

IN THE MATTER

of the Resource Management Act
1991

AND

IN THE MATTER

of applications to the **WAIKATO
DISTRICT COUNCIL** and
WAIKATO REGIONAL COUNCIL
by **WEL NETWORKS LTD** for
resource consents to authorise the
establishment, operation and
maintenance of 28 wind turbines for
the generation of electricity and
associated activities on the
Wharaurua Plateau near Te Uku

STATEMENT OF EVIDENCE OF ANDREW KERLEY

1. INTRODUCTION

Qualifications and experience

- 1.1 My name is Andrew Kerley. I am employed as a wind power engineer working for Parsons Brinckerhoff Australia Pty Ltd out of our Melbourne office.
- 1.2 Parsons Brinckerhoff (PB) is a global engineering consultancy which was founded in 1885 and numbers 10,000 staff in over 280 offices reaching across five continents. Since the early 1990's PB has been involved in all major aspects of wind farm development from initial site and feasibility assessments, wind resource monitoring and analysis, detailed wind farm design and planning, selection of technology through to the actual project implementation, construction management and performance monitoring. PB has undertaken and managed wind-monitoring programmes on behalf of numerous clients in New Zealand and internationally.
- 1.3 I am a member of Engineers Australia and graduated from Monash University (Melbourne) in 2003 with honours degrees in both Mechanical Engineering and Atmospheric Science.
- 1.4 I have four years experience working in the wind energy industry with projects in Australia, New Zealand, Asia and the Pacific.

- 1.5 I have been involved in many stages of wind farm design and feasibility studies including site selection, wind monitoring, wind data analysis, layout design, environmental impact modelling, and wind resource and energy assessment.

Involvement in the project

- 1.6 PB was engaged by WEL Networks Ltd (WEL Networks) in December 2004 to assist with the installation of wind monitoring towers and data monitoring equipment, and the ongoing analysis of data collected from the monitoring towers at the Te Uku site.
- 1.7 The PB staff involved in the monitoring tower installation and verification of much of the data collected to date from the site have since left PB, however I have historically had occasional exposure to the data collected at this site. In November 2007, I took over managing the collection and verification of data from the on-site towers at Te Uku. I am in a suitable position to submit this evidence on wind data collected to date at Te Uku.

Purpose and scope of evidence

- 1.8 The purpose of my evidence is to comment on the validity and suitability of the on-site wind data collected to date which forms part of the feasibility assessment of the proposed Te Uku Wind Park.
- 1.9 In my evidence I will address the following matters:
- a) An outline of wind monitoring best practice for the wind energy industry (section 3);
 - b) An outline of the industry accepted and relevant International Electrotechnical Commission ("IEC") wind turbine classifications (section 4);
 - c) A description of wind monitoring and data collected to date at Te Uku (section 5); and
 - d) Address wind measurement specific matters raised in the submission by Mr Sean Cox (section 6).

Expert Witness Code of Conduct

- 1.10 I have been provided with a copy of the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Notes 2006. I have read and agree to comply with that Code. This evidence is within my area of

expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

1.11 I am authorised to present this evidence on behalf of WEL Networks.

2. **SUMMARY**

2.1 Although there are no mandatory standards in New Zealand, the international wind energy industry has developed guidelines and procedures for use in monitoring wind characteristics and undertaking feasibility investigations of wind farm sites that are generally accepted as best practice (including in New Zealand). These are from the International Energy Agency (IEA): “Recommended Practices for Wind Turbine Testing and Evaluation. No.11 Wind Speed Measurement and Use of Cup Anemometry (1999)” and from the International Electrotechnical Commission (IEC): “Wind Turbine Generator Systems – 61400 Part 12-1: Wind turbine power performance testing, Edition 3, 2005”. There are certain facets of wind feasibility measurements and data analysis that are not covered by standards or guidelines (for example methodology for data analysis, or specific models of instruments to use on a monitoring tower) however, there are generally accepted industry best practices which are discussed in Section 3.

2.2 Wind turbine classes (and the associated criteria defining these classes) are introduced. Wind resource (eg wind speed) and various climate parameters at each individual turbine location need to be investigated to assist in the suitable selection of a wind turbine for a given location i.e. to ensure the wind turbine is designed to withstand the site wind conditions. This has not been undertaken at Te Uku by PB although I understand it is being undertaken by Hydro Tasmania Consulting Ltd. This is generally done as part of a wind farm feasibility study or energy yield assessment, and in any case established before progressing to wind farm construction.

2.3 Wind monitoring towers are installed to measure the wind resource. It is acceptable practice to take a staged approach to the type and height of the tower installed due to the high cost of the towers.

2.4 It is best practice to measure wind speed at various heights above ground to enable a wind shear profile to be established. Wind shear being the increase in wind speed with height above ground level. Hub-height wind speed data is required to predict energy yield and this can either be measured or calculated (from measurements below hub-height). It is best practice to install a near to or at hub-height monitoring

tower at some stage of a feasibility study. Hub height being the centre of the turbine blades.

- 2.5 Anemometers are often calibrated in order to provide increased confidence that wind resource is measured accurately.
- 2.6 The IEC and IEA guidelines recommend mounting arrangements that will reduce, to an acceptable level, the impact that the monitoring tower and equipment has on the recorded wind speed data in order to represent free and unobstructed conditions. These recommendations relate to the orientation of booms, locations of instruments on the tower etc.
- 2.7 Industry best practice regarding data collection and analysis recommends that data be collected and analyzed regularly to ensure consistent quality of data collected at the tower, the early detection of any instrument malfunction or failure, and the identification of any invalid data.
- 2.8 Most wind turbine models with proven design are given a standardised 'class' (per the IEC standards) to reflect the conditions in which they are designed to operate. Therefore, the wind conditions for each turbine location need to be investigated to ensure that the turbines installed are suitably designed for the specific site conditions.
- 2.9 The monitoring towers that have been installed at Te Uku, include two 50 metre (m) high towers and one 80 m high tower. Each of these towers has been installed and maintained in accordance with industry guidelines and best practice.
- 2.10 Data collected at the wind monitoring towers is verified by PB and reported on a monthly basis. In my opinion the wind monitoring conducted at Te Uku to date is robust, valid and reliable and furthermore, is in accordance with industry best practice described in my evidence. I would like to note that in my opinion (and that of my colleagues at PB) the data is suitable for use in the energy yield predictions for the Te Uku Wind Park
- 2.11 While PB Power has not undertaken the detailed analysis required to determine the appropriate IEC class of turbines for this site, a visual inspection of the monthly average wind speeds shows that (assuming a hub height in the order of 80 m) the average wind speed could be close to the average wind speed criteria between Class I and II (ie 8.5 metres per second m/s), although some sites may require a Class I turbine.

- 2.12 Given the commercial sensitivity of the wind data recorded by WEL Networks at Te Uku, I am not surprised that WEL Networks did not allow Mr Cox to access to their data.
- 2.13 Mr Cox's data would only be considered useful data for wind energy calculations if it were; collected from a consistent location, at a height above ground of at least 10 m (the height of many of the NIWA wind data sources but obviously higher is better for reasons described herein), in an open area free from obstructions, using suitable quality instruments, at regular, preferably small time-scale intervals (e.g. 10 minute averaging from continuous data), for a continuous period, has complete maintenance history and has thorough quality assurance procedures in place.
- 2.14 Mr Cox has estimated the wind resource at the plateau based on measurements taken at his 'recording site' approximately 10 km from the Te Uku Wind Park site. The modelling of wind over 10 km across terrain present at Te Uku is very difficult to do accurately. For this reason, monitoring towers(s) are installed on a proposed wind farm site to minimise the distance over which computer modelling is required. The WEL Networks on-site measured data clearly shows that Mr Cox's estimates are simply incorrect.
- 2.15 Mr Cox's method of wind resource assessment is inaccurate for several reasons:
- a) The nature of the site is too complex to allow any generic wind translation rules to result in an accurate annual average wind prediction.
 - b) Mr Cox's assessment considers the wind farm output on a "representative day" being 1/365 the annual output, however Mr Cox offers no explanation or data as to how his "representative day" was established.
 - c) The diurnal wind speed pattern presented in Mr Cox's submission is different to the diurnal pattern taken from 12 months of on-site data at 50 m above ground (i.e. Mr Cox's data is not representative of the Te Uku on-site data).
 - d) To consider a diurnal pattern to be 'average' (ie, 1/365 of total energy production) is an inaccurate oversimplification of an energy prediction and no reputable consultant in the industry would endorse this methodology.
- 2.16 The annual average wind speed of 6.1 m/s for the site quoted by Mr Cox is lower than the lowest monthly average wind speed that has been recorded on-site until the end of November 2007 (approximately 12 months) at the height of 80 m.

- 2.17 The wind data collected from the two monitoring towers at Te Uku is downloaded and independently checked and verified by PB, and is then passed onto an independent party (Hydro Tasmania Consulting Ltd) to perform energy calculations. PB does not “fudge” this data in any way prior to its delivery to WEL Networks.
- 2.18 Wind farm sites are generally located in specific locations that have a high local wind resource. Unless measurements are specifically taken in these windy areas, such a local wind resource is often not simulated when completing a large-scale wind resource map (eg, for an entire country, such as what NIWA has produced). NIWA does not measure wind data for the purpose of wind energy calculations hence is unlikely to have any weather stations on potential wind farm sites, or record data at wind farm hub-height. To suggest that NIWA data does not support the average wind speeds being reported for the Te Uku Wind Park is an inappropriate comparison of wind speed data.

3. **WIND MONITORING BEST PRACTICE**

- 3.1 In this section of my evidence I will address the wind industry best practices for wind monitoring.
- 3.2 There are no mandatory standards in New Zealand for undertaking wind monitoring in the feasibility stage of a wind farm project. There are however industry recognised international recommendations and guidelines that can be, and are, used locally (in New Zealand) to ensure that the data collected is accurate and useful in determining the viability of a proposed project.
- 3.3 Two commonly used guidelines that form part of industry best practices are:
- (a) From the IEA: namely “Recommended Practices for Wind Turbine Testing and Evaluation. No.11 Wind Speed Measurement and Use of Cup Anemometry (1999)” ; and
 - (b) From the IEC: namely “61400-12-1 First edition 2005-12 Wind Turbines – Part 12-1: Power performance measurements of electricity producing wind turbines”.
- 3.4 The IEA recommended practices referred to above address mounting of the anemometers and other equipment on the monitoring towers, support boom orientation, boom lengths for correct separation from the actual tower and so on.
- 3.5 The IEC standards referred to above are aimed at verifying the performance of installed wind turbines, rather than feasibility wind monitoring, however these

standards suggest instrument separations and mounting configurations that are often adopted by the international wind industry as best practices that should be generally adhered to during feasibility wind monitoring.

Wind monitoring tower

- 3.6 There are industry norms and best practice (such as the Australian Wind Energy Association Best Practice Guidelines, 2006) which are accepted internationally and locally in New Zealand regarding the wind monitoring tower height in the wind industry.
- 3.7 The wind resource at a given site is generally not known to a high level of certainty before monitoring commences, therefore it is accepted in the industry that on-site measurements are required in order to eliminate the risk that a site may not have as good a wind resource as anticipated. The cost of installing a monitoring tower increases significantly with the height of tower, therefore we generally advise developers to undertake a staged approach to the type and height of tower installed to reduce the level of uncertainty while controlling initial cost during the project development phases.
- 3.8 The hub-height of most multi-megawatt wind turbines today is in the order of 70 to 80 m. Initial monitoring with one or more lower towers (eg 50 m), with three or four levels of wind speed measurements, is commonplace since this collects data at a reasonable height relative to the hub-height, and also represents reasonable cost to the developer. At a suitable time during the project development it is common and preferable to install one or more hub-height monitoring towers on the site.

Instruments

- 3.9 The IEA and IEC guidelines both recommend the use of cup anemometers (as opposed to propeller, sonic or ultrasonic for example) to measure the wind speed at a potential wind farm site. Industry best practice regarding appropriate instruments for use in measuring the wind resource at a given site suggests that these anemometers be calibrated (or in some cases selective anemometers on a monitoring tower be calibrated).
- 3.10 Examples of manufacturers of commonly used anemometers in wind measurements during various stages of the project development include NRG Systems, Second Wind, Risø and Vector instruments. This list is not exhaustive.
- 3.11 NRG and Second Wind anemometers represent a lower cost, and subsequently marginal lower accuracy, than the higher precision anemometers offered by

manufacturers such as Risø and Vector. Furthermore, the calibration of the higher precision anemometers is generally done by industry certified organisations. For example these instruments are often calibrated to the MEASNET procedures, where MEASNET is a wind industry specific co-operation of institutes that produces guidelines and procedures designed specifically for the wind industry. NRG and Second Wind instruments are generally also calibrated to the USA National Institute of Standards and Technology (NIST) standards which are not specific to the wind industry but cover all uses of the anemometers (such as general meteorology).

- 3.12 At the feasibility stage, the viability of a given wind farm project is generally not sensitive to the relatively small discrepancies that may be observed between the various manufacturers' calibrated anemometers. While calibration procedures can differ between manufacturers and calibration facilities, a calibration certificate for an anemometer gives some degree of increased confidence in the wind speed being measured by the anemometer. As with the height of the monitoring tower, there are significant cost variations in different anemometer models, and the developer needs to make their own cost/benefit decision regarding the type of anemometer purchased for a given monitoring tower and seek advice from suitable consultants. The uncertainty associated with the wind speed measurements will be small compared to other sources of uncertainty in the feasibility assessment (assuming the instruments have been mounted appropriately).

Mounting of Instruments

- 3.13 The guidelines referred to above recommend mounting arrangements that will reduce, to an acceptable level, the impact that the monitoring tower and equipment has on the recorded wind speed data, which would thus represent free and unobstructed conditions (or 'free-stream' conditions).
- 3.14 During the feasibility stage of a wind farm, it is in the developer's interest to record accurate wind data to use in the feasibility assessment of a site.
- 3.15 The orientation of booms for mounting the anemometers should consider the predominant wind direction and minimise sheltering of the anemometers by the tower. Mounting is recommended to be into the prevailing wind direction or at 45 degrees to the prevailing direction if the site is highly directional (i.e. the site exhibits one narrow band of prevailing wind direction).
- 3.16 The guidelines referred to above are also intended for power performance testing of wind turbines. For this application, flow distortion of less than 0.5% is required to ensure the data recorded by the instruments is a close representation of the free-

stream wind. For feasibility studies, while it is desirable to have a similar flow distortion in the mounting arrangement, values between 0.5% and 1% may also be considered acceptable.

- 3.17 Side-mounted anemometers on tubular towers should be mounted at least six tower diameters away from the centre of the tower (this will result in less than 1% flow distortion due to tower effects).
- 3.18 Side-mounted anemometers on lattice towers should be mounted at least four tower diameters away from the tower centre (this will result in less than 1% flow distortion due to tower effects).
- 3.19 Anemometers mounted above the top of the tower should be mounted with a similar separation vertically from the top of the tower as indicated for side mounted anemometers, for tubular and lattice towers respectively.
- 3.20 Instruments should generally be mounted 12 to 15 boom diameters above the top of the boom on which they are mounted to avoid the boom impacting materially on the wind characteristics being recorded.
- 3.21 The booms used on the monitoring towers should be circular in cross-section rather than square or angled to minimise their impact on wind measurements.
- 3.22 One other common practice is to have back-up anemometers at chosen levels on the monitoring tower. This eliminates the need for immediate site maintenance in the event of instrument failure. It is also a convenient verification of the data recorded by the primary anemometer.

Data collection and analysis

- 3.23 Industry best practice regarding the data collection and analysis in the wind industry recommends that data be collected and analysed regularly to ensure consistent quality of data collected at the tower, the early detection of any instrument malfunction or failure and the identification of any invalid data.
- 3.24 Data for wind speed and wind direction is generally collected in 10-minute averages of continuously measured data. This is industry common practice as the 10-minute averaging period is considered suitable to allow accurate prediction of the energy output and operation of the turbine.
- 3.25 Average values, as well as maximum (for gust calculations), minimum and the standard deviation (for turbulence calculations) within each given 10-minute period

should be recorded for each of the instruments (or at least the anemometers) for a suitable duration (typically a minimum of 12 months).

- 3.26 The sampling interval of the data logger should be no longer than 3 seconds. A sampling interval of 3 seconds will enable the capture of 3-second gust wind speeds and a sampling interval of 2 seconds will enable capture of 2-second gust wind speeds. Use of either sampling period is considered acceptable when considering gust wind speeds.
- 3.27 Regular (at least monthly) data collection and analysis enables early diagnosis of instrument malfunction and assessment of any required site maintenance, thus minimising the loss of or corruption of data collection from site.
- 3.28 The annual wind speed distribution (i.e. the frequency of occurrence of wind speeds at various speed magnitudes) is critical to understanding the available wind resource at any site; thus a minimum of 12 months of data as mentioned earlier (with high degree of capture rate) should be collected in the fashion described.
- 3.29 Annual average wind speed also has natural variability, hence data recorded over one 12 month period is not necessarily representative of the long-term average conditions at the site. Therefore, to gain an understanding of the long-term wind resource at a site, it is common practice to perform a long-term wind resource assessment for the monitoring tower location once 12 months of data has been collected. This is done by correlating the 12 months of on-site data to a reference site that has been collecting data for a longer term, ideally in the order of 10 -15 years. The result of this long-term wind resource assessment is then input into industry standard computer simulation software to predict the energy yield of a wind farm.
- 3.30 As discussed, monitoring towers used during the feasibility stage of a wind farm are not necessarily installed up to turbine hub-height, therefore the monitoring towers should measure the wind speed at various heights above ground. Generally individual monitoring levels have a vertical separation of at least 10 m. This will enable a wind shear profile (increase in average wind speed with height) to be determined and a more accurate extrapolation of the wind speed data from the top of the monitoring tower to the hub height. This is significantly more appropriate compared with extrapolations performed based only on wind speeds near ground level, surface roughness, and topography. Measured or calculated hub-height wind speed data is required to accurately predict the energy yield from a turbine or wind farm, which is why a hub-height monitoring tower is often installed on site at some stage of a feasibility study.

4. WIND TURBINE CLASSIFICATION

4.1 In this section of my evidence I will discuss wind turbine classification.

4.2 The international industry accepted organisation providing independent design guidelines for wind turbines is the International Electrotechnical Commission (IEC). The IEC prepares and publishes international standards for all electrical, electronic and related technologies. These standards remove international technical barriers to trade and ensure that wind turbine models manufactured to a given standard in one part of the world can be installed confidently in a location that meets the design criteria of the given standard. Simplistically for example, if a turbine is built in Denmark for use in a site with an average wind speed of 10 m/s and other known climate characteristics, it can be installed confidently at a site in New Zealand with an average wind speed of 10 m/s and similar climate characteristics.

4.3 Wind turbine models can be assigned an IEC Class to reflect the wind speed, turbulence and gust parameters in which they are designed to operate. There are other associated considerations, such as wind shear, air density and extreme wind conditions.

4.4 These classes are recognised internationally and defined in the IEC standard “61400-1 Third edition, 2005-08 Wind Turbines – Part 1: Design requirements”. The basic parameters for wind turbine classes are as follows:

Wind turbine class	I	II	III	S
V_{ref} (m/s)	50	42.5	37.5	Values specified by the designer
A I_{ref} (-)	0.16			
B I_{ref} (-)	0.14			
C I_{ref} (-)	0.12			

Where V_{ref} is 5 times the 10-minute annual average wind speed for normal wind conditions at the turbine site

A designates the category for higher turbulence characteristics

B designates the category for medium turbulence characteristics

C designates the category for lower turbulence characteristics

I_{ref} is the expected value of the turbulence intensity at 15 m/s at hub-height.

4.5 Wind turbine classes are given numerical identifiers (I, II or III) based on wind speed characteristics related to the average wind speed at the given turbine location,

defined as V_{ref} . For example a Class II turbine is suited for sites with a V_{ref} value of less than 42.5 m/s, a Class I turbine is suited to sites with a V_{ref} value less than 50 m/s. These numerical classes are also given alphabetical categorisation (A, B or C) for high, medium or low (respectively) turbulence characteristics (I_{ref}). For this purpose, turbulence intensity is stated at 15 m/s. A turbine rated for the high turbulence category A is limited to a turbulence intensity of 16%, medium turbulence category B is limited to 14% and low turbulence category C is limited to 12% (I should note these figures are averages and not the extreme values which are also assessed). For example, a site with an average annual wind speed of 9 m/s (hence a V_{ref} of 5 times 9 equals 45 m/s) and an average turbulence intensity of 13% would most likely require a class IB turbine. There are exceptions to the rule hence my statement of 'most likely'.

- 4.6 A further wind turbine class, Class S, can be used when a special mix of wind conditions and other external conditions are investigated and specified by the designer and/or the customer. For such designs, the resultant design conditions will reflect an environment at least as severe as is anticipated for the use of the wind turbine.
- 4.7 The wind speed, turbulence and gust conditions for each turbine location needs to be investigated to ensure that the turbines being installed in any given wind farm are suitably designed for specific site wind conditions. This is generally done as part of a wind farm feasibility study or energy yield assessment and in any case established before progressing the wind farm construction.

5. **WIND MONITORING AT TE UKU**

- 5.1 In this section of my evidence I will describe the wind monitoring undertaken to date at the Te Uku site, and how this data conforms to the best practices referred to in section 3.
- 5.2 Three monitoring towers have been installed at Te Uku (referred to herein as 0950, Whar80, and 0951) and are considered separately in the following sections of this evidence.
- 5.3 The data collected from the monitoring towers is of suitable accuracy for use in energy yield assessment of the wind farm. Data has been removed where instruments have required maintenance or replacement,— this is noted later in my evidence.

Monitoring tower 0950

- 5.4 Monitoring tower 0950 was the first tower installed at Te Uku on April 7, 2005. This is a 50 m tubular tower which monitors the wind speed at heights (above ground) of approximately 50 m (primary and back-up anemometers), 40 m, 30 m, and 10 m, wind direction at 50 m and 40 m, and temperature at approximately 2 m.
- 5.5 Wind speed is measured using a MEASNET calibrated Vector A100LM anemometer at 50 m, and uncalibrated NRG Max40 anemometers at 50 m, and the remaining 3 levels.
- 5.6 The fact that two anemometers have been installed at 50 m is in accordance with best practice. Failure of one of the two top anemometers will therefore not result in the loss or inconsistency of wind speed data.
- 5.7 Anemometers on this tower are mounted either pointing south or east therefore there is no significant tower sheltering on these instruments from winds from the dominant southwesterly or easterly directions.
- 5.8 All wind vanes and anemometers on this tower are side mounted, on booms at least 1100 m long. The width of the tubular tower is 152 mm, making the boom length to tower width ratio at least 7.2 which is greater than the ratio of six which is recommended by best practices. Therefore, the monitoring tower is not expected to have significantly influenced the wind data recorded at this site.
- 5.9 Wind direction is measured using Vector #200P wind vanes at both 50 m and 40 m levels.
- 5.10 Data from this tower was automatically emailed to PB on a daily basis. This data was verified and reported on a monthly basis.
- 5.11 This tower was decommissioned on May 8, 2007 due to the installation of an 80 m tower approximately 200 m away from the 0950 tower location in December 2006. An overlap in data collection at both monitoring towers between the installation of the 80 m tower and the decommissioning of this 50 m tower (5 months) enabled a statistical relationship between the two towers to be established, and 80 m data to be calculated (or synthesised) for the period of data collection from the 0950 monitoring tower (2 years). The synthesis of data in this way is common practice in wind energy analyses if there is a strong correlation relationship between two tower sites. There is in this case an expected close correlation relationship considering the close proximity of the two towers.

- 5.12 The 50 m wind vane was observed to be recording invalid data, as reported in the monthly reports, however the back-up 40 m vane recorded valid data, apart from a short period of 18 days in October 2005 which will not affect the data's suitability for assessing the wind energy potential at Te Uku.
- 5.13 The data logger used at this site was an NRG Symphonie. These are commonly used data loggers designed specifically for the wind industry and record data in 10-minute averages, along with the maximum (gust), minimum and standard deviation (for use in turbulence assessment) of the parameters within the 10-minute period. These loggers have a sampling interval of 2 seconds which meets best practice.
- 5.14 In my opinion, valid and appropriate data has been collected and preliminary analysis indicates a strong wind resource being recorded at this tower site.

Monitoring tower Whar80

- 5.15 Monitoring tower Whar80 was the second tower installed at Te Uku. It was installed on December 14 2006. This is an 80 m lattice tower which monitors the wind speed at heights of approximately 80 m (primary and back-up anemometers), 50 m, 30 m, and 10 m, wind direction at 80 m and 50 m, atmospheric pressure at 80 m, and temperature at approximately 2 m.
- 5.16 Wind speed is measured using MEASNET calibrated Risø 2729 anemometers at all monitoring levels, and one backup calibrated NRG Max40 anemometer at 80 m.
- 5.17 The fact that two anemometers have been installed at 80 m is in accordance with best practice. Failure of one of the two top anemometers will therefore not result in the loss or inconsistency of wind speed data.
- 5.18 Anemometers on this tower are mounted either pointing southeast or northwest therefore there is no significant tower sheltering on these instruments from winds from the dominant southwesterly or easterly directions.
- 5.19 All wind vanes and anemometers on this tower are side mounted, on 2 m long booms. The width of the lattice tower is 450mm, making the boom length to tower width ratio 4.44 which is greater than the ratio of four recommended by best practices (clause 3.18). Therefore, the monitoring tower is not expected to be significantly influencing the wind data being recorded at this site.
- 5.20 Wind direction is measured using a Vector #200P wind vane at 79 m and an NRG #200 vane at 50 m.

- 5.21 Data from this tower is downloaded by PB on a weekly basis. This data is verified and reported on a monthly basis.
- 5.22 This tower is still recording valid wind and environmental data (with the exception of temperature data since the thermometer on this tower is malfunctioning). Note that there is some pressure data missing due to a faulty sensor in the early stages of monitoring at this site, but this is not expected to alter the accuracy of the overall energy yield calculations.
- 5.23 The data logger used at this site is a Campbell Scientific CR1000. These are completely programmable loggers and have been set to a sampling interval of 3 seconds. The average, maximum (gust), minimum and standard deviation (for turbulence assessment) for the wind speeds for each 10-minute period are recorded.
- 5.24 In my opinion, valid and appropriate data has been collected and preliminary analysis indicates a strong wind resource being recorded at this site.
- 5.25 Monthly data verification reports for the highest wind speed month (October 2007 at 11.1 m/s) and the lowest month (April 2007 at 6.7 m/s) at Whar80 are included at **Appendices A and B** respectively to this evidence. This shows the typical level of detail that monthly data is analysed from each of the on-site towers at Te Uku.

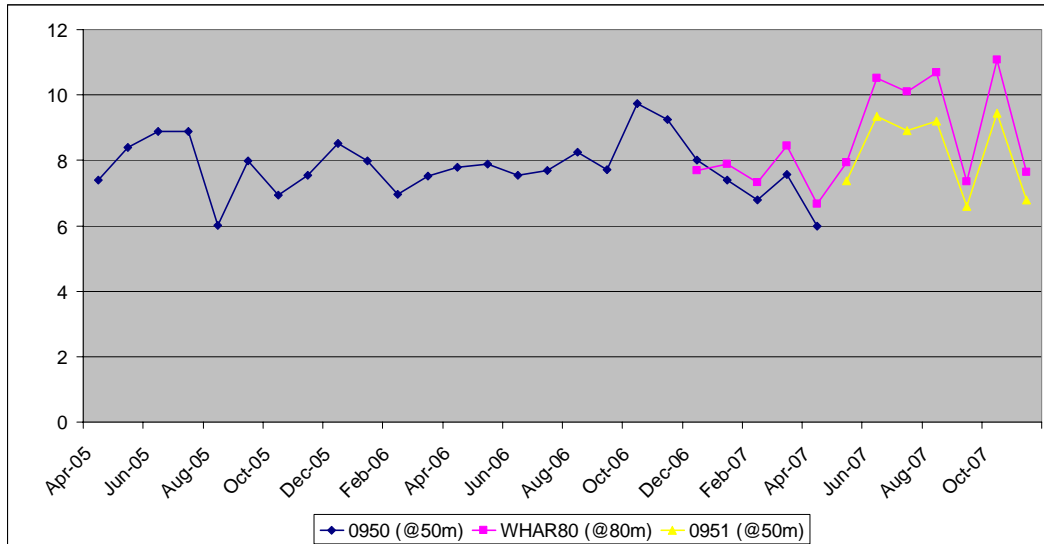
Monitoring tower 0951

- 5.26 Monitoring tower 0951 is the same tower originally installed at 0950 however a faulty 50 m direction sensor was replaced and the tower was moved approximately 3 km north-northwest of the Whar80 tower. This monitoring tower was installed on May 10, 2007. This is a 50 m tubular tower which monitors the wind speed at heights of approximately 50 m (primary and back-up anemometers), 40 m, 30 m, and 10 m, wind direction at 50 m and 40 m, and temperature at approximately 2 m.
- 5.27 Comments regarding the validity of the wind data recorded at site 0950 (above) are applicable to the wind data recorded at the 0951 monitoring tower location.
- 5.28 Anemometers at 40 m and 30 m on this tower are mounted pointing west hence the tower shelters these instruments during easterly winds. The wind data can be corrected for this tower sheltering during an energy yield assessment and it is not considered a major issue.
- 5.29 Data from this tower is emailed to PB on a daily basis. This data is verified and reported (in the form of a 'Data Verification Report') on a monthly basis.

- 5.30 This tower is still recording valid wind and environmental data.
- 5.31 The data logger used at this site is an NRG Symphonie. These are commonly used data loggers in the wind industry and record data in 10-minute averages, along with the maximum (gust), minimum and standard deviation (for turbulence assessment) of the parameters within the 10-minute period. These loggers have a sampling interval of 2 seconds.
- 5.32 As discussed above this monitoring tower is located approximately 3 kilometres to the north northwest of the Whar80 tower. The distance between these two monitoring towers provides a detailed coverage of the wind regime at this site and will most likely result in more accurate energy yield predictions compared to having only one monitoring tower.
- 5.33 In my opinion, valid and appropriate data has been collected and preliminary analysis indicates a strong wind resource being recorded at this site.

Wind Turbine Class at Te Uku

- 5.34 A visual inspection of the monthly average wind speeds in the graph (shown below) indicates that the recorded average wind speed at 50 m at this site is approximately 8 m/s. For a hub height of 50 m the corresponding wind turbine class (referred to in clause 4) required is theoretically likely to be Class II. The hub height is likely to be higher than 50m at the site and thus the hub-height average wind speed will be higher than this 8 m/s noted. In my opinion it is likely that (assuming a hub height in the order of 80 m) the average wind speed could be close to the wind speed criteria between Class I and II (8.5 m/s). Given also the variation in wind speed that is expected across the 28 wind turbine sites, it is reasonable to expect that some turbine locations at Te Uku will require a Class I turbine. Long-term wind resource assessment and more detailed analysis of the individual turbine sites would be required to confirm this expectation. I understand WEL Networks has engaged consultants to undertake this assessment.



6. SUBMISSION BY SEAN COX

6.1 In this section of my evidence I will address those issues raised by Sean Cox’s submission that are relevant to the evidence I am providing.

Mr Cox’s concern regarding WEL Networks not sharing their wind data

6.2 I am not surprised that WEL Networks has elected not to share data in relation to wind resource. As someone who has had access to a large amount of data from various wind farms across New Zealand, Australia, the Pacific, Asia and America, it is in my experience standard commercial practice and common for developers to be prudent with whom they release their on-site data, with confidentiality agreements protecting this data being typical. Given the commercial sensitivity of this data, and the likely irrelevance of Mr Cox’s data, I am not at all surprised that WEL Networks did not allow Mr Cox access to their data.

6.3 The “10 years of detailed wind data” Mr Cox states to have collected would only be considered useful data for wind energy calculations if it were; collected from a consistent location, at a height above ground of at least 10 m (the height of many of the NIWA wind data sources but obviously higher is better for reasons described herein), in an open area free from obstructions, using suitable quality instruments, at regular, preferably small time-scale intervals (e.g. 10 minute averaging from continuous data), for a continuous period, has complete maintenance history and has thorough quality assurance procedures in place.

6.4 Mr Cox describes his data as “poor at night”. This can be interpreted two ways. If Mr Cox means that data is unavailable at night and therefore of poor quality, this indicates that his data is incomplete and therefore cannot provide an accurate distribution of the wind at Te Uku. If Mr Cox means that the wind resource itself is

poor (or low) at night, this is incorrect, as shown by the diurnal average plots in the two Data Verification Reports attached to this evidence, where the average night time wind speed is clearly well above 4.5 m/s for even the lowest average wind speed month.

- 6.5 Mr Cox does not provide any information to support the quality of his data. From the description of the data we certainly could not recommend its use for feasibility and or energy assessment. At best, Mr Cox's data may provide some indicative reference site data however, we would suggest that NIWA has already provided what is required.

Mr Cox submits his own wind resource assessment for the proposed Te Uku site which is significantly lower than the wind resource suggested by WEL Networks

- 6.6 Mr Cox has estimated the wind resource at the plateau based on measurements taken at his 'recording site'. No information is presented on the nature of the wind data collected from this site, the exact location of the site, its height above ground, distance to nearest obstacles, instrumentation used to measure the data, data averaging period, continuity of the data set, or average wind speed collected at the site.
- 6.7 The modelling of wind over 10 km in terrain such as that in the Raglan region is very difficult to do accurately. For this reason, monitoring tower(s) are installed on a proposed wind farm site to minimise the distance over which computer modelling is required. In my opinion, the figures produced by Mr Cox's described methods amount to a guess at the long-term hub-height wind speed and energy output at the proposed Te Uku Wind Park and are completely inaccurate. The WEL Networks on-site measured data clearly shows that Mr Cox's estimates are simply incorrect.
- 6.8 Mr Cox implies his method of wind resource assessment is better than "present(ing) the output from a computer program and say(ing) 'here is the answer' ". I do not agree with Mr Cox on this point, for several reasons, outlined below.
- a) The distance between his input data and the wind farm site, and the nature of the terrain between the wind farm and the recording site, is too far and too complex to allow any generic wind translation rules to result in an accurate annual average wind prediction.
 - b) Mr Cox has indicated that his "representative day" consists of a "representative gust cell" passing the site, which resulted in the daily energy output being 1/365 of the expected annual output. There is no explanation on how Mr Cox

calculated the criteria of this “representative gust cell”. Also, given Mr Cox’s uncertainty regarding the speed of the cell (“the characteristic gust cell of this day took about 15 minutes to pass the site”) it seems contradictory that he can quote his wind speed and energy predictions with such confidence. Given the significant daily and annual variation in wind resource at any given site, Mr Cox has also given no explanation into ensuring that this “representative day” is typical of a ‘representative year’.

- c) The diurnal wind speed pattern presented in Mr Cox’s submission is different to the diurnal pattern taken from 12 months of on-site data at 50 m above ground. The maximum wind speed is observed to occur during early afternoon from the on-site data, whereas Mr Cox’s data shows a maximum wind speed occurring between 6 and 8pm. Mr Cox’s data is not representative of the Te Uku on-site data.
- d) 12 months of data shows a significantly different diurnal wind speed pattern at a height of 50 m compared with 10 m. I assume Mr Cox’s data is recorded at quite lower than 50 m above ground and hence does not necessarily represent the actual upper-level wind conditions observed even at his own site let alone the proposed wind farm site.
- e) Drawing a line at 6.1 m/s (Mr Cox’s stated annual average at Te Uku) on Mr Cox’s diurnal plot generally appears to go through the middle of the data set, implying that this 6.1 m/s average includes the 0 m/s wind speeds that are ‘observed’ to occur during the ‘representative’ night. This is not reflected by measurements taken to date at Te Uku. A paradox within Mr Cox’s statement is that if night time data is not valid (refer to clause 6.4), then it should not be included in the average.
- f) Mr Cox’s analysis has not taken into account the wind distribution at the site. While Mr Cox believes his diurnal pattern to be ‘average’ and has performed his energy calculation on these numbers, the wind speed in fact will rarely be these exact values. Performing calculations in this way is an inaccurate oversimplification of an energy prediction and no reputable consultant in the industry would endorse this methodology.
- g) When introducing his methodology on the wind resource and energy yield assessment at Te Uku, Mr Cox makes the statement (or assumption) that the “turbine position assumed is not the best but it is better than average for this direction” also implies that Mr Cox has been able to predict the average wind speeds at each exact turbine location, which given the implied primitive nature

of his calculations, is in my opinion seems an absurd statement. To accurately predict the average wind speed at each of 28 turbine locations, or even the spatial distribution of average wind speed across the site, based on a single data input (of apparently poor quality) 10 km away could not be done with sophisticated computer modelling, let alone an individual's rule of thumb calculation. Therefore, to suggest that any given value of wind speed is above or below average for the entire wind farm is unreasonable.

- 6.9 The annual average wind speed of 6.1 m/s for the site quoted by Mr Cox is lower than the lowest monthly average wind speed that has been recorded on-site until the end of November 2007 (approximately 12 months) at the height of 80 m. A graph of these monthly average wind speeds is presented in paragraph 5.34. Although not stated by Mr Cox, it is assumed that this value is supposed to represent the average wind speed at the proposed hub-height of 80 m, since Mr Cox compares his wind speed with "Mr Burchett's numbers" which are calculated at hub-height. The graph in paragraph 5.34 shows the actual monthly average data recorded since wind monitoring began at this site in mid-2005. If the long-term site average hub-height wind speed was 6.1 m/s then there would be a significant number of data points below 6 m/s. This is clearly not the case and the long-term average at site (without having performed a long-term wind resource assessment) appears that it will be significantly higher than 6.1 m/s.

Mr Cox's submits that WEL Networks intend to "fudge" the wind data

- 6.10 The wind data collected from the two monitoring towers at Te Uku is downloaded and independently checked and verified by PB. Only once this data has been verified (and a monthly report created) is the data passed onto WEL Networks. This data is then passed onto an independent party (Hydro Tasmania Consulting Ltd) to perform energy calculations.
- 6.11 PB does not "fudge" this data in any way prior to its delivery to WEL Networks. Further we operate under our Quality Assurance system accredited to ISO standards.

Mr Cox submits that NIWA data does not support WEL Networks energy predictions

- 6.12 Wind farm sites are generally located in specific locations that have a high local wind resource (such as a ridgeline). These 'windy' areas are generally on a relatively small spatial scale and, unless measurements are specifically taken in these 'windy' areas, are often not simulated when compiling a wind resource map

for an entire country (such as what NIWA has produced). The grid size for such resource maps is generally in the order of kilometres to tens of kilometres. Therefore taking the average of each grid square will not be the same as taking the average of a relatively narrow ridgeline that only forms a small portion of that grid square.

- 6.13 Since NIWA are not measuring wind data for the purpose of wind energy calculations (but rather to obtain climatic information for all of New Zealand) it is very unlikely that any of the weather stations are going to be located on potential wind farm sites (but rather they may be at a local airport for example).
- 6.14 NIWA sites generally measure the wind speed at a height of 10 m above ground as opposed to the hub height of modern wind turbine. Generally the wind speed at say a hub-height of 80 m is in the order of 40% higher than 10 m wind speed.
- 6.15 Since the wind data collected at NIWA sites is generally at a height of 10 m above ground, they are also often susceptible to interference by vegetation or surrounding buildings, and therefore may record lower than expected wind speeds at a given site. This would then given the false impression that the general wind resource of a region is lower than what may actually be the case. This is a common issue with public weather stations in all countries.

Andrew Kerley

January 2008

Appendix A

**PB Power- Monthly data verification reports for the highest wind speed month
(October 2007)**

Appendix B

**PB Power- Monthly data verification reports for the lowest wind speed month (April
2007)**

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