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Oamaru Wind Resource Study

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1. Executive Summary

This low-resolution wind resource study has been completed for an area of approximately 700 km^2 of North Otago from near the Waitaki River mouth in the north, to about 10 km south of Oamaru, and extending about 25 km inland. The main aim of this study was to assess the general wind resource over this area and to quantify the wind resource at four specific sites/areas of interest identified by Energy 3.

The wind maps are based on wind data obtained from simulating the weather regimes affecting the region during the period from November 2001 to October 2002 using a mesoscale meteorological model at a resolution of 800 m. This period is considered to be sufficiently representative of the longer-term wind climate in this area for the purposes of this wind resource analysis.

Mean wind speeds at 25 m above ground level are predicted to exceed 6.5 m s^{-1} over a number of elevated areas. It is likely that mean wind speeds exceed this where local scale topographic features enhance the wind flow.

Mean wind speeds at 50 m above ground level are predicted to exceed 7.5 m s^{-1} over some elevated areas. It is likely that mean wind speeds exceed this where local scale topographic features enhance the wind flow.

Modelling at 800 m resolution does not fully resolve the speed-up and slow-down effects due to small-scale topographic features. Locations with favourable topography may experience mean wind speeds of 0.5 m s^{-1} higher than that indicated on the wind maps and reductions of a similar scale 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 wind resource over an area of North Otago from near the Waitaki River mouth in the north to about 10 km south of Oamaru, and extending approximately 25 km inland. Four specific areas/sites of interest were identified by Energy 3 within the modelled region. These include Airedale, Brockmans Hill, Cape Wanbrow and Whitstone and are shown on the map in Figure 4. At this model resolution, the wind maps at 25 and 50 m above ground level provide a picture of the general wind resource over the area. Wind climate summaries based on modelled hourly wind data were obtained at representative locations in the specific areas of interest.

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 800 m (i.e. 800 m separation between grid points). The wind maps were based on hourly wind data obtained from approximately 1100 grid points over the modelled area. At this 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.

The project deliverables are:

- Low-resolution wind maps covering an area approximately 26 km by 26 km at 25 and 50 m above ground level.
- Wind climate summaries for four representative locations specified by Network Waitaki.
- A report summarising the methodology, results and limitations of the work completed.

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 being located in the lee of the Southern Alps during prevailing westerly winds, weather patterns in this region are complicated. Wind data from four sources were therefore evaluated to provide confidence that the one year period from November 2001 to October 2002 is reasonably representative of 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 representation 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
Le Bons Bay	Feb 1984 – Apr 2005	10 m
NCEP data (1)	Jan 1986 – July 2006	10 m
NCEP data (2)	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. 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 and the Le Bons Bay winds were hourly measurements from an automatic weather station located at 236 m elevation on the eastern side of Banks Peninsula.

Table 2 shows that the mean winds speeds for the modelled period are similar to the long term mean wind speed for all four data sources. The mean wind speed at Le Bons Bay is slightly less than the long-term mean, as is the mean speed for the upper level NCEP data. For the Invercargill and low-level NCEP wind data, the mean speeds were the same for the modelled period and longer term. The graphs in Figures 1 and 2 illustrate the time series of wind data for the Invercargill and Le Bons Bay wind speed data. Analysis of these data provides sufficient evidence that the period from November 2001 to October 2002 is reasonabley representative of the long term wind climate for the North Otago region.

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

Period	Mean wind speed at Invercargill (m s^{-1})	Mean wind speed at Le Bons Bay (m s^{-1})	Mean wind for NCEP dataset 1 (m s^{-1})	Mean wind for NCEP dataset 2 (m s^{-1})
Nov 2001 – Oct 2002	12.0	6.7	5.5	9.9
All data	12.0	6.9	5.5	10.2

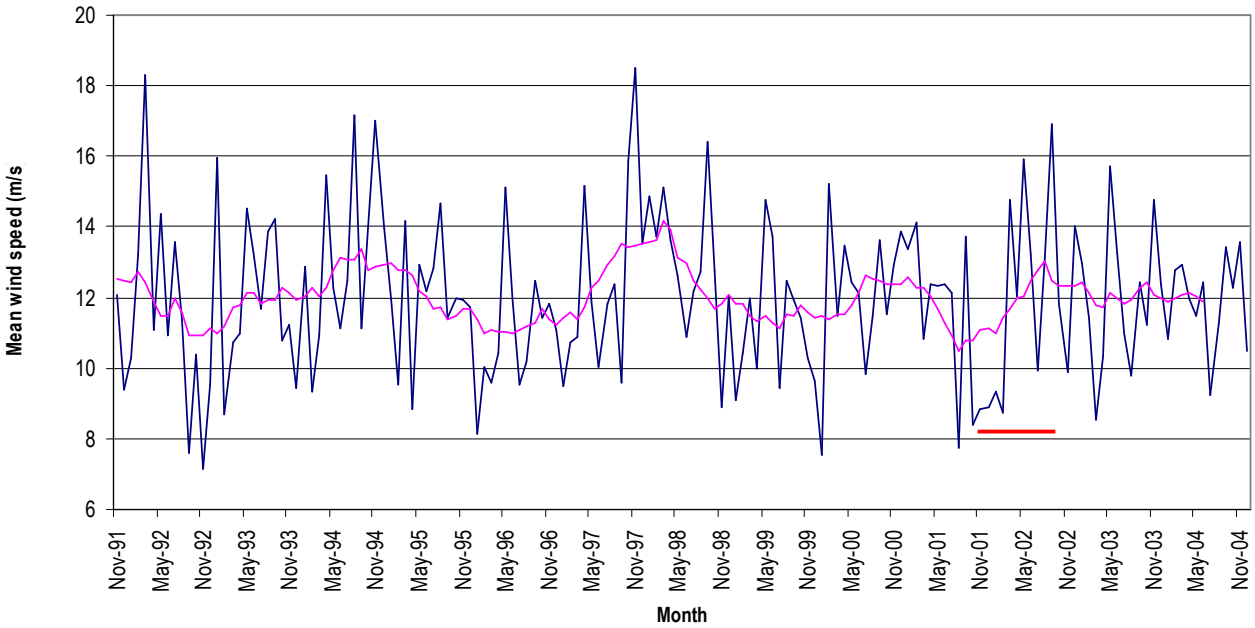

Figure 1: Monthly mean wind speed and 12-month moving average (pink line) at Invercargill. The modelled period is indicated by the red line segment on the graph.

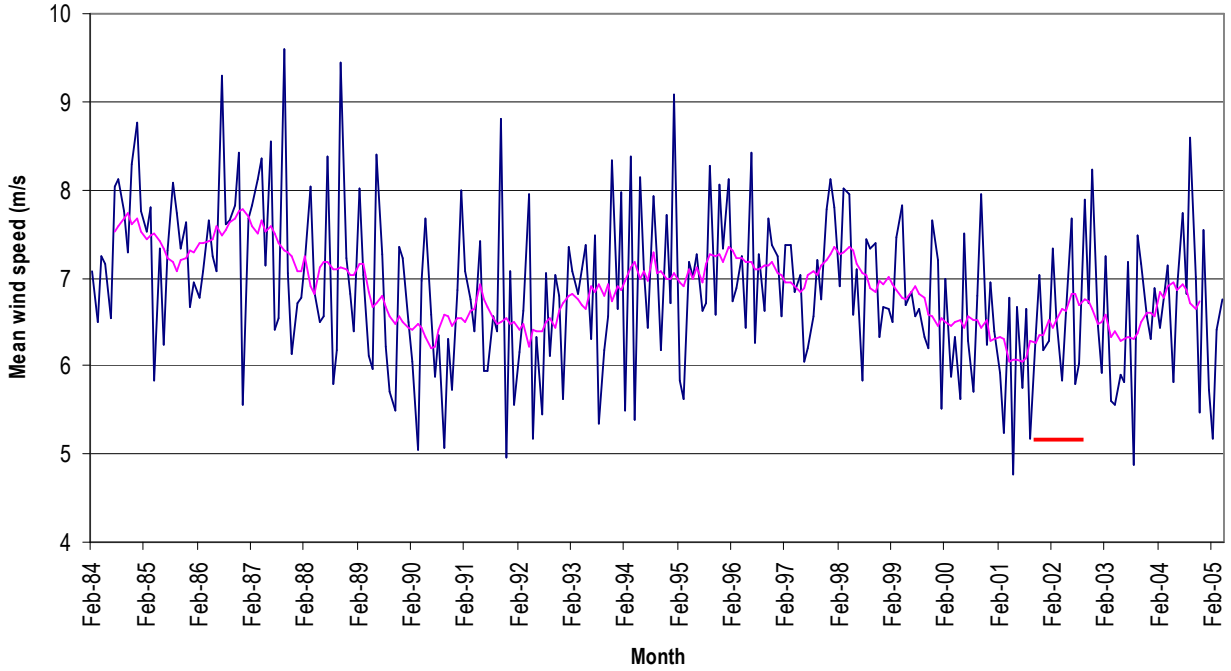

Figure 2: Monthly mean wind speed and 12-month moving average (pink line) at Le Bons Bay. The modelled period is indicated by the red line segment on the graph.

5. Area and General Wind Climate Description

The region modelled is shown in Figure 3 and covers an area of approximately 700 km^2 of the North Otago region from near the Waitaki River mouth, to about 10 km south of Oamaru, and extending inland about 25 km. The topography of much of this region is relatively uncomplicated, with the Waitaki River valley to the north and mostly gentle hill country close to and south of Oamaru. There are some steeper hills and valley systems extending over the northwest part of the area and also in the far west. However, the topography is mostly complex and steep outside of the area of interest to the north and west, including the Southern Alps and closer features such as the Hunters Hills, Kirkliston and Hawkdun Ranges, and Kakanui Mountains, as shown in Figure 3. Figure 4 shows terrain contours within the modelled area and the locations of sites of interest indicated by Energy 3.

The general wind climate of the North Otago area is very complicated. While wind regimes in this region are dominated by prevailing westerlies, the orographic influences from the high country to the north and west can shelter and distort the airflow, sometimes resulting in northeast component winds at lower elevations, especially near the coast. Strong westerly component flows do affect this area at times, resulting in very turbulent and gusty conditions. Strong southwest winds affect coastal Otago and are often deflected to the east of the North Otago area.

Figure 3: Topographic map showing the location of the modelled region.

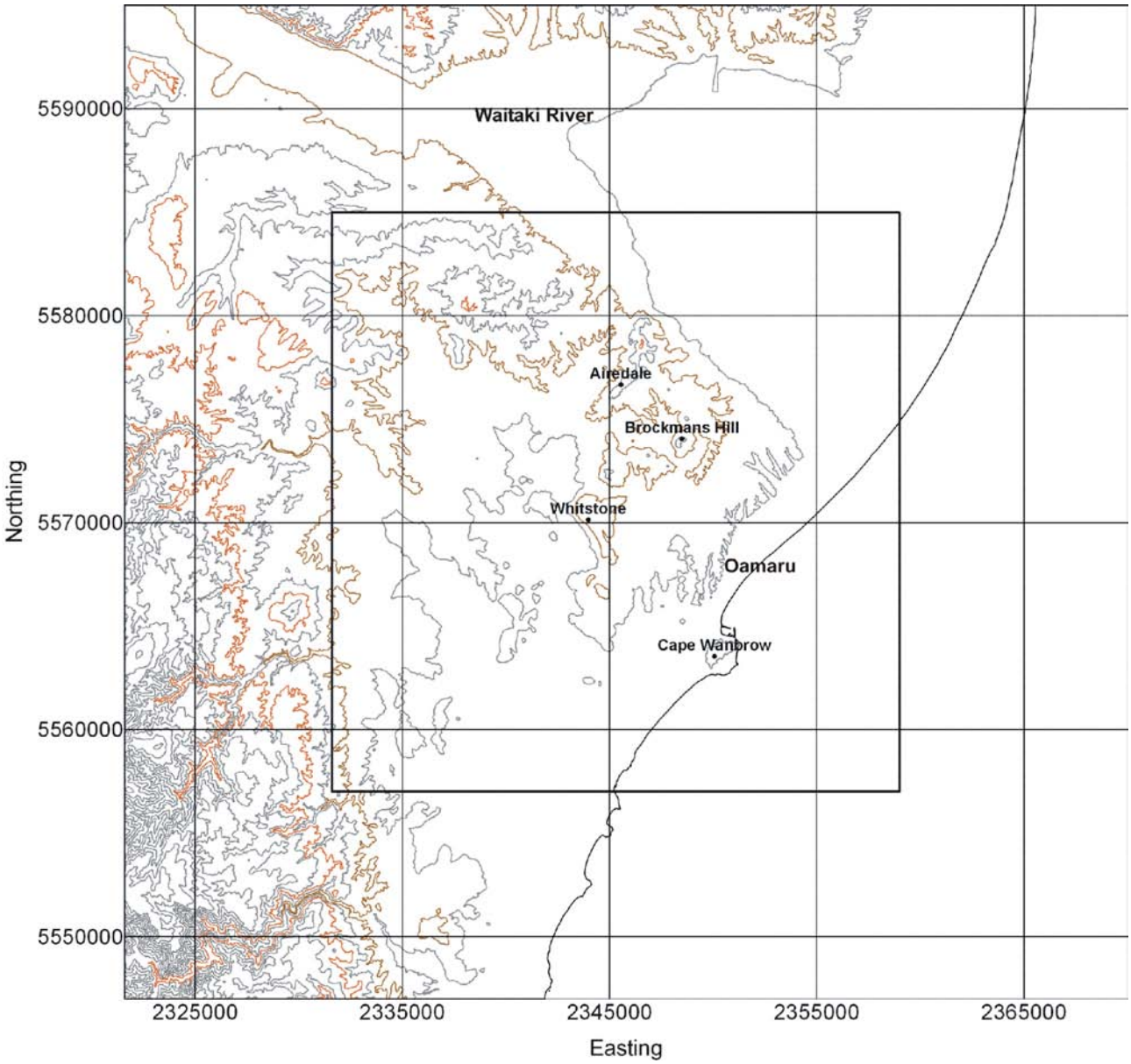

Figure 4: New Zealand Map Grid showing modelled region within the box and with terrain contours at 75 m intervals. The dark brown contour is 150 m and the light brown contour is 300 m.

6. Wind Maps

The wind maps for the North Otago area of interest at 25 m and 50 m above ground level are shown in Figures 5 and 6. The highest mean wind speeds occur over the elevated terrain extending from the northwest and also in the far west of the area. Here, mean wind speeds at 25 m above ground level are predicted to exceed 6.5 m s^{-1} in a number of areas. At 50 m above ground level, mean wind speeds are expected to be above 7.5 m s^{-1} in some places. An area of higher mean wind speed extends over the land area near Cape Wanbrow from the higher mean wind speed area offshore.

The lowest mean wind speeds are predicted to occur in the Waitaki River valley, at lower elevations to the west and south of Whitstone, and near the Oamaru urban area. Here mean winds speeds are predicted to be below 6.5 m s^{-1} at 25 m above ground level.

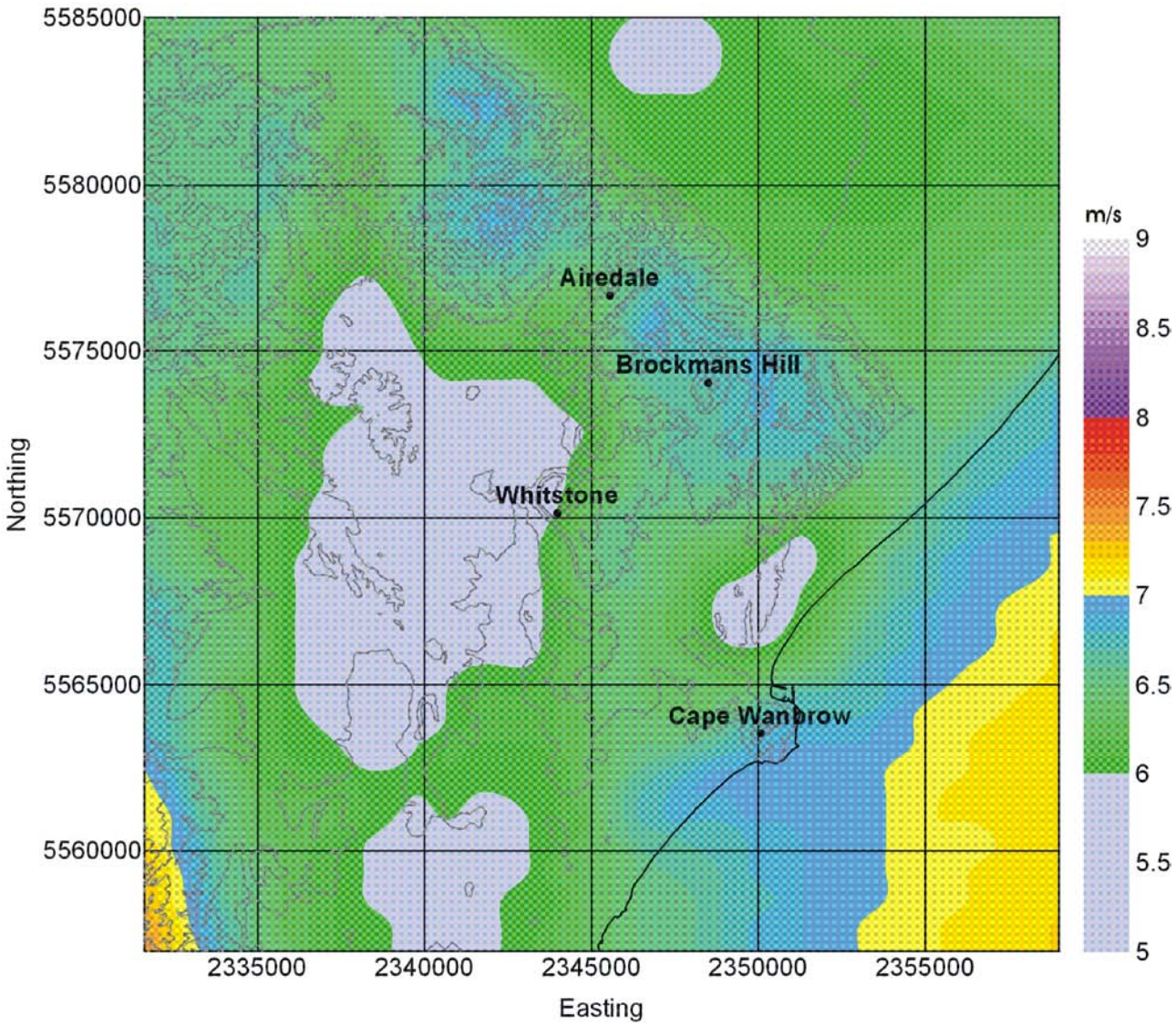

Figure 5: Wind map of the North Otago area at 25 m above ground level showing mean wind speed contours at 0.1 m s^{-1} intervals. The elevation contours are given at 50 m intervals.

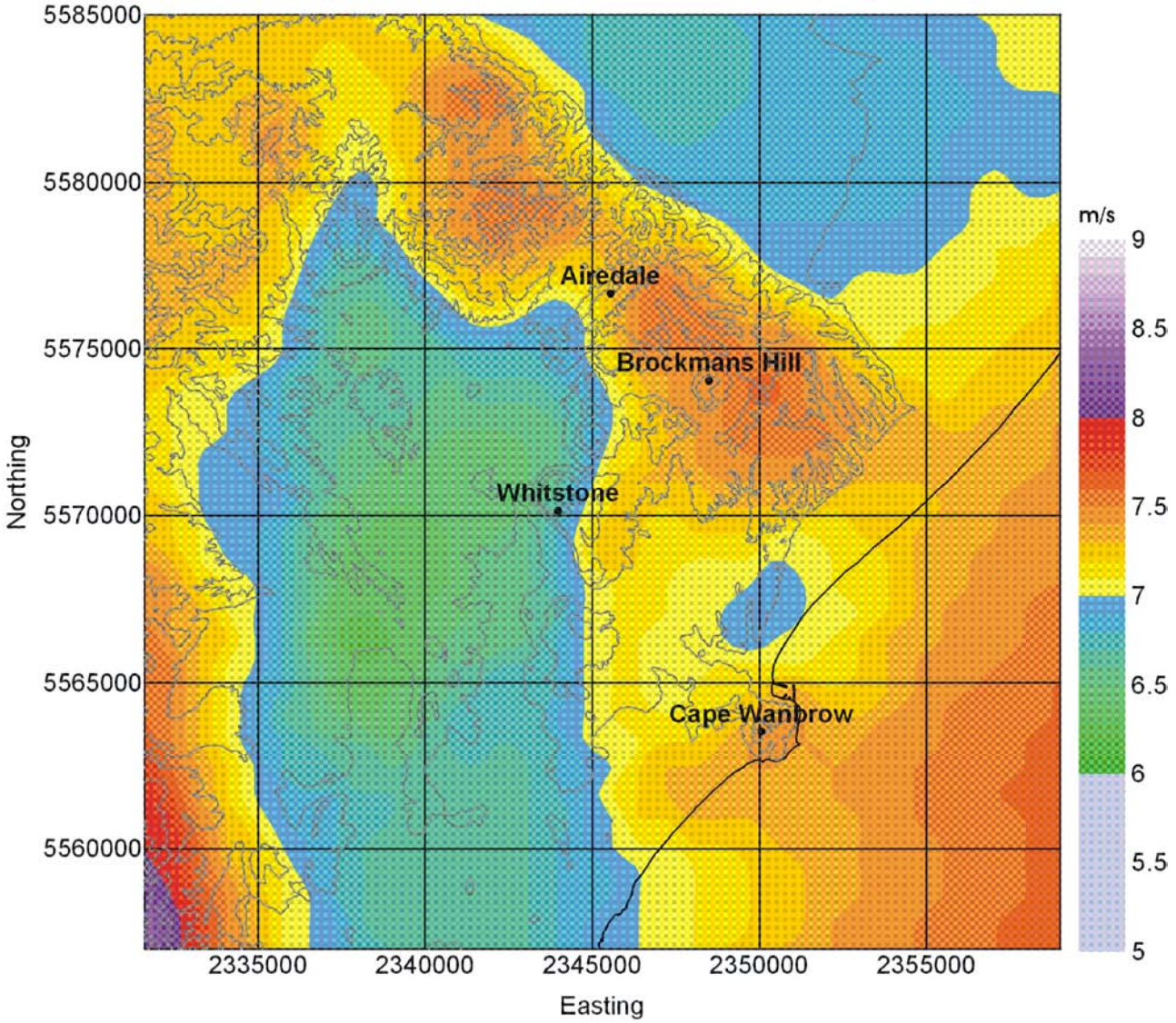

Figure 6: Wind map of the North Otago area at 50 m above ground level showing mean wind speed contours at 0.1 m s^{-1} intervals. The elevation contours are given at 50 m intervals.

At 800 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 potentially 0.5 m s^{-1} higher than that indicated on the maps, particularly in the vicinity of significant ridge lines or where local channelling of winds results from local topographic features. 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 is required to better represent such areas.

7. Virtual Wind Climate Summaries

Energy 3 identified four sites of interest within the modelled region. These are Airedale, Brokmans Hill, Cape Wanbrow, and Whitstone, as shown on the map in Figure 4. Hourly wind data from virtual mast sites at representative locations were obtained for each of the four sites at 25 and 50 m above ground level. Wind rose diagrams and Weibull curves at 25 m are provided to illustrate the virtual wind climates at these four sites. Table 3 shows the overall predicted mean wind speeds at the four virtual mast sites. (Note that the elevations of the virtual mast do not exactly represent the actual elevation of the sites of interest due to the resolution of the modelling.)

Table 2: Mean wind speed at virtual mast sites.

Site	25 m mean wind speed (m s^{-1})	50 m mean wind speed (m s^{-1})
Airedale	6.5	7.3
Brockmans Hill	6.7	7.5
Cape Wanbrow	6.8	7.4
Whitstone	6.3	7.0

7.1 Airedale

The Airedale virtual mast site was located near 2345600E 5576700N at an elevation of about 210 m above mean sea level. This site is considered to be representative of the specified area of interest. Slightly higher mean wind speeds were identified by the modelling just to the east of the virtual mast site. The wind rose and Weibull curve diagrams are given for this site in Figures 7 and 8.

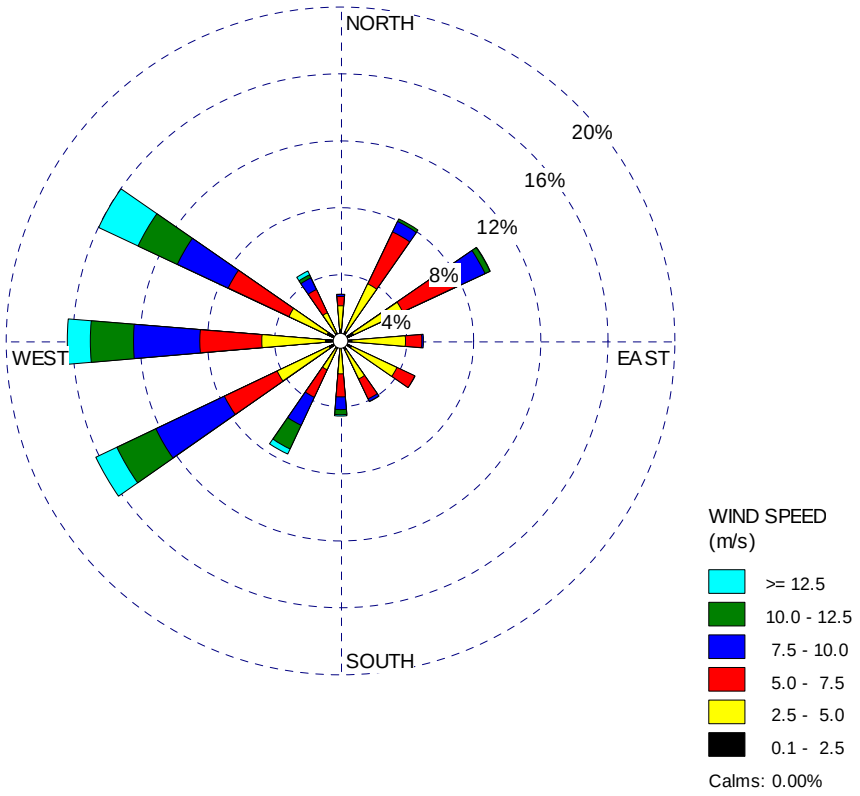

Figure 7: Wind rose for the Airedale virtual mast site at 25 m above ground level.

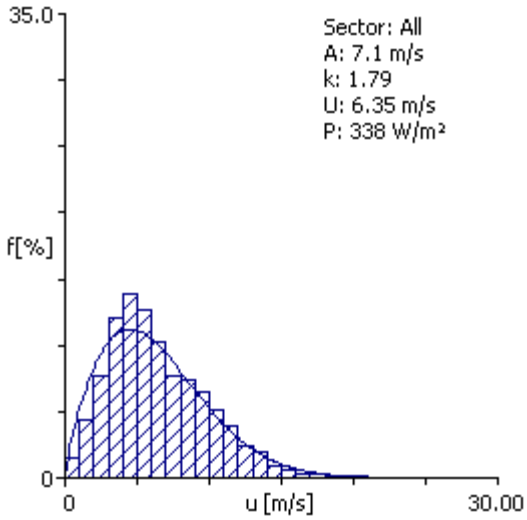

Figure 8: Weibull curve for the Airedale virtual mast site at 25 m above ground level.
(Note that A and k are the Weibull parameters, and U and P are the Weibull mean wind speed and mean power density.)

The wind rose diagram in Figure 7 shows that the prevailing wind direction at the Airedale site is from the southwest to northwest sector. There is also a secondary maximum frequency of wind from the northeast direction. The wind speed distributions are a reasonably good fit to the Weibull distribution, as shown in Figure 8. The highest hourly mean wind speed for the modelled period at 25 m above ground level was 29.3 m s^{-1} from a west-northwest direction, and occurred on 17 September 2002.

7.2 Brockmans Hill

The Brockmans Hill virtual mast site was located near 2348500E, 557400N at approximately 180 m above mean sea level. Although the wind climate derived for this site is considered to be representative of the area of interest, the actual site is near the top of an isolated hill and likely to be at a higher elevation than the virtual mast site. Therefore, the mean wind speed at the actual site is likely to be about 0.5 m s^{-1} higher than that indicated by the virtual wind data. Slightly higher mean wind speeds were also identified by the modelling just to the east of the virtual mast site. The wind rose and Weibull curve diagrams for Brokmans Hill are given in Figures 9 and 10.

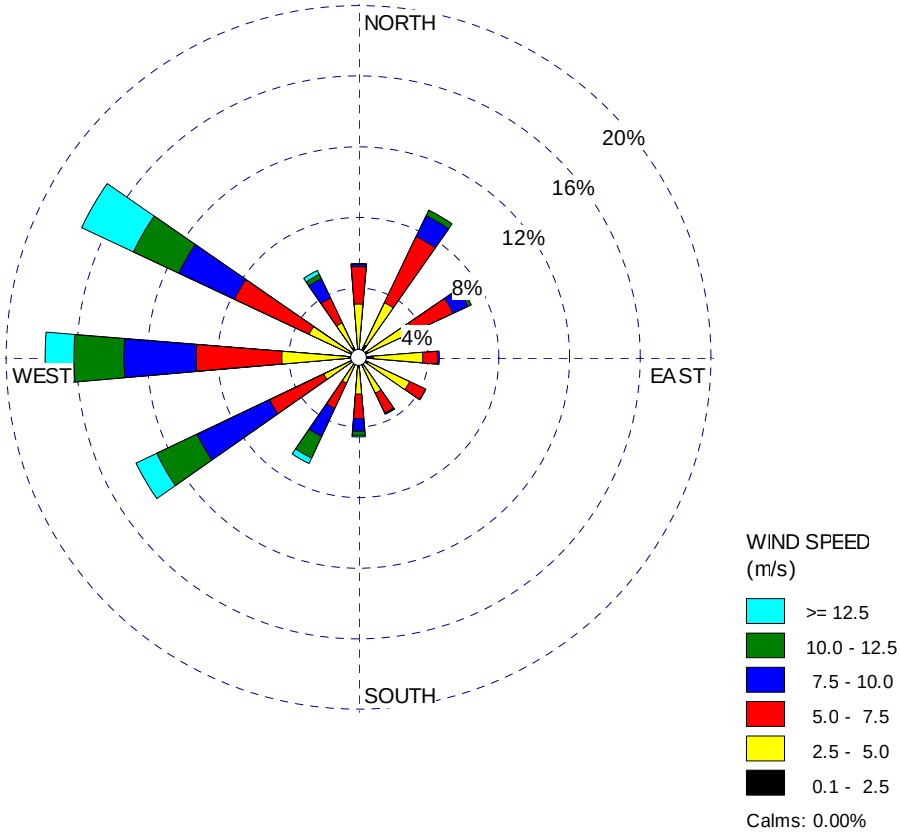

Figure 9: Wind rose for Brockmans Hill virtual mast site at 25 m above ground level.

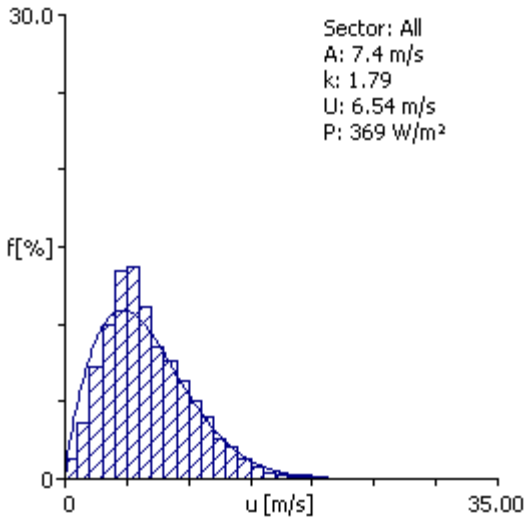

Figure 10: Weibull curve for Brockmans Hill virtual mast site at 25 m above ground level.
(Note that A and k are the Weibull parameters and U and P are the Weibull mean wind speed and mean power density.)

The wind rose diagram for the virtual mast site at Brockmans Hill is very similar to the Airedale site with the prevailing wind direction from the northwest to southwest sector. Almost all of the strong wind events also occur from these directions. The maximum hourly mean wind speed (31.3 m s^{-1}) at 25 m at this site occurred from the west-northwest direction on 17 September 2002.

7.3 Cape Wanbrow

The Cape Wanbrow virtual mast site was located near 2350000E 5563500N at an elevation of about 95 m above mean sea level. This site is considered to be representative of the specified area of interest. Wind rose and Weibull curve diagrams are given for this site in Figures 11 and 12.

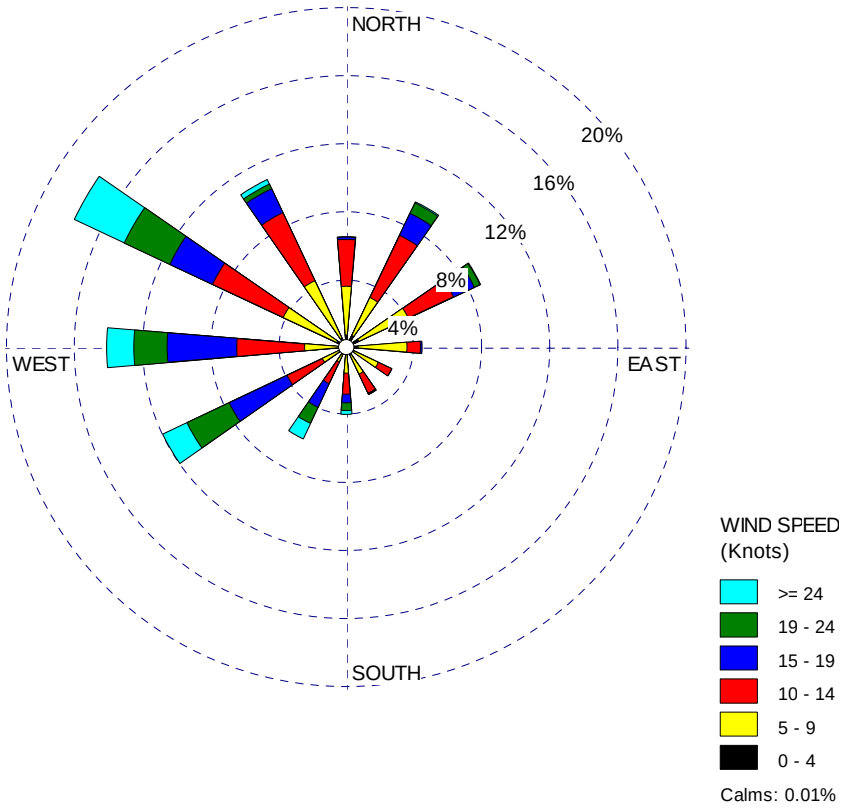

Figure 11: Wind rose for the Cape Wanbrow virtual mast site at 25 m above ground level.

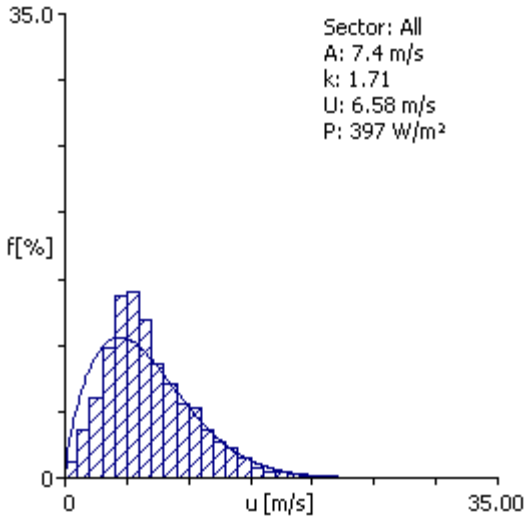

Figure 12: Weibull curve for Cape Wanbrow virtual mast site at 25 m above ground level.
(Note that A and k are the Weibull parameters and U and P are the Weibull mean wind speed and mean power density.)

The wind rose diagram for the virtual mast site at Cape Wanbrow is again similar to the Airedale site, with the prevailing wind direction from the west and northwest directions. A secondary maximum frequency of wind directions occurred from the northeast sector. The maximum hourly mean wind speed (31.1 m s^{-1}) at 25 m occurred from the west-northwest direction on 17 September 2002. The wind speed distribution at this site did not closely fit the Weibull curve, as shown in Figure 12.

7.4 Whitstone

The Whitstone virtual mast site was located near 2344000E 5570100N at an elevation at about 180 m above mean sea level. Although the wind climate derived for this site is considered to be generally representative of the area of interest, the actual site is near the top of a narrow ridge and likely to be at a higher elevation than the virtual mast site. Due to this higher elevation and speed-up effects over the ridge, the mean wind speed at the actual site is likely to be about 0.5 – 1.0 m s^{-1} higher than indicated by the virtual wind data. Wind rose and Weibull curve diagrams are given for this site in Figures 11 and 12.

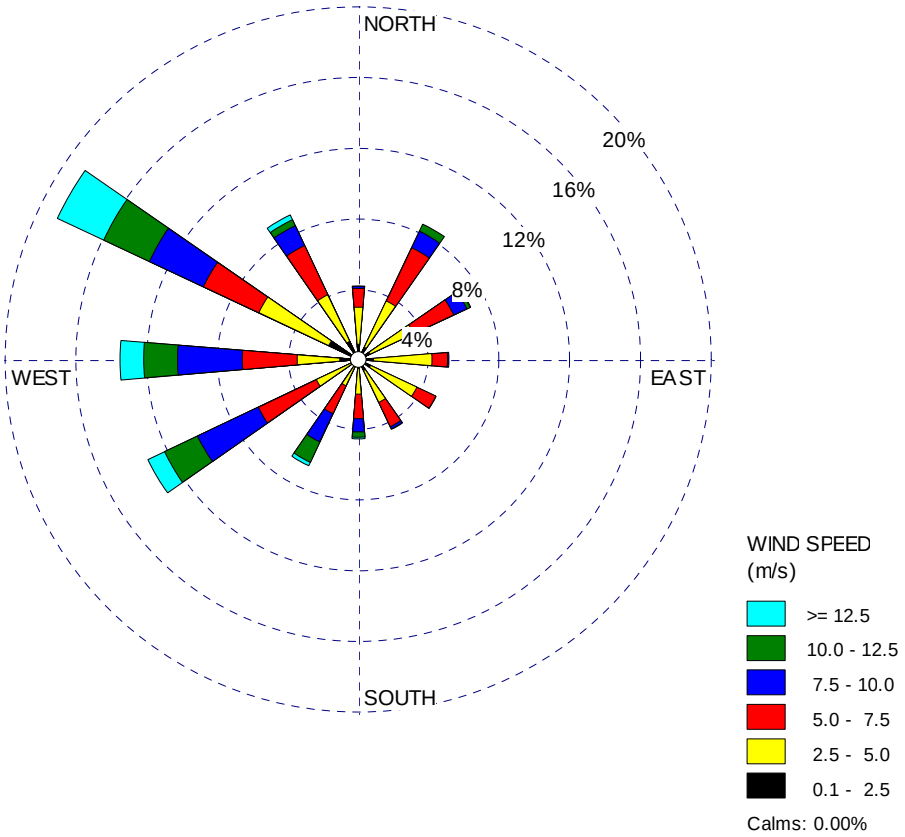

Figure 13: Wind rose for Whitstone virtual mast site at 25 m above ground level.

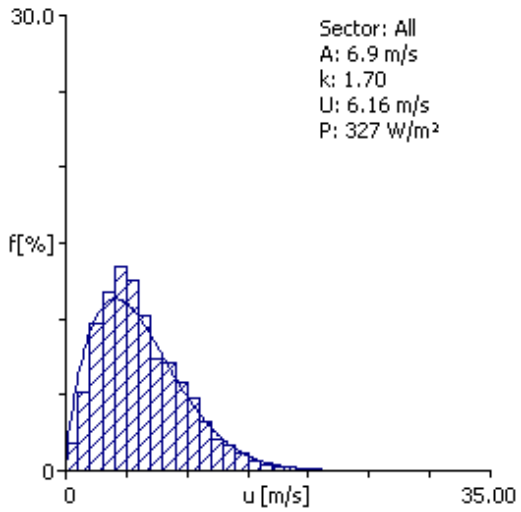

Figure 14: Weibull curve for Whitstone virtual mast site at 25 m above ground level.
(Note that A and k are the Weibull parameters and U and P are the Weibull mean wind speed and mean power density.)

The Whitstone virtual mast wind rose diagram at 25 m shows that the prevailing wind direction is from the west-northwest. Strong wind events at this site occur from the northwest to southwest sector. The highest modelled hourly mean wind speed was 30.2 m s^{-1}, again from the west-northwest direction on the 17 September 2002. The wind speed distribution shows a good fit to the Weibull curve as shown in Figure 14.