EVIDENCE IN CHIEF OF OLIVER MICHAEL MANINS - INDEX

BOARD OF INQUIRY

HAUAURU MA RAKI WIND FARM PROPOSAL

In the matter	of the Resource Management Act 1991
And	
In the matter	of resource consent applications by Contact Wind Limited in respect of the Hauāuru mā raki Wind Farm Proposal
And	
In the matter	of notices of requirement and a resource consent application by Contact Energy Limited for transmission infrastructure related to the Hauāuru mā raki Wind Farm Proposal

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BRIEF OF EVIDENCE IN CHIEF OF OLIVER MICHAEL MANINS

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Introduction

1. My name is **Oliver Michael Manins.** I am a **Wind Engineer** employed by **Garrad Hassan**.

2. I have the following qualifications and experience relevant to the evidence I shall give:

   (a) Bachelor of Technology (Hons), Massey University, (1998).

   (b) Master of Mechanical Engineering, University of Auckland (2005).

   (c) I worked as a Wind Engineer for Wind Farm Group for over 3 years, during which time I was closely involved in development of the indicative turbine layout at the Hauāuru mā raki site and a range of other project development issues.

   (d) I have worked as a Wind Engineer for Garrad Hassan Pacific Limited for approximately 1 year. Garrad Hassan (GH) are engineers and technical advisors to banks, financial institutions and wind farm owners globally. GH is a leading independent authority on wind engineering, has offices in 18 countries world wide and has assessed approximately 20% of the world's wind farms.

   (e) I have over 10 years of engineering and commercial work experience, including over 4 years in the wind engineering industry.

3. I confirm that I have read the 'Code of Conduct for Expert Witnesses' contained in the Environment Court Consolidated Practice Note 2006. My evidence has been prepared in compliance with that Code in the same way as I would if giving evidence in the Environment Court. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

Scope of Evidence

4. My evidence will cover the following matters:

   (a) The quality of the wind resource at the Hauāuru mā raki site:

   (b) A discussion of the wind turbine models available on the market, and the implications for the Hauāuru mā raki site: and

(c) A discussion of the factors affecting layout design and how this applies to the Hauāuru mā raki site.

Summary of Conclusions

5. A wind assessment programme has been undertaken at the Hauāuru mā raki (HMR) site since September 2004. The wind data collected to date indicate a good wind resource on the site, with mean wind speeds clearly within the IEC[1] Class II range. Turbulence on the site is expected to be acceptable at most wind turbine positions. Overall the site is considered suitable for commercial scale wind generation.

6. Wind turbine models on the world market vary in output: they can be up to 6 MW. However wind turbines larger than approximately 3 MW are primarily intended for the offshore market (installation in the sea). The most likely wind turbine designs for the HMR site are in the 1.5 - 3 MW range, with the final turbine choice likely to be made on a range of factors including economic and technical considerations. Wind turbines in the 1.5 - 3 MW range typically have hub heights in the 70 to 100 metre range with blade lengths 35 to 50 metres. Contact Wind Limited's resource consent applications cover wind turbines up to the upper point of this range.

7. Designing a wind turbine layout involves balancing a number of factors. These include installing wind turbines in locations with the best wind resource, avoiding areas of unfavourable wind conditions, observing environmental constraints, minimising energy loss due to the inter-action of turbine wakes and meeting wind turbine spacing requirements. A number of these factors vary with the wind turbine model selected and so it is not possible to produce an optimal layout until final wind turbine selection has been made. Having said that, the layouts are likely to be broadly similar, and occupy similar areas of the site to the indicative layout shown in the application documents and produced by Mr James with his evidence.

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[1] The International Electrotechnical Commission whose classification system is discussed in my evidence.

Wind Resource

8. Wind data has been recorded at the HMR site at five met mast locations each with a top monitoring height of 60 m. Data monitoring began at the site in September 2004 with the first mast installed on the Black property, with four additional masts being installed in April and May 2007. The total length of the data coverage is over four years, and is continuing to increase as all five masts were operational at the time of preparing this evidence. A map showing the location of the five monitoring sites is attached as **Exhibit OM 1**. Another met mast has recorded wind data since July 2005 with a top monitoring height of 40 metres on the Sunset Views property, north of the proposed wind farm site but I have not used results from it for the purposes of my analysis.

9. Each mast has at least three height levels of wind speed monitoring and at least two levels of wind direction monitoring. In addition temperature, barometric pressure, relative humidity, rainfall, and three-dimensional wind speeds have been recorded at various masts. Data have been sampled at two second intervals and recorded at 10 minute intervals as a mean, standard deviation, maximum and minimum.

10. All five 60 metre masts were visited by Philip Wong Too (Engineer from Garrad Hassan) and myself. The equipment was evaluated relative to industry best practice. The wind speed and direction monitoring equipment used by Contact Wind Limited was considered standard equipment in the industry. Calibration certificates were checked for each calibrated anemometer, which included four anemometers calibrated by Svend Ole Hansen ApS., an industry-accredited calibration facility in Denmark, and 15 anemometers calibrated by Otech Engineering Inc., which is a calibration facility in the USA, with a reliable track record. Overall, all five mast set ups allowed high quality wind data to be recorded.

11. The recorded wind data were provided to GH, and I have processed them checking for errors by comparing time traces of wind speeds at different heights, and by using statistical techniques to compare the different levels to each other. Any data that was erroneous or suspect was not used for the analysis. Missing data was synthesised using correlated data from different levels on the mast and other masts on the site. This made it possible to create a data set of wind data for each of the 5 met masts for a period of 4 years and 2 months, with a data coverage of 99.8%. A data record of this

length is considered to be very useful in representing the long term wind climate of the site.

12. The data recorded at the site has been correlated to a long term NIWA reference station, Auckland Airport, which has consistent hourly wind records at a height of 10 m, since 1994. This correlation confirmed that the HMR data is broadly consistent with the Auckland Airport wind data, with a longer period of 14 years. Therefore I believe that the HMR on-site data is representative of the long term wind resource at the site, and can be used to assess the wind climate at the site for the duration of the wind farm project.

13. I have used industry standard wind modelling software, Wind Atlas Analysis and Application Program (WAsP), to estimate the wind speeds across the 180 proposed wind turbine locations at a hub height of 80 m from the input data of the five masts. The modelling method has been found to result in predicted wind speeds of a high accuracy as long as the turbine location is in close proximity to the monitoring mast, and the terrain is relatively homogenous. On average, a reasonably good estimate of the wind speeds expected at the potential wind turbine positions can be made, although due to the distances across the HMR site, there are some areas where the wind speed predictions may have a lower accuracy. Ongoing monitoring at the existing met masts and installation of additional masts that I understand are planned will progressively improve the confidence of wind speed predictions.

14. I have summarised the data in terms of International Electrotechnical Commission (IEC) classifications to demonstrate the viability of the resource. The classifications of mean wind speeds according to IEC 61400-1 3rd edition are:

(a)	IEC Class I:	8.5 to 10.0 m/s
(b)	IEC Class II:	7.5 to 8.5 m/s
(c)	IEC Class III:	Less than 7.5 m/s

15. The best estimate of the average of the annual mean wind speeds across all of the 180 potential wind turbine positions at a hub height of 80 m at the HMR site is very clearly in the range of IEC Class II. The data collected at the met mast on the Black property is presented in **Exhibit OM 2** as a wind rose, which shows the wind speed and direction frequency distribution there. It is a good representation of the general wind regime across the HMR site.

16. Wind speed generally increases with height at a location, and the wind shear data recorded at the HMR site indicates that this is the case. Therefore a hub height of 100 m would result in slightly higher wind speeds than a hub height of 80 m (just as a lower hub height than 80 m would result in lower wind speeds). I have reviewed the wind shear data, which indicates that on average the annual mean wind speed across the current layout of 180 wind turbines at a hub height of 100 m is approximately 8 m/s.

17. In New Zealand, almost all of the commercial wind farms to date have been built at sites with Class I mean wind speeds. However, these locations, which also need to have acceptable extreme wind characteristics,[2] viable access, proximity to transmission with available capacity, and suitable environmental characteristics, are rare and have mostly already been developed. Wind farm sites with IEC Class II wind conditions, and which also have favourable characteristics are now being considered as viable for wind farming in New Zealand. I am aware of several Class II sites in New Zealand that have been consented and are being actively progressed, or are in the consent process.

18. Turbulence intensity is a measure of the short-term variability in the wind, and is defined as the standard deviation of the wind speed divided by the mean wind speed. Turbulence leads to higher loads on the wind turbine since the wind turbine has to constantly adjust to changing wind speeds, and experiences different wind speeds in different parts of the rotor.

19. I have reviewed the work of Philip Wong Too, of GH, which analyses the wind data recorded at the five 60 metre met masts for turbulence conditions and compared them to the IEC 61400-1 3rd edition standard for acceptable turbulence intensity for wind turbines. The “representative turbulence”, which is a technical definition within the Standard, is required to be below a defined turbulence curve. The IEC turbulence conditions for class A[3] are satisfied at all five masts. Once terrain complexity, flow and wind turbine wake induced turbulence is taken into consideration, it is likely that some areas of the site may need to be tested further to confirm acceptable levels of turbulence. Overall, however, the wind data recorded indicates that the site is suitable for the operation of wind turbines in terms of turbulence.

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[2] The IEC 61400- 3rd Edition defines maximum allowable operating conditions including maximum wind speeds or the maximum wind gust speed which the wind turbine can survive.

[3] The “A” in the IEC Class refers solely to the turbulence. A is the highest turbulence class to which all major wind farms in New Zealand to date have been built.

20. From the wind data that has been supplied and the analysis that I have conducted and reviewed, I conclude that the HMR wind farm site has a good wind resource with moderate turbulence levels, and from these perspectives, is suitable for large scale wind generation.

21. I acknowledge that the suitability and attractiveness of a wind farm development site is not solely determined by the factors I have discussed. Mr Geoghegan addresses a number of points in his evidence that will in practice be taken into account by a developer and which are not within my expertise to comment on.

Wind Turbine Options

22. There are a very large number of wind turbine models on the wind turbine market today. These range from a few hundred watts up to 6 MW. Wind turbines 3 MW and above are largely intended for offshore usage (i.e. at sea). Turbines below around 500 kW are unlikely to be competitive for the generation of commercial quantities of electricity for the national grid.

23. The basic concept behind all wind turbine generators is essentially the same – to convert the kinetic energy of moving air (wind) into electrical energy. This is achieved by using blades on a rotor to convert the kinetic energy in the wind to mechanical energy, which is then converted into electrical energy by a generator. A gearbox is often required as the rotational speed produced by the rotor is usually different to that required by the generator[4]. The output of the generator is usually fed through a transformer, to increase the voltage of the electricity and reduce transmission losses.

24. Externally most wind turbines consist of three main components; the wind turbine rotor, the nacelle, and the tower. These are shown schematically in **Exhibit OM 3**.

25. Most modern commercial wind turbines have a three bladed rotor that is positioned upwind of the tower, although some wind turbines have fewer blades, and some have rotors downwind of the towers. I understand that Contact Wind Limited proposes to only use three-bladed turbines with the rotor upwind of the tower.

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[4] Some wind turbine designs do not have gearboxes; they use direct drives and specially designed generators.

26. The blades have aerodynamic profiles, and most are manufactured from fibreglass, although other materials like wood and carbon fibre are also used in the manufacture of some blade types. Blades for large wind turbines are fitted with lightning protection, usually copper, and may be fitted with other metallic components, such as attachment bolts. The blades are fixed to a hub, and in most designs are fitted with bearings, so that the blade pitch is able to be adjusted. In large wind turbines the hub often contains the pitching mechanism (which may be hydraulic or electrical) and the pitch controllers. In large wind turbines like the ones expected to be used on the HMR site, the rotor usually rotates at less than 20 rpm. A typical turbine is shown in profile in **Exhibit OM 4**.

27. The nacelle is the box that sits on the tower and contains the main wind turbine machinery as well as supporting the rotor on the tower. The nacelle commonly contains a gearbox (although some wind turbines do not have a gearbox), generator, wind turbine controls, yaw system and cooling systems. In some wind turbine designs a power converter and the transformer may also be located in the nacelle. The nacelle is able to rotate horizontally on top of the tower in order to keep the rotor upwind of the tower (this is called yawing). The nacelle will have a steel or cast iron frame and is commonly clad in fibreglass. Instruments for measuring the wind are placed on top of the nacelle.

28. The tower is normally constructed of steel and supports the wind turbine nacelle and rotor. As a minimum the tower needs to be tall enough to support the rotor at a safe distance from the ground. However, wind speed almost always increases with height, so increasing the tower height will likewise almost always increase energy capture. The trade-off between increasing tower cost and energy capture means that typically wind turbines have a similar tower height and rotor diameter. As well as supporting the wind turbine, the tower will contain electrical cables bringing down the electricity generated in the nacelle, control cables, and an access ladder. Depending on the turbine the tower may also contain a lift, controllers, power converters, and the transformer.

29. Wind turbine manufacturers often optimise their wind turbines for certain wind conditions. This is often done by adjusting the rotor diameter, and thus the swept area, of the turbine according to the wind conditions expected at a site. This is similar to sail selection for weather conditions on a yacht, where a larger sail might be used where light winds are expected

or conversely the sail area might be reduced where strong winds are expected. Likewise, smaller and larger rotor diameters are often used to optimise wind turbines for high and more moderate wind speed conditions respectively.

30. In the wind turbine market today, most wind turbines sold are in the 1.5 - 3 MW range, and indeed, this is what has been installed most recently in New Zealand, except for at Te Rere Hau, located near Palmerston North, which uses locally manufactured Windflow 500 kW wind turbines suited to high wind conditions and which are not likely to be optimal for the HMR site. Tararua Stage 3, also located near Palmerston North used 3 MW wind turbines, White Hill in northern Southland used 2 MW wind turbines and West Wind near Wellington will use 2.3 MW wind turbines. These turbines all have blade lengths in the range of 39 to 44 metres.

31. In my view, the most likely technically and economically optimal wind turbine size for the Hauāuru mā raki site will be in the range of 1.5 - 3 MW, and will have a blade length somewhere in the range of approximately 35 – 50 metres.

32. I have calculated an estimate of the percentage of time that the proposed wind farm would be contributing some power output to the grid, for a typical wind turbine in the range that I have identified as likely to be optimal. The wind farm would be expected to generate power over 85% of the time.

Wind Turbine Layout

33. Creating layouts for wind farms often involves the balancing of multiple factors:

    (a) the siting of the wind turbines should be in the areas of the site that have the greatest wind resource, wherever possible. However, wake effects from other turbines, which reduce energy production, also have to be taken into account;

    (b) the wind turbines should not be placed too closely together or else when the turbines are operating in the wake of another turbine, the turbulence will cause the downwind turbine to operate less efficiently, and could also exceed the allowable design limit for the turbine. The spacing required varies with a number of factors including the wind turbine size, topography and the wind direction distribution;

(c) there may be areas of a site where the wind conditions are not suitable for the installation of wind turbines, due to excessive turbulence or flow separation; and

(d) the siting has to take into account practical aspects, such as whether there is available room for wind turbine assembly and whether road access to the wind turbine site is practicable.

34. There may be areas that need to be avoided for archaeological, ecological, visual, cultural or other reasons. A thorough wind turbine siting process involves identifying these areas and protecting these values, wherever possible. This generally involves multiple modifications of the layout so that the impact of the wind turbines and the associated civil works avoids or minimises the impacts on these values of the site.

35. The topography of the HMR wind farm, area stretching approximately 34 km between Port Waikato and Raglan, can be described as complex. There are many steep ridges, steep rising hills, and some larger elevated plateaus. In terms of wind resource, the key features of the terrain are elevation and exposure. Other important factors are proximity to the coast and individual hill shapes, which produce wind speed-up effects that are desirable in terms of increasing output. Reduction of wind speeds occurs due to blockage by obstacles and the effect of any forestry.

36. Wind maps have been produced for the HMR site that show areas along ridges and hill tops with good wind resource. Areas of lower elevation, valleys and the lees of hills have significantly reduced wind resource making them unsuitable for the generation of electricity using wind turbines.

37. Practical considerations also play a part. For example the construction area required for a wind turbine, a flat area of approximately 55 m by 25 m, make many areas impractical for wind turbine construction, e.g., where ridges become narrow or drop off steeply.

38. As a result of the natural topography, the practicability of wind turbine construction, and where the wind resource is, the suitable areas for locating wind turbines are constrained to tops of ridges and elevated hills and plateaus. Therefore the final boundaries of the proposed HMR wind turbine consent areas have resulted in relatively narrow shapes following these suitable areas.

39. Lost energy and increased wear and tear result from wake effects where wind turbines are located too close to each other, and therefore suitable separation between turbines is necessary. The wake from a wind turbine acts downstream of the wind turbine, emanating from the swept area of the turbine blades in a conical shape and gradually dissipating with distance. The predominant wind direction at the HMR site is from the southwest, and therefore a much greater percentage of the effects are caused in turbines down stream in this wind direction. As a result, a greater emphasis is put on the separation distance along this axis, and less from other directions.

40. Contact Wind Limited has developed an indicative turbine layout that addresses all of these issues as shown in the evidence of Mr James. Contact Wind Limited has constrained the extent of variations from the indicative layout by defining required turbine separation as follows:

> "*A separation ellipse is applied around each wind turbine defined as 5 rotor diameters along the main axis, and 3 rotor diameters along the minor axis. The major axis has been aligned at 239 degrees from true north or approximately southwest. The ellipses must not overlap each other by more than 50 m along a line drawn between the respective turbines*."

41. The practice of imposing separation distances defined by an ellipse of 5 by 3 rotor diameters is commonplace among the wind industry. There are variations to these ratios implying both smaller and larger separation distances are used at times in the industry. Individual wind turbine manufacturers will review a proposed site layout to confirm suitability for their wind turbine. If wake effects are considered too high then additional separation distances may be imposed by the manufacturer as a condition of operation in order to maintain suitable operating conditions.

42. The commercial nature of purchasing wind turbines is such that it is necessary to have several options of supplier and models, due to the variability of the significant initial capital cost of the wind turbines (which often accounts for over 70% of total project cost), the results of technical investigation to individual turbine suitability, and supply availability on the world market for an uncertain start date. The trend in New Zealand and other countries has been that a turbine contract is finalised post resource consent process, when there is more certainty around the construction schedule.

43. Contact Wind Limited has reviewed the supply options and produced a summary of parameters in its applications, which encompasses the available models. While there are many individual feature differences of each model, the main parameter which causes difficulty is the required separation distance. This varies with the size of rotor diameter, and the unknown additional separation distances that may be imposed by the manufacturer.

44. The second consideration is the unknown results of detailed geotechnical investigations to each proposed wind turbine location. Dr McKenzie addresses geotechnical issues in his evidence but in summary, bore holes are likely to be required to assess geotechnical conditions at each wind turbine location, along with detailed civil site surveys. Although a preliminary investigation has been carried out, the scale and expense of performing this for 180 turbine locations (in this case) means final investigations are generally performed post resource consent during the process of finalising the wind turbine locations. It is likely that the result for several turbine locations is such that the recommendation will be to move the location. For example, this may occur where the geotechnical investigation reveals the existence of caves or unstable ground conditions.

45. While moving a short distance (e.g. 50 m) may avoid the geotechnical problem, the nature of the terrain may be that there is then no space to build the turbine. In addition, the separation distance to the next turbine could be violated. This turbine then has to be moved, and again the terrain may not allow the space to build the next turbine. This chain reaction carries on along the whole string of wind turbines.

46. The third consideration is where as a result of the wind flow over a local region of terrain, the turbine location is found to be highly turbulent or flow separation is occurring. These conditions can make some locations unsuitable for the operating limits of the turbine. Movement of these turbines is required. Although many wind turbines have already been located to avoid areas where the risk of high turbulence and flow separation is great, more detailed wind monitoring, modeling, and analysis is required. The scale and nature of this task also usually makes it best suited for post resource consent and to be carried out in conjunction with the turbine manufacturer for a known turbine model.

47. For the reasons explained above it is extremely difficult to lock in a certain wind turbine model prior to resource consents being granted. Given the complex nature of the terrain at the HMR site, it is advisable to retain flexibility in turbine placement.

48. The indicative positions chosen for the HMR site tend to be those of highest wind resource, which are usually also the highest elevation and exposure. Movements that may be necessary from these positions in general will require movement along a ridge, and the overall chain reaction of turbine relocations to maintain the required separation will usually result in an overall slightly lower elevation and exposure.

49. In the event of Contact Wind Limited selecting a wind turbine smaller than the maximum proposed, it is possible that in some areas the turbines will be able to be spaced closer than the indicative layout indicates. For example, blade lengths of 35 m versus 50 m would equate to a proportional reduction in the minimum separation distance, to approximately[5] 160 m, from 250 m. It is possible that the smaller distances would allow more positions of higher base elevation to be captured, although the number of turbines in each cluster will not increase because it is capped in Contact Wind Limited's applications. However, tip heights of the turbines would also be reduced due to the smaller blade length. In addition, when selecting a smaller wind turbine rotor diameter, it is usual to have a proportional sized tower, i.e. it is unlikely that the maximum 100 m tower would be selected for a turbine with a blade length of 35 metres. Therefore again the overall elevation of the wind turbine nacelles and tip heights would be reduced for the smaller turbines.

50. Given the overall reduction of effects of choosing a smaller than maximum sized wind turbine, it is worth examining the worst case effects of movements of the maximum permitted turbine. Isthmus Group has rearranged the layout in order to produce a worst cased layout in terms of visibility from key view points (discussed in Mr Lister's evidence). It is noted that this layout would be a poor optimisation and would not be preferred in terms of energy capture.

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[5] Approximate because the rotor diameter takes into account the diameter of the hub separating the turbine blades

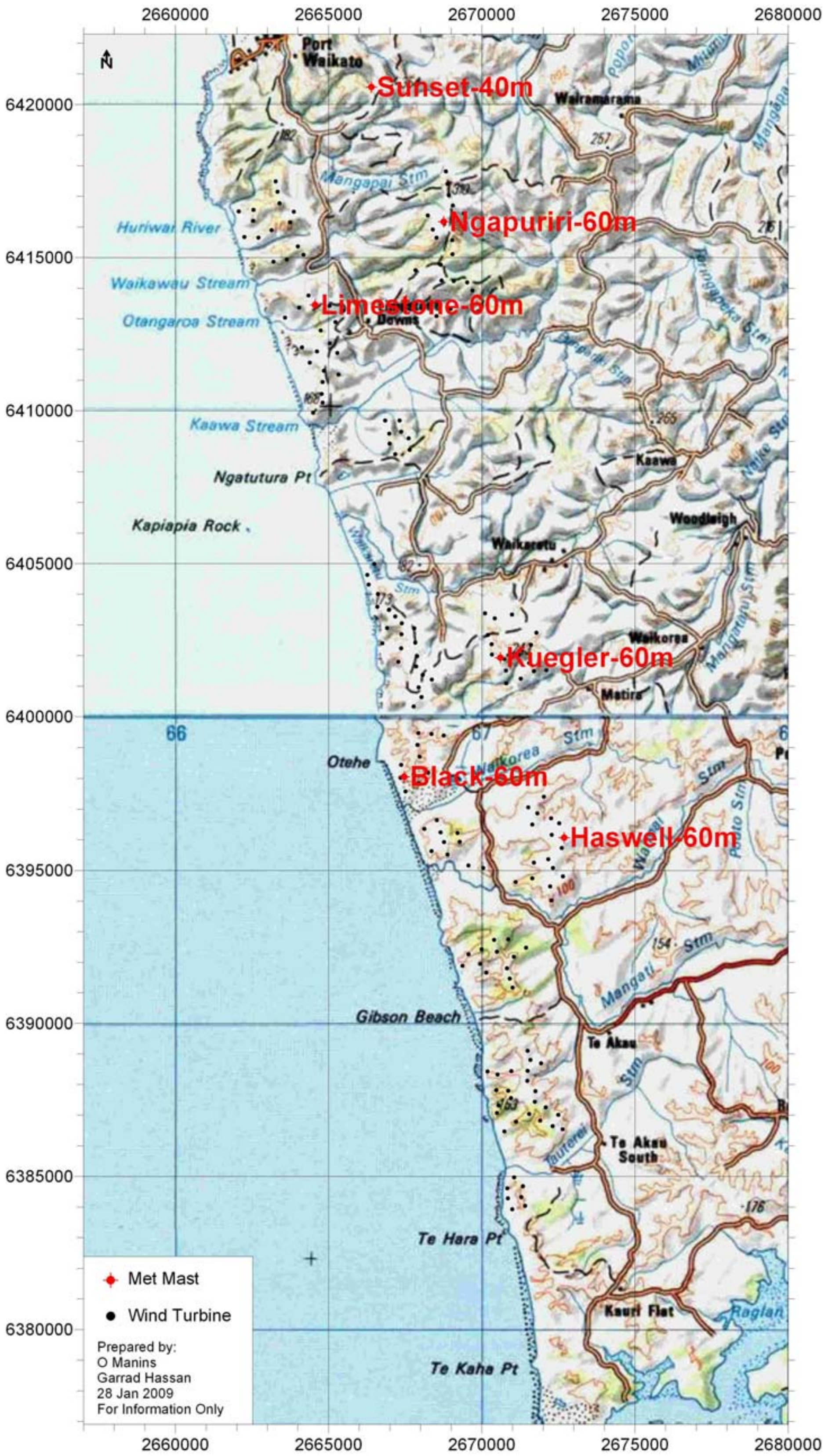


Exhibit OM 1

Location of Met Masts at the HMR wind farm site.

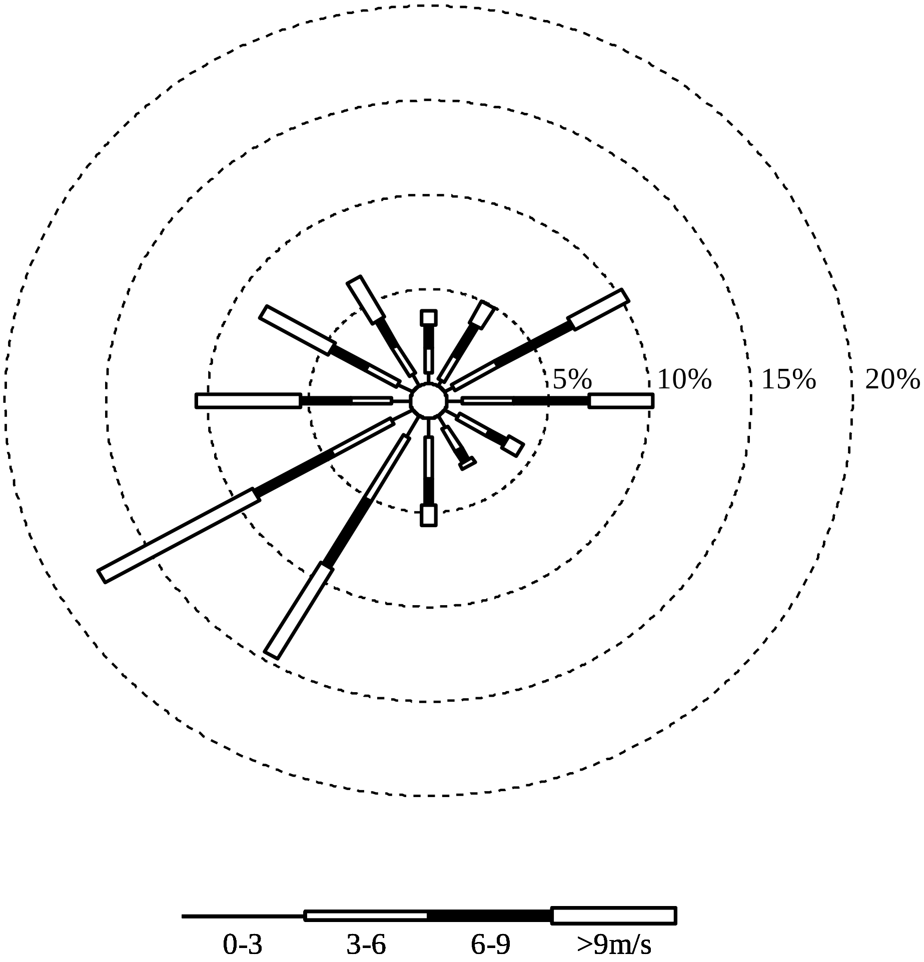


Exhibit OM 2

Long term wind speed and direction frequency distribution at a height of 80 m at HMR site (Black Met Mast)

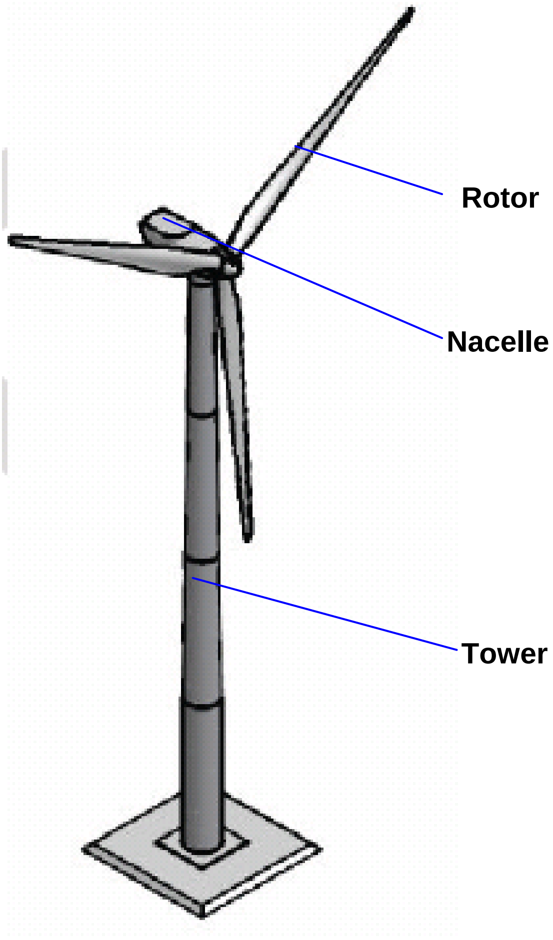
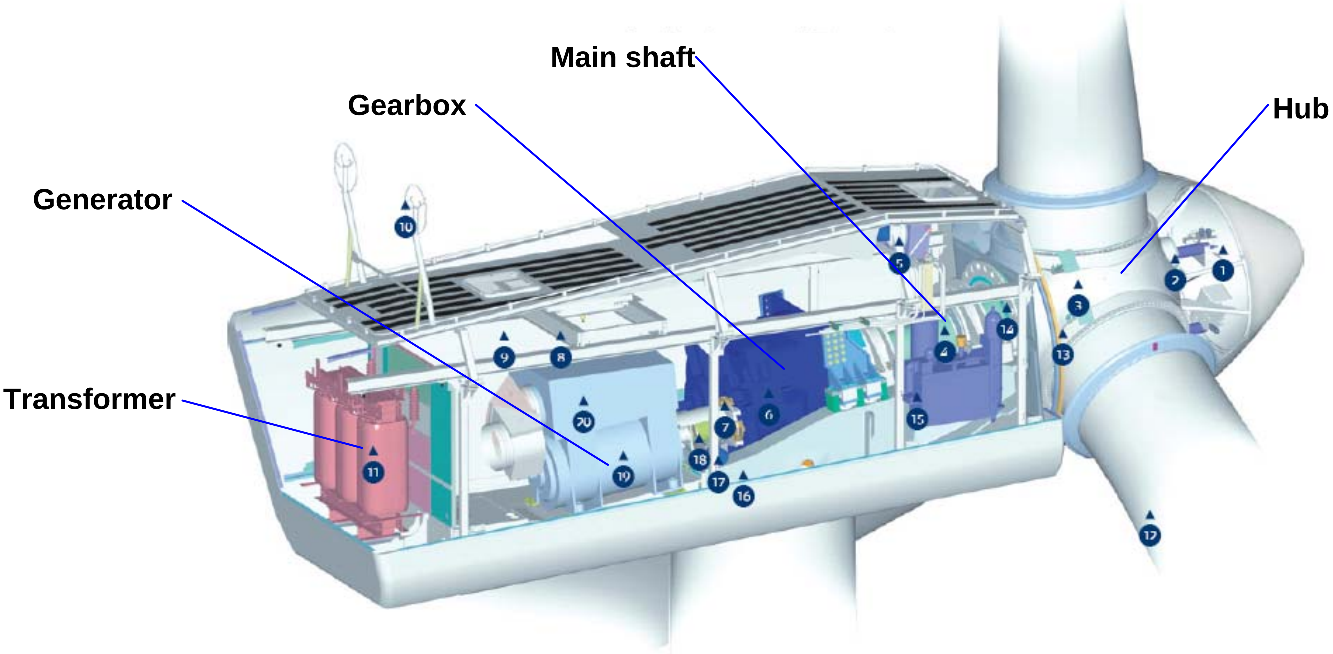


Exhibit OM 3

Wind turbine basic diagram



1. Hub controller
2. Pitch cylinders
3. Blade hub
4. Main shaft
5. Oil cooler
6. Gearbox
7. Mechanical disc brake
8. Service crane
9. VMP-Top controller with converter
10. Ultrasonic sensors
11. High voltage transformer
12. Blade
13. Blade bearing
14. Rotor lock system
15. Hydraulic unit
16. Machine foundation
17. Yaw gears
18. Composite disc coupling
19. OptiSpeed® generator
20. Air cooler for generator

Exhibit OM 4

Typical Wind Turbine Components. (Vestas V80 - 2.0 MW)