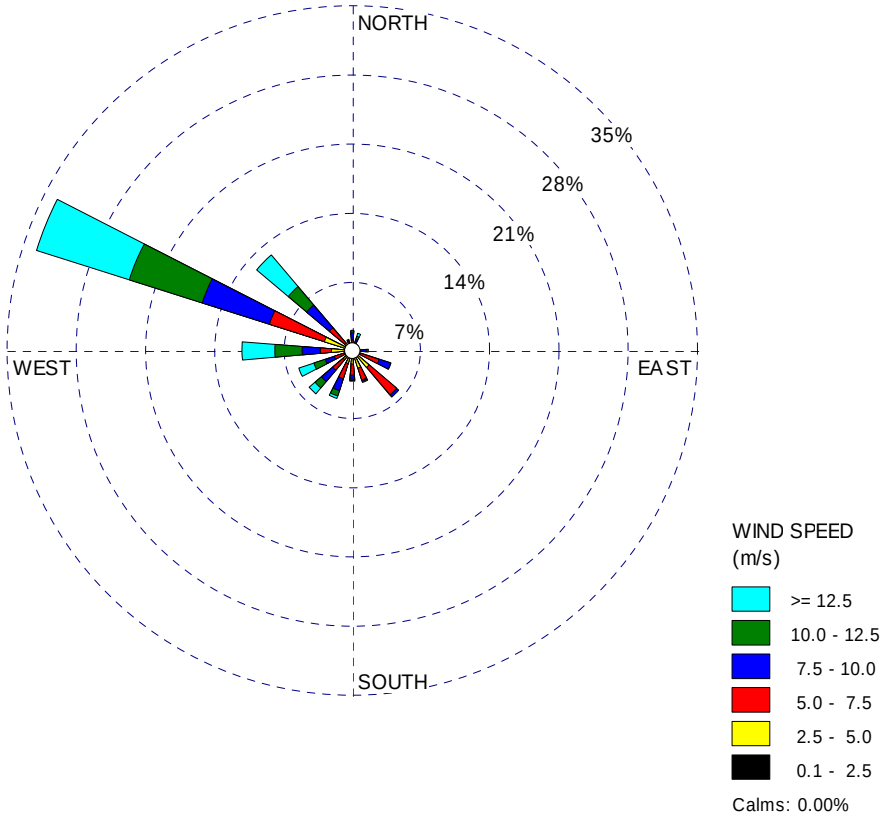


Figure 6: Wind rose for the Morrisons virtual mast site at 50 m above ground level.

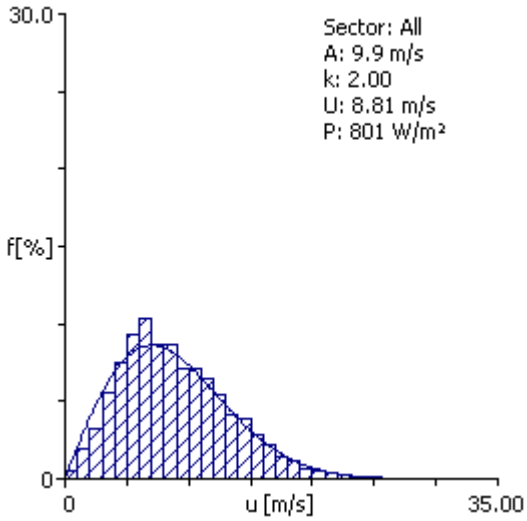


Figure 7: Weibull curve for the Morrisons virtual mast site at 50 m above ground level.
(Note that A and k are the Weibull parameters, while U and P are the Weibull mean wind speed and mean power density.)

The wind rose diagram shows that the dominant wind direction at the Morrisons site is from the west-northwest direction due to the channeling of winds in this area. As expected, there is a low frequency of winds from many directions due to the effects of surrounding topography. The wind speed distribution is a good fit to the Weibull distribution, as shown in Figure 7. Almost all strong wind events occur from the southwest to northwest sector. It is likely that strong wind events in this area are gusty and turbulent. The highest hourly modelled mean wind speed for the period November 2001 to October 2002 at 50 m above ground level was 32.0 m/s from the west-northwest occurring on 4 May 2002.

7.2 Kakanui

This virtual mast site is located on the Kakanui Mountains at an elevation of about 1250 m above mean sea level near 231600E, 5557000N. This site is considered to be representative of high elevation areas on the Kakanui Mountains. Wind rose and Weibull curve diagrams are given in Figures 8 and 9.

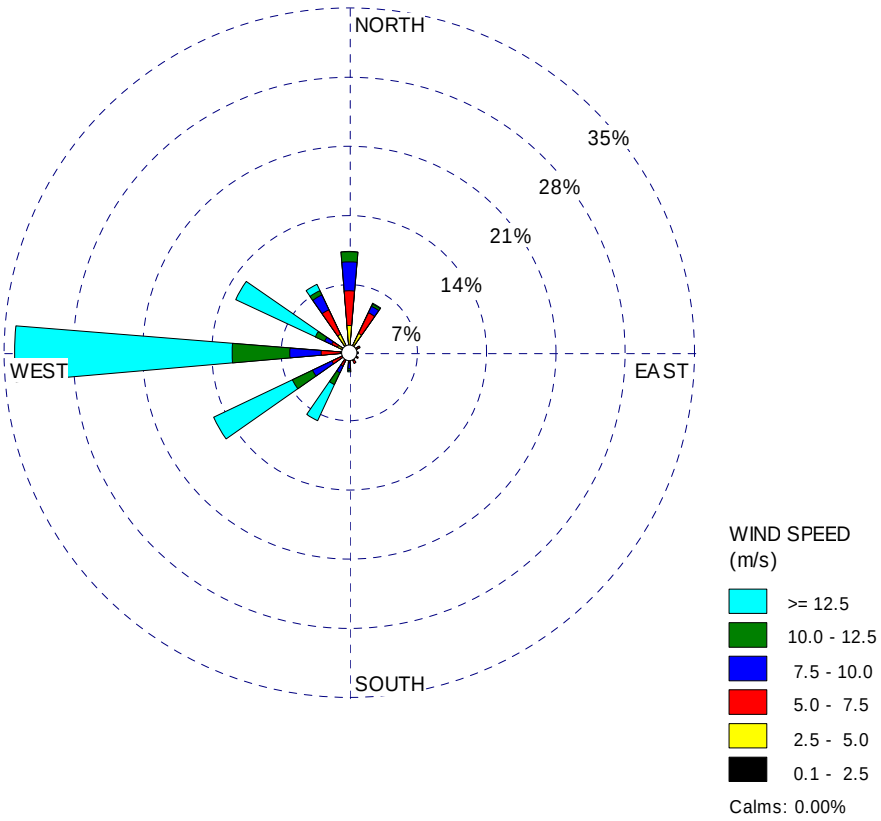


Figure 8: Wind rose for Kakanui virtual mast site at 50 m above ground level.

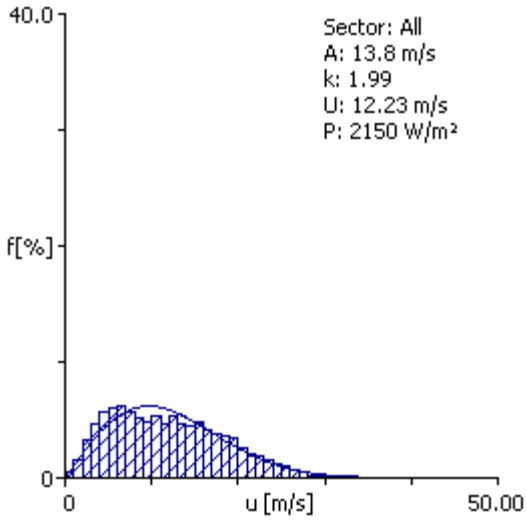


Figure 9: Weibull curve for the Kakanui virtual mast site at 50 m above ground level.
(Note that A and k are the Weibull parameters, while U and P are the Weibull mean wind speed and mean power density.)

Due to its altitude and exposure to the prevailing westerly winds, this is a high mean wind speed site. The wind rose shows that the prevailing wind direction is from the west, with a very low frequency of winds occurring from the east and south sectors. All strong wind events occur from the southwest to northwest sector, with the highest hourly modelled wind speed for the November 2001 to October 2002 period at 50 m above ground level being 44.5 m/s from the west on 4 May 2002. The wind speed distribution is a reasonable fit to the Weibull distribution, as shown in Figure 9.