Appendix 5

Mt Emerald Wind Resource and Energy Yield Assessment

Prepared by Parsons Brinckerhoff

Mount Emerald Wind Resource and Energy Yield Assessment

27 November 2012

RATCH Australia Corporation Limited

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Revision	Details	Date	Amended By
00	Draft	5 September 2012	Authors
01	Update to include various WTG layout scenarios	10 September 2012	Authors
02	Update to include discussion on uncertainty	27 November 2012	Authors

Author: We-Ki Chua...

Signed: ....

Reviewer: Ben Inkster...

Signed: ....

Approved by: Taraz Saba ....

Signed: ....

Date: 27 November 2012 ....

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Our reference 2158879A-REP-001

27 November 2012

Terry Johannesen
RATCH Australia Corporation Limited
Level 4, 52 Merivale Street,
South Brisbane
QLD 4101

Dear Terry,

Mount Emerald Wind Resource and Energy Yield Assessment

Please find enclosed the Mount Emerald energy yield assessment as per the original scope agreed upon by Parsons Brinckerhoff and RATCH Australia Corporation Limited. This assessment was based on the wind farm layout provided by RATCH, wind data collected from the Mount Emerald/Arriga site and the High Road long-term reference site. The methodologies and results are detailed herein.

Should you have any questions, please contact me at your convenience.

Yours sincerely

Ben Inkster
Wind Engineer
Parsons Brinckerhoff Australia Pty Limited

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Glossary

AEP	Annual Energy Production
AWS	Automatic Weather Station
BoM	Bureau of Meteorology
C_t	Coefficient of thrust
EYA	Energy Yield Assessment
IEC	International Electrotechnical Commission
IEC Class	Wind turbine class, as defined in IEC61400-1:2005 ed.3
kg/m^3	Kilograms per cubic metre
kW, MW, GW	Kilowatt, Megawatt, Gigawatt
m/s	Metres per second
mAGL	Metres above ground level
mASL	Metres above sea level
MERRA	Modern Era Retrospective Analysis for Research and Applications
MEWF	Mount Emerald Wind Farm
MWh	Megawatt hour
NASA	National Aeronautics and Space Administration
RATCH	RATCH Australia Corporation Limited
SRTM	Shuttle Radar Topography Mission
WTG	Wind Turbine Generator

Executive summary

RATCH Australia Corporation Limited (RATCH) has requested Parsons Brinckerhoff perform an energy yield assessment for the proposed Mount Emerald Wind Farm (MEWF), formerly known as the Arriga Wind Farm. This report is an energy assessment of a three turbine layouts at a nominal hub-height of 80 m, as specified by RATCH, using on-site monitored data to predicted long-term annual energy production.

The MEWF site has two monitoring towers of two different heights: 80 m and 50 m. Both towers were commissioned in May 2010. Parsons Brinckerhoff was present during the installation and verified the configuration and mounting arrangement of the towers to the relevant wind monitoring standards. Both towers record wind speed and direction data from three height levels.

The wind resource assessment has been conducted using on-site monitored data from two monitoring towers currently being managed by Parsons Brinckerhoff, adjusted using a longer term reference site, to predict the longer term wind resource at MEWF. The towers used in this assessment have recorded data at various heights and durations. A summary of the data collection period from these two sites is detailed below:

Site ID	Mast Height	Start Date	End Date	Duration
9530	80 mAGL	24/05/2010	26/08/2012	2y 3m
9531	50 mAGL	24/05/2010	25/08/2012	2y 3m

The data recorded by the two MEWF monitoring towers required several levels of verification and processing for use in the assessment. To account for variations in wind speed for durations greater than those measured at MEWF, Parsons Brinckerhoff conducted a correlation study of several longer term reference sites; based on this study, the RATCH wind monitoring tower 9420 mast at High Road was determined to be the most suitable longer term reference site. Correlations between this site and the MEWF monitoring towers averaged to 90.1%. This longer term reference site was then used to determine and adjust the wind speeds at each of the two masts to be representative of the longer term wind speed.

A wind shear extrapolation was performed on both data sets to determine wind speed for a single hub height of 80 m. The results of these adjustments and shear extrapolation are summarised below:

Mast ID	Instruments used for shear	Measurement heights	Longer-term adjusted wind speed at measurement height	Extrapolated wind speed at hub height (80 m)	Multi-dimensional wind shear exponent
		mAGL	m/s	m/s	
9530	S1 & S3	81.0 & 50.2	9.3	9.3	0.05
9531	S1 & S3	49.6 & 29.9	7.4	8.2	0.22

The adjusted data sets for the two monitoring towers have been used as inputs into a flow simulation using WindPro, utilizing WAsP. The results of the energy yield assessment are detailed below:

MEWF Energy production			
WTG	Siemens SWT3.0-101	REpower 3.4M-104	Acciona AW3000-100
Capacity (kW)	3000	3370	3000
Nominal hub height	80 m		
Wind farm losses (%)			
Wake (calculated)	15.3	15.1	14.5
Electrical losses (estimated)	3.0	3.0	3.0
Others	1.0	1.0	1.0
Non-availability of WTGs (unscheduled)	3.0	3.0	3.0
Non-availability of Scheduled maintenance	0.6	0.6	0.6
Balance of Plant availability	0.2	0.2	0.2
Overall Losses	21.7	21.5	21.0
Energy Output			
Gross Annual Energy Output (GWh)	674.1	693.8	606.9
Gross Annual Energy Output minus wake loss (GWh)	570.9	589.1	518.6
Net Annual Energy Output (GWh)	527.7	544.5	479.4
Net Capacity Factor	28.7%	26.4%	26.1%

The predicted energy values for each WTG model is based on the wind farm layouts provided by RATCH. It is noted the wake losses for all layouts are notably higher than typical wind farm layouts seen in other projects. An inter-WTG spacing of 5 rotor diameters in the predominant wind direction and 2.5 rotor diameters perpendicular to the predominant wind direction appears to have been applied. It is assumed that RATCH has considered a sensitivity analysis to evaluate the net annual energy yield against the installed Capex and annual Opex for each layout – as well as the impact of higher turbulence on the fatigue life of the WTGs.

Parsons Brinckerhoff has conducted an uncertainty and probability of exceedance analysis for the net energy yield for each WTG model using a Monte Carlo simulation using calculated and estimated uncertainties. The results of this analysis are shown in the following tables.

Siemens SWT3.0-101 80m hub height		Probability of Exceedance				
	Long-term Average (P50)	75%	80%	90%	95%	99%
Net Energy (GWh/y), 1 year period	527.7	501.5	494.9	477.8	463.7	437.2
Net Energy (GWh/y), 10 year period	527.7	505.9	500.5	486.3	474.6	452.5
Net Energy (GWh/y), 20 year period	527.7	506.2	500.8	486.8	475.2	453.5

REpower 3.4-104 80m hub height		Probability of Exceedance				
	Long-term Average (P50)	75%	80%	90%	95%	99%
Net Energy (GWh/y), 1 year period	544.5	515.0	507.7	488.5	472.6	442.9
Net Energy (GWh/y), 10 year period	544.5	520.0	513.9	497.9	484.7	459.9
Net Energy (GWh/y), 20 year period	544.5	520.3	514.3	498.5	485.4	460.9

Acciona AW3000-100 80m hub height		Probability of Exceedance				
	Long-term Average (P50)	75%	80%	90%	95%	99%
Net Energy (GWh/y), 1 year period	479.4	453.3	446.8	429.8	415.8	389.4
Net Energy (GWh/y), 10 year period	479.4	457.7	452.4	438.2	426.6	404.7
Net Energy (GWh/y), 20 year period	479.4	458.0	452.7	438.8	427.2	405.6

The uncertainty in the estimated energy production is caused by several factors. Parsons Brinckerhoff has identified three factors which are within the control of RATCH that would potentially lead to a reduction in uncertainty, as discussed in Section 5.2. It should be noted that all three factors can be addressed by installing a strategically located and specified, additional monitoring tower(s) at the MEWF site.

To assess the various layout options available to RATCH by removal of WTGs, Parsons Brinckerhoff has iteratively reduced the 70 WTG layout by removing the lowest performing WTGs (for energy production) in five-WTG increments, eventually arriving at a layout of 30 WTGs. This assessment has revealed an approximately linear relationship between the increase in number of WTGs in the layout and the decrease in capacity factor. Parsons Brinckerhoff has presented this information for consideration by RATCH for cost benefit and operational assessment; no optimisation was undertaken on the layout provided by RATCH. The results of this assessment are shown below (using the Siemens SWT3.0-101 WTG as a representative WTG).

Number of WTGs	Net AEP	Net capacity factor
	GWh	%
70	527.7	28.7
65	506.8	29.7
60	482.5	30.6
55	455.1	31.5
50	424.9	32.3
45	392.2	33.2
40	357.4	34.0
35	320.3	34.8
30	282.7	35.9

Additionally, Parsons Brinckerhoff has also conducted an optimised layout development for RATCHs consideration using the REpower 3.4M-104 for comparative purposes. This process began by optimising solely for the highest possible energy production whilst maintaining the industry standard spacing of five rotor diameters in the predominant wind direction and three rotor diameters perpendicular to the predominant wind direction. The locations of the surrounding houses were then taken into consideration and were used as a noise constraint input in the optimisation process. Some WTGs were then manually relocated to comply with AirServices Australia requirements of a tip height of less than 1179.5 mASL, and to avoid encroaching into the telecommunication links that intercept the wind farm area. Whilst the minimum three rotor diameter spacing was kept where possible, some WTGs were placed within a closer spacing to take advantage of higher wind speed locations. A summary of the energy results from this optimisation are shown below.

Optimised Layout Energy production	
WTG	**Repower 3.4M 104**
Capacity (kW)	3370
Nominal hub height	80
Wind farm losses (%)	
Wake (calculated)	14.5%
Electrical losses (estimated)	3.0%
Others	1.0%

Optimised Layout Energy production	
Non-availability of WTGs (unscheduled)	3.0%
Non-availability of Scheduled maintenance	0.6%
Balance of Plant availability	0.2%
Overall Losses	21.0%
Energy Output	
Gross Annual Energy Output (GWh)	728.4
Gross Annual Energy Output minus wake loss (GWh)	622.6
Net Annual Energy Output (GWh)	575.5
Net Capacity Factor	27.8%

1. Introduction

RATCH Australia Pty Ltd (RATCH) has proposed to build a wind farm in the Arriga region of Northern Queensland, southwest of Cairns. RATCH has requested Parsons Brinckerhoff Australia Pty Ltd (Parsons Brinckerhoff) conduct an energy yield assessment of the Mount Emerald Wind Farm (MEWF) based on data collected from two wind monitoring towers at the MEWF site and a long term reference site 36 km south of Arriga; which is owned and operated by RATCH. Parsons Brinckerhoff was commissioned to install and monitor the two on-site monitoring towers at MEWF as well as the nominated reference site mentioned above. RATCH has nominated a layout consisting of 70 WTGs with a nominal hub height of 80 m for evaluation and prediction of annual energy yield from the MEWF, using three separate WTG models.

1.1 Scope of work

The following scope of work and input data is taken from the proposal email agreed on by Terry Johannesen (RATCH) and Ben Inkster (Parsons Brinckerhoff), 24 August 2012.

1. Compilation of on-site recorded wind data - (2 masts);
2. Data verification and analysis of on-site wind data from all monitoring masts;
3. Compilation and analysis of a dataset from RATCHs High Road site as the long-term reference wind data;
4. Assessment and calculation of wind shear profiles where relevant;
5. Cross-correlation and estimating the long-term wind speed for all two monitoring towers;
6. Energy yield estimation for three WTG models and layouts, with a hub height to be nominated by RATCH
7. Layout scenario modelling estimating the effect on capacity factor due to number of WTGs
8. WTG layout optimisation with constraints provided by RATCH
9. Report outlining the results of the above analyses.

1.2 Requested input data

Since Parsons Brinckerhoff has previously assessed MEWF on behalf of RATCH, the following information was requested from RATCH to perform the required update:

1. WTG Layout;
2. WTG power and thrust curves.

1.3 Received input data

RATCH has provided a single layout consisting of 70 WTG locations, and WTG specifications for the following models:

1. Siemens SWT3.0-101 3 MW
2. REpower 3.4-104 3.37 MW
3. Acciona AW3000-100 3 MW

2. Wind monitoring at MEWF

The wind monitoring data for the proposed MEWF has been acquired using two monitoring stations. The duration of logged data and the locations of these masts are included in Table 2-1 and Table 2-2.

Table 2-1: MEWF monitoring towers

Site ID	Mast Height	Start Date	End Date	Duration
9530	80 mAGL	24/05/2010	26/08/2012	2y 3m
9531	50 mAGL	24/05/2010	25/08/2012	2y 3m

Table 2-2: MEWF monitoring tower locations

Site ID	Easting	Northing	UTM Zone	GPS Datum
9530	329088	8100271	55	UTM WGS84 South
9531	325608	8101256	55	UTM WGS84 South

The proposed MEWF is located approximately 6 km southwest of Walkamin in the Atherton Tablelands, 55 km southwest of Cairns in Northern Queensland.

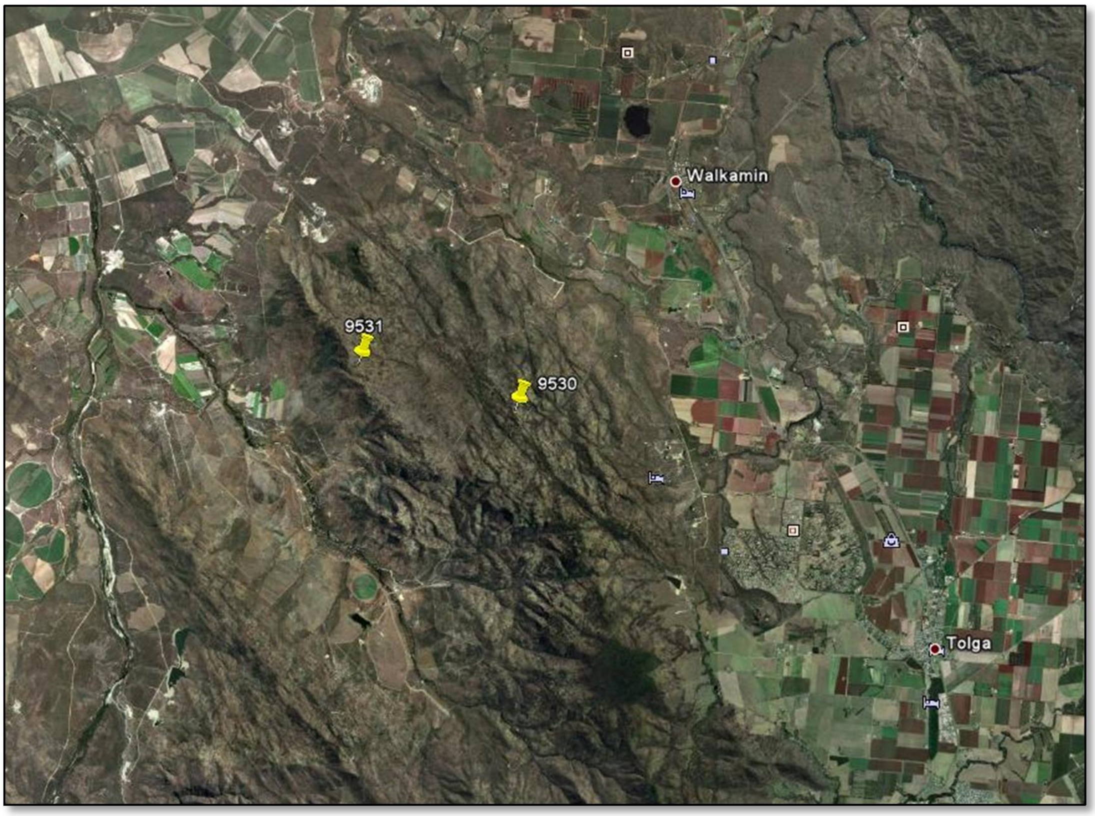

Figure 2-1: MEWF monitoring masts relative to surrounding townships

(source of background image: © Google Earth 2009, © 2012 Whereis® Sensis Pty Ltd, © 2012 GeoEye, © 2012 Digital Globe)

2.1 9530

2.1.1 9530 monitoring tower

The 80 mast (site ID 9530) is a lattice tower commissioned in May 2010 and has been logging data from the 24th May 2010. Parsons Brinckerhoff was present during the installation and commissioning of this tower and the configuration and types of the anemometer have been verified to conform to the relevant IEA anemometry standards. Appropriate offsets were applied to the wind vanes so readings corresponded to true north bearings. The logging equipment used for this tower is an NRG Symphonie data recorder and the list of all instruments is detailed in Table 2-3. The calibration values listed for each instrument have been verified by Parsons Brinckerhoff for consistency with the installation report and the channel report included in the monitored data.

Table 2-3: 9530 instrument details

Instrument	Serial Number	ID	Height [mAGL]	Scale	Offset
Anemometer NRG Max40C	1795000095708	S1	81.0	0.757	0.38
Anemometer NRG Max40C	179500132407	S2	80.9	0.761	0.38
Anemometer NRG Max 40C	179500127837	S3	50.2	0.762	0.35
Anemometer NRG Max40C	179500096006	S4	11.5	0.758	0.36
Wind Vane NRG 200P	NA	Dir1	77.8	0.351	157°
Wind Vane NRG 200P	NA	Dir2	47.5	0.351	161°
Wind Vane NRG 200P	NA	Dir3	11.4	0.351	345°
Temperature NRG 100S	NA	Temp	2.0	0.136	-86.38
Pressure NRG BP20	18059972	Press	2.0	0.4255	650

The terrain surrounding the mast has been classified by Parsons Brinckerhoff as complex terrain; this includes steep cliffs, exposed rock outcrops and medium to low density alpine scrub, 1 - 6m in height.

Figure 2-2: Typical terrain and vegetation surrounding 9530

2.1.2 9530 data analysis

Parsons Brinckerhoff has assessed the data from 9350 and found that no data was lost or deemed to be invalid over the monitoring period; a summary of the data is detailed in Table 2-4.

Table 2-4: 9530 data summary

9530						
Recording period	**Date**	**Time**	**Data recovery**			
Start	24/5/2010	0:00	Averaging period			10 min
Finish	26/8/2012	14:50	Data recovery for concurrent S1 and Dir1			100.0%
Wind Statistics	**S1**	**S2**	**S3**	**S4**		
Height above ground level (m)	81.0	80.9	50.2	11.5		
Recovery rate (%)	100.0	100.0	100.0	100.0		
Average wind speed (m/s)	**9.1**	**9.0**	**8.9**	**8.2**		
Max gust wind speed (m/s)	27.9	27.7	25.7	23.6		
Mean TI at 15 m/s (%)	10.1	10.0	11.5	14.5		
IEC3 TI at 15 m/s (%)	14.1	14.1	14.8	17.2		
Wind vanes	**Dir1**	**Dir2**	**Dir3**			
Data recovery rates (%)	100.0	100.0	100.0			
Environmental sensors	**Temperature**	**Pressure**				
Data recovery rates (%)	100.0	100.0				
Height above ground level (m)	2.0	2.0				
Average (°C; hPa)	19.7	909.8				

Following the verification of data recorded on 9530, Parsons Brinckerhoff determined that the 81 m anemometer (S1) and 78 m vane (Dir1) recorded the most useful data for the assessment (where lower level instruments were not required). The analysis presented here is based on these two instruments unless otherwise specified.

The combined availability of S1 and Dir1 instruments can be seen in Figure 2-3.

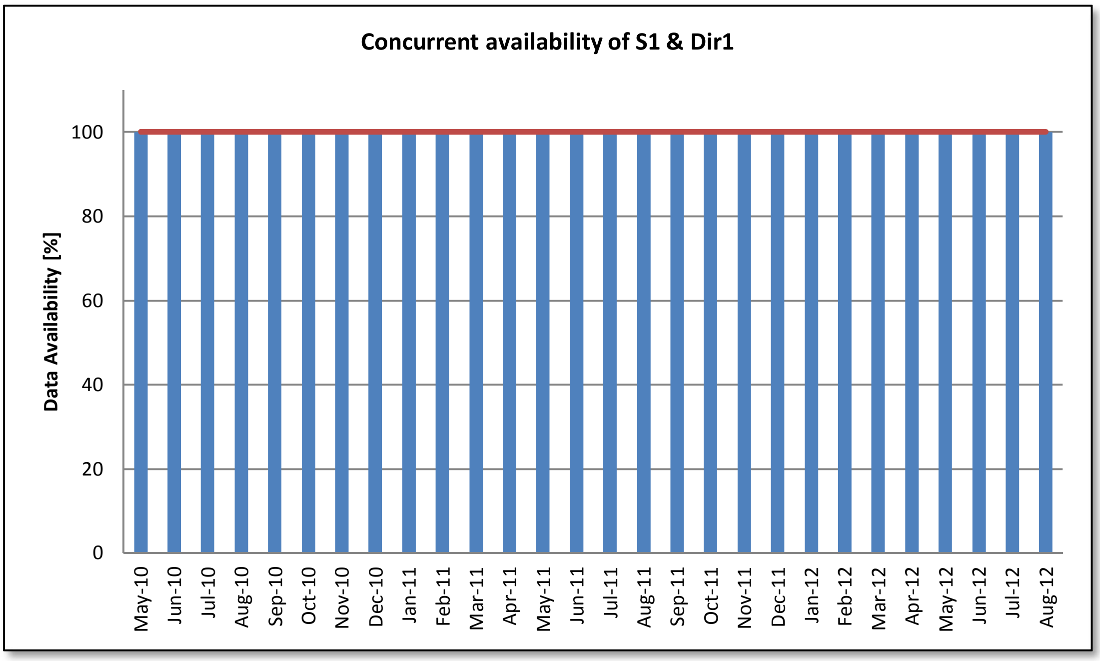

Figure 2-3: Concurrent availability of S1 and Dir1 instruments for 9530

Almost all wind energy during the monitoring period is directed from the east to southeast sector. Figure 2-4 shows the directional mean wind speed and the wind direction distribution for 9530.

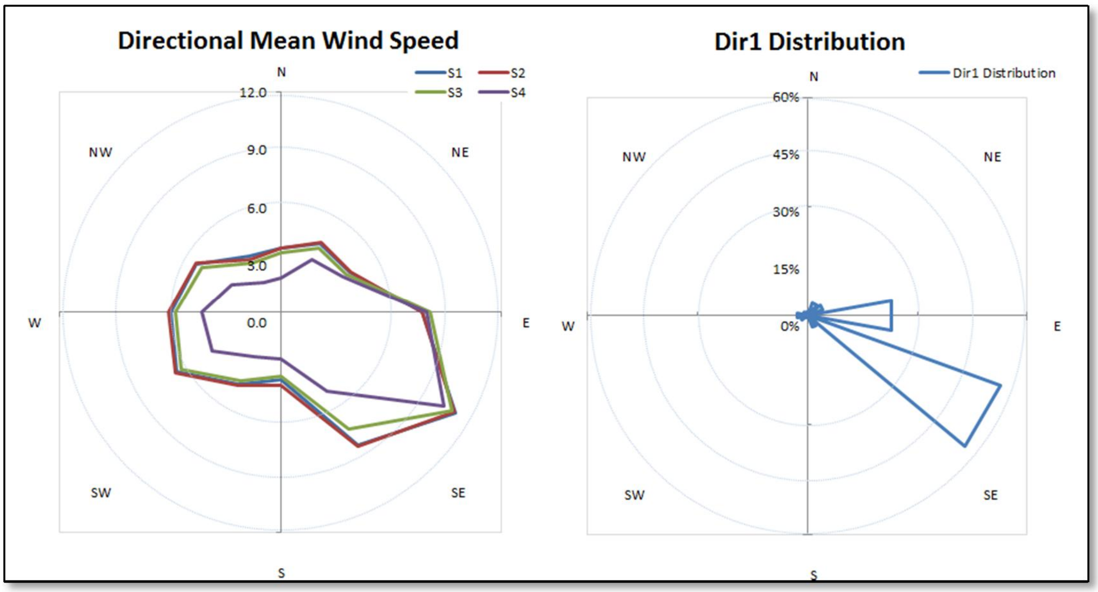

Figure 2-4: The directional wind speed and frequency distribution for 9530.

The wind speed distribution for the S1 anemometer has been analysed and a Weibull distribution has been fitted. These distributions are shown in Figure 2-5.

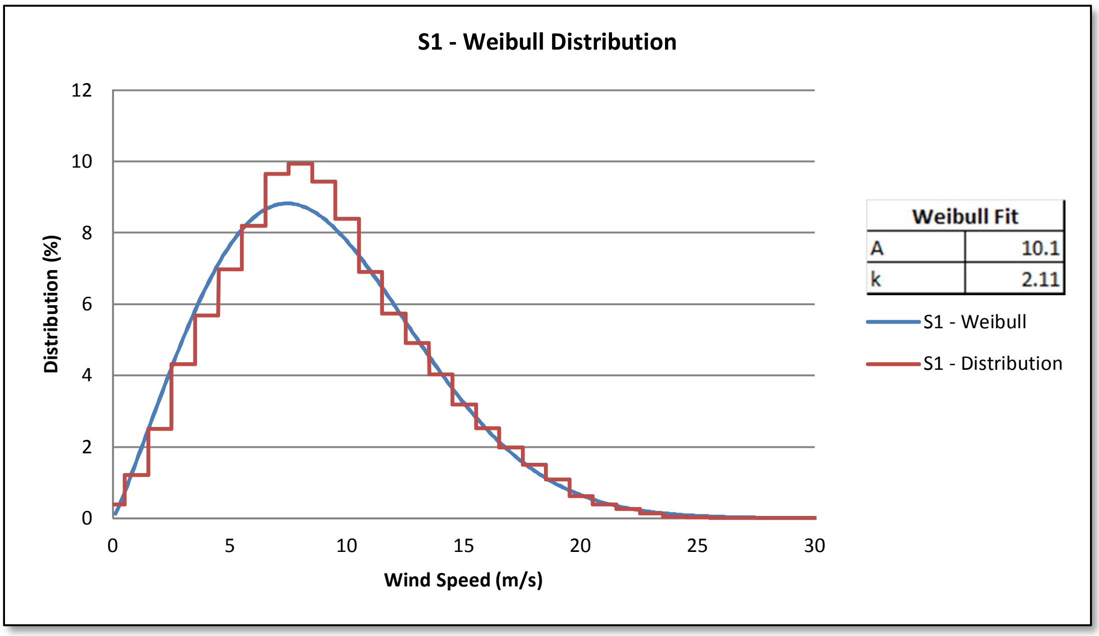

Figure 2-5: Wind speed distribution and Weibull distribution for 9530

The wind shear profile is an assessment of the variation of wind speed with height. The wind speed data from selected anemometer levels is used to fit an exponential function to the data and calculate wind speeds at different heights to those measured by the mast. The wind shear profile for 9530 is shown in Figure 2-6 and the multi-dimensional extrapolation of wind speed to turbine hub heights is described in further detail in Section 3.3.

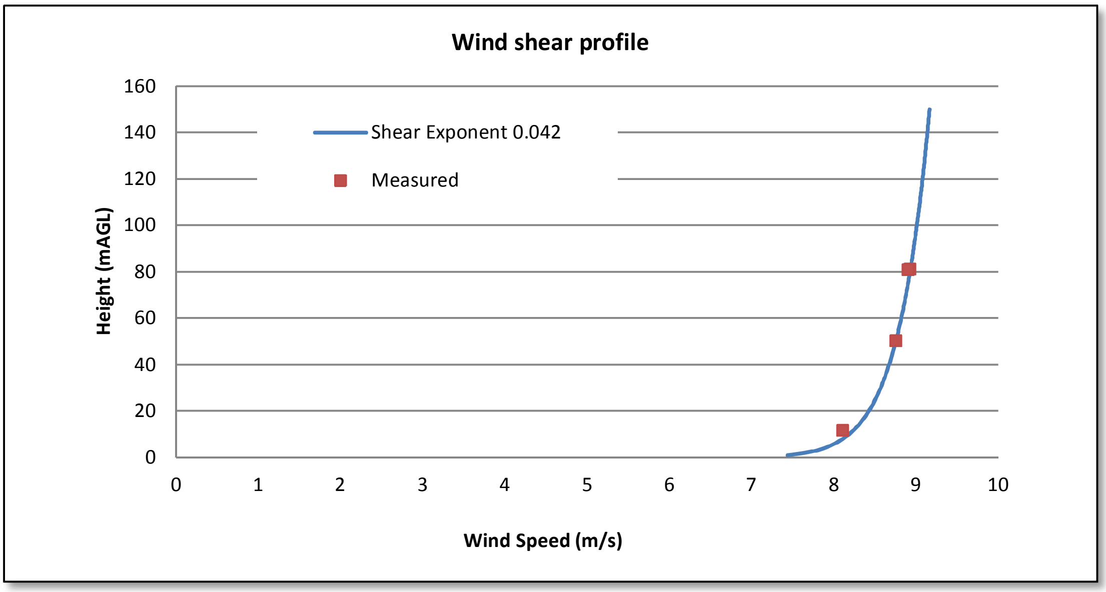

Figure 2-6: Wind shear profile for 9530

The diurnal pattern of the wind speeds and directions are shown in Figure 2-7 and Figure 2-8. These patterns show that the higher two levels at the 9530 site generally experiences below average wind shear during the daytime period and above average wind shear during the night. This trend is typically attributed to thermal heating of the surface during the day; increasing mixing in the lower boundary layer and reducing wind shear. During the night, these thermal effects are less present and therefore the wind shear increases.

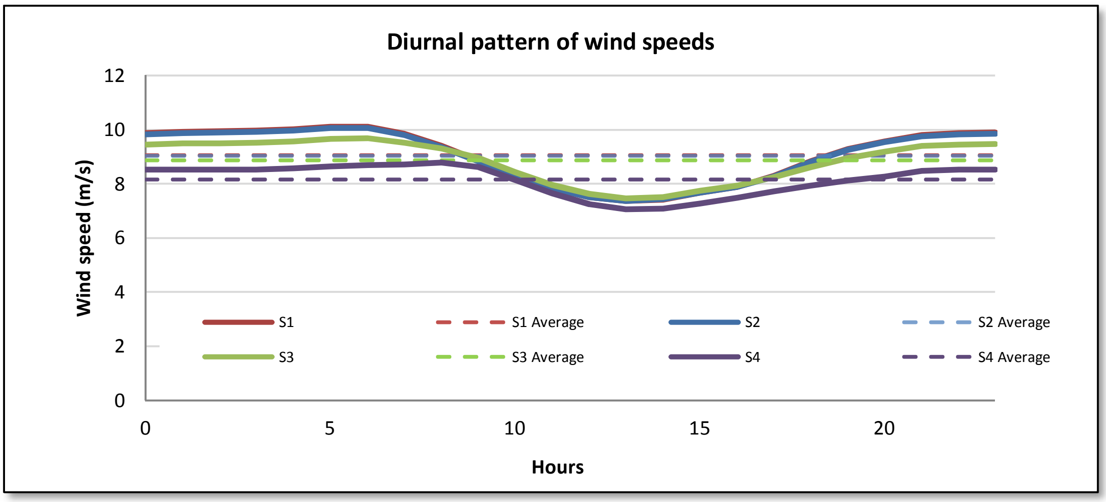

Figure 2-7: Diurnal pattern of wind speeds for 9530

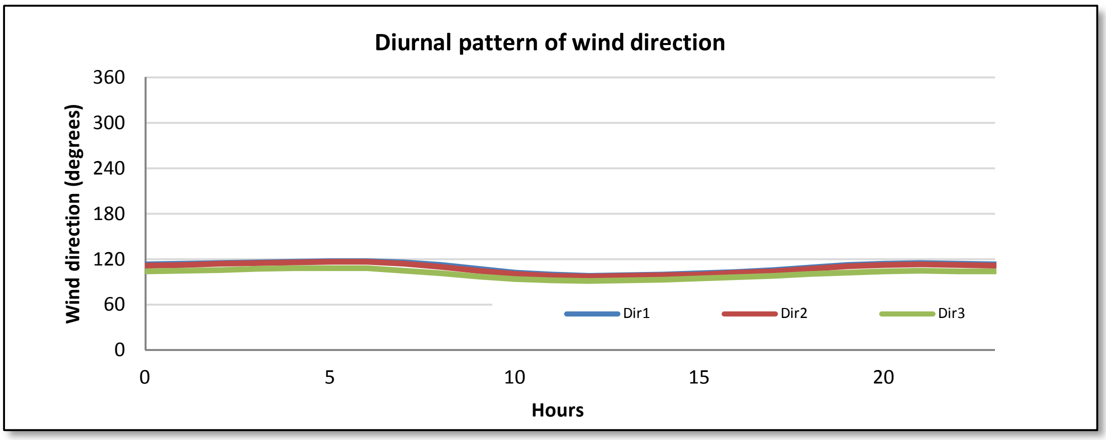

Figure 2-8: Diurnal pattern of wind direction for 9530

The seasonal variation in wind speed for 9530 can be seen in Figure 2-9. It can be seen that the months of April, July and October record notably high wind speeds whereas the months of December to March record significantly low wind speeds. When compared to the long term reference site as shown in Figure 3-7 in Section 3.1, it can be observed that the seasonal wind speed recorded at the 9530 site generally follows the trend of that recorded at the 9420 site shown in Section 3.1.

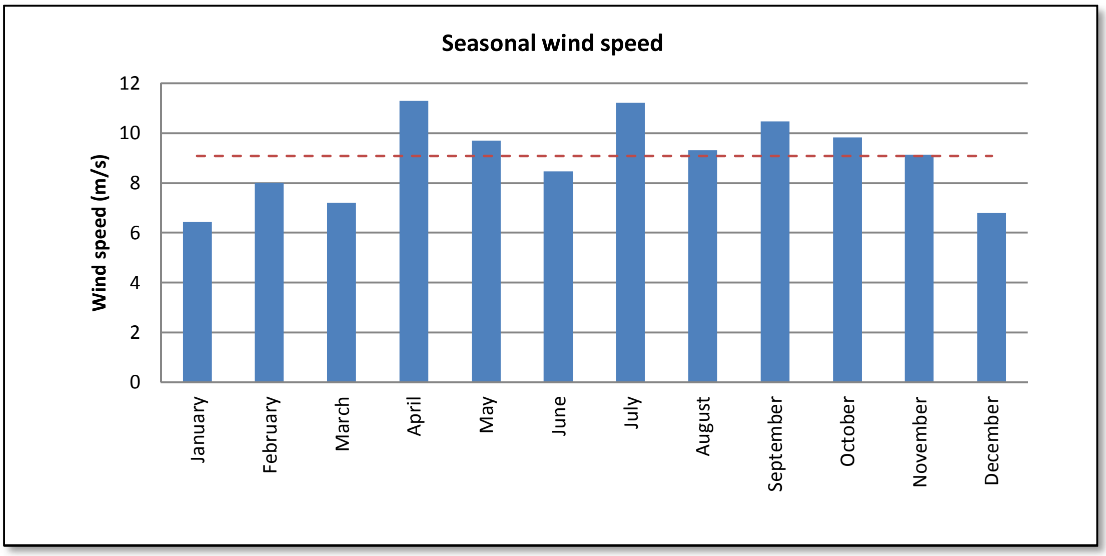

Figure 2-9: Seasonal variation of wind speed for 9530 (S1 anemometer)

The annual mean wind speeds seen in Figure 2-10 indicate that below average wind speeds were measured at the site in 2011. It should be noted that years 2010 and 2012 did not include 12 months of data and therefore the data presented below may not be representative of the actual mean wind speed for the entire year.

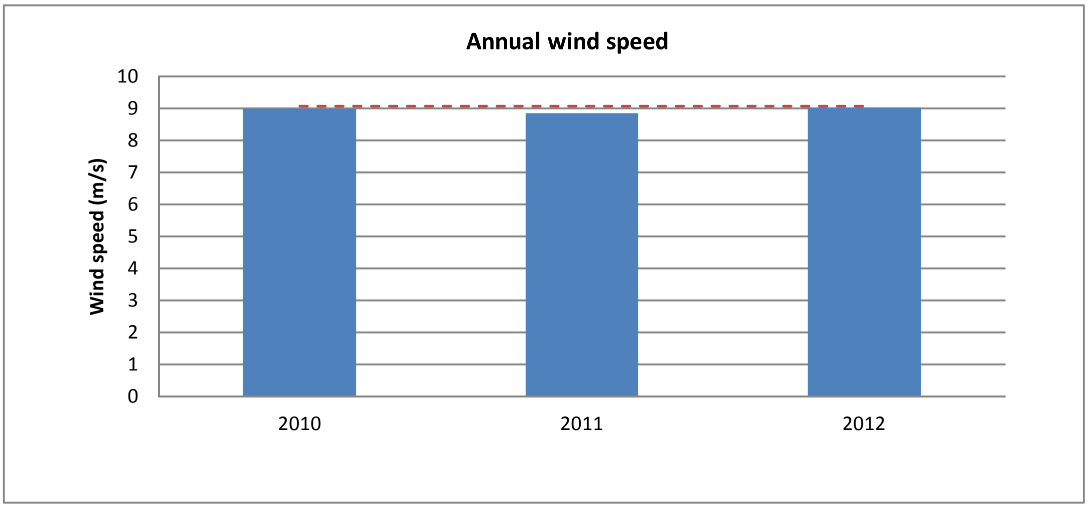

Figure 2-10: Annual mean wind speed for 9530 (S1 anemometer)

2.2 9531

2.2.1 9531 monitoring tower

The 9531 mast is a tubular steel tower commissioned in May 2010 and has been logging data from the 24th May 2010. Parsons Brinckerhoff was present during the installation and commissioning of this tower and the configuration and types of the anemometers have been verified to conform to the relevant IEA anemometry standards. Offsets have been applied to the wind vane data so that recordings correspond to true north values. The logging equipment used for this tower is an NRG Symphonie data recorder and a list of all instruments installed at this site is detailed in Table 2-5. The calibration values listed for each instrument have been verified by Parsons Brinckerhoff for consistency with the installation report and in the monitored data.

Table 2-5: 9531 instrument details

Instrument	Serial Number	ID	Height [mAGL]	Scale	Offset
Anemometer NRG Max40C	179500121853	Spd1	49.6	0.759	0.39
Anemometer NRG Max40C	179500096012	Spd2	49.6	0.755	0.37
Anemometer NRG Max 40C	179500095706	Spd3	29.9	0.755	0.39
Anemometer NRG Max40C	179500096001	Spd4	9.9	0.754	0.38
Wind Vane NRG 200P	NA	Dir1	46.4	0.351	227°
Wind Vane NRG 200P	NA	Dir2	30.0	0.351	47°
Wind Vane NRG 200P	NA	Dir3	9.7	0.351	47°
Temperature NRG 100S	NA	Temp	2.2	0.136	-86.38
Pressure NRG BP20	18059973	Press	2.0	0.4255	650

The site is surrounded by alpine scrub with vegetation including long grass and forest with up to 10 m tree heights. The site is generally flat with slopes extending downward approximately 100 m from the tower and further.

Figure 2-11: Typical vegetation surrounding 9531

2.2.2 9531 data analysis

The data received from the 9531 site has been assessed and contains no missing or invalid data. A summary of results from the data is shown in Table 2-6.

Table 2-6: Data summary for 9531

9531					
Recording period	**Date**	**Time**	**Data recovery**		
			Averaging period		10 min
Start	24/5/2010	0:00			
Finish	25/8/2012	18:50	Data recovery for concurrent S1 and Dir1		100.0%
Wind Statistics	**S1**	**S2**	**S3**		**S4**
Height above ground level (m)	49.6	49.6	29.9		9.9
Recovery rate (%)	100.0	100.0	100.0		100.0
Average wind speed (m/s)	**7.1**	**7.0**	**6.4**		**4.9**
Gust wind speed (m/s)	26.7	26.0	22.0		15.6
Mean TI at 15 m/s (%)	13.5	13.7	15.7		18.7
IEC3 TI at 15 m/s (%)	17.0	17.2	19.0		20.6
Wind vanes	**Dir1**		**Dir2**		**Dir3**
Data recovery rates (%)	100.0		100.0		100.0
Environmental sensors	**Temperature**			**Pressure**	
Data recovery rates (%)	100.0			100.0	
Height above ground level (m)	2.2			2.0	
Average (°C; hPa)	21.5			904.9	

Figure 2-12 shows the combined availability of concurrent wind speed and direction data.

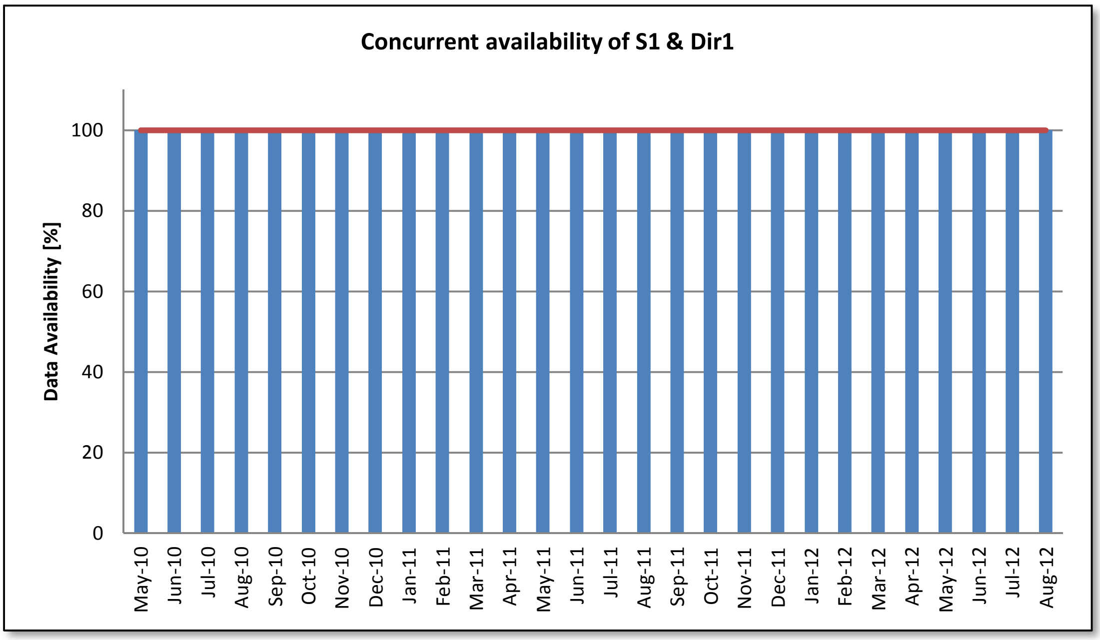

Figure 2-12: Combined availability of S1 and Dir1 instruments for 9531

The wind direction distribution shows a slightly different trend to the 80 m site 9530. The 9531 site has predominant easterly wind whereas site 9530 experienced most of the measured wind from the east-southeast direction. These differences may be a result of the differences in local topography affecting the wind direction. The highest proportion of energy from this site is resulting from a direct east bearing, as can be seen in Figure 2-13.

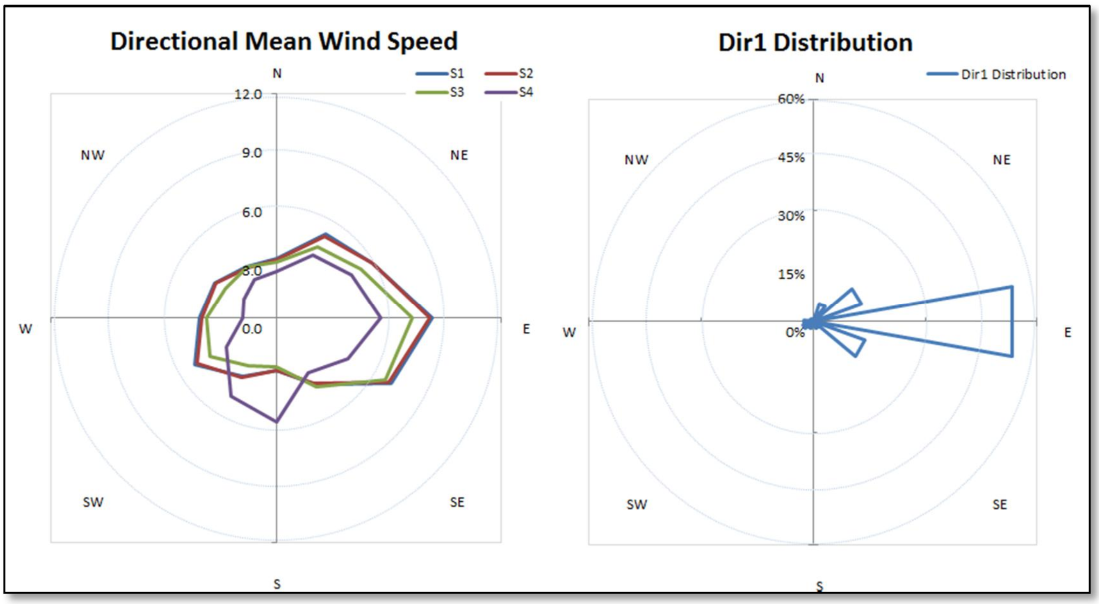

Figure 2-13: The directional wind speed and frequency distributions for 9531

The wind speed distribution for the S1 anemometer has been analysed and a Weibull distribution has been fitted. These distributions are shown in Figure 2-14.

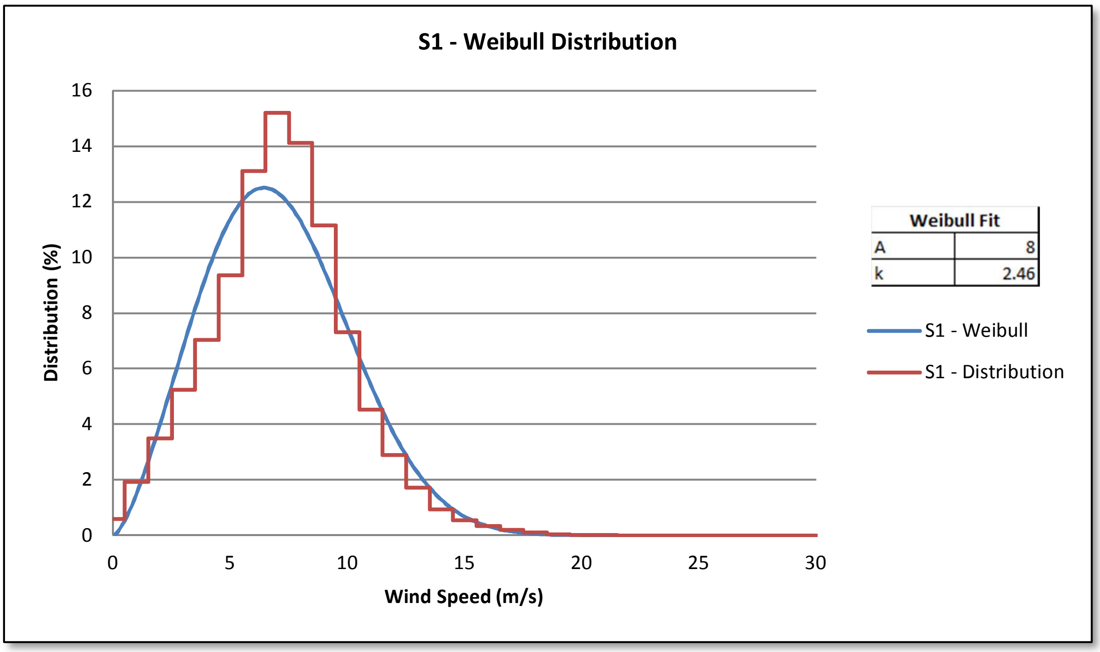

Figure 2-14: Wind speed distribution and Weibull distribution for 9531

The wind shear at the site 9531 has an exponent of 0.22, which is comparatively greater than the wind shear at the 80 m site 9530. A comparison of the two sites can be seen in Figure 2-15. This result highlights the variability and complexity of the terrain and roughness at MEWF. The average wind shear profile for 9531 is shown in Figure 2-15 and is calculated using S2 and S3 data. The multi-dimensional extrapolation of wind speed to turbine hub heights is described in further detail in Section 3.3.

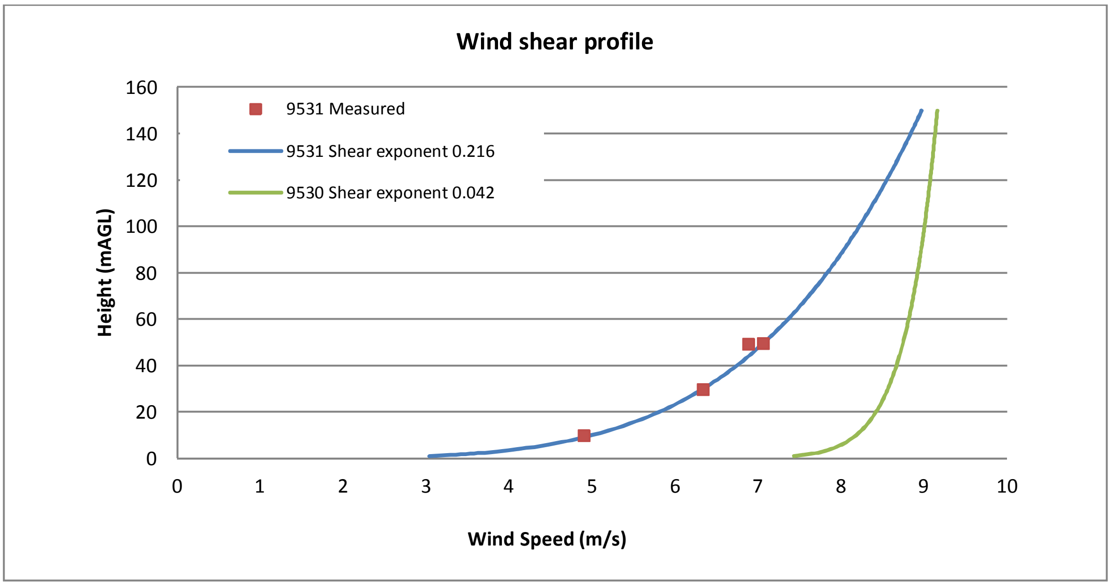

Figure 2-15: Wind shear profile for 9531

The site displays a diurnal variation in wind speed similar to the 9530 monitoring site for the top two anemometers. Wind speeds are at the highest during night time hours followed by a steady decline until 2 pm, where the speeds begin to increase. This trend is not as pronounced on the lower level anemometer which is typically attributed to thermal heating of the surface during the day; increasing mixing in the lower boundary layer and reducing wind shear. During the night, these thermal effects are less present and therefore the wind shear increases.

The diurnal pattern can be seen in Figure 2-16 and Figure 2-17.

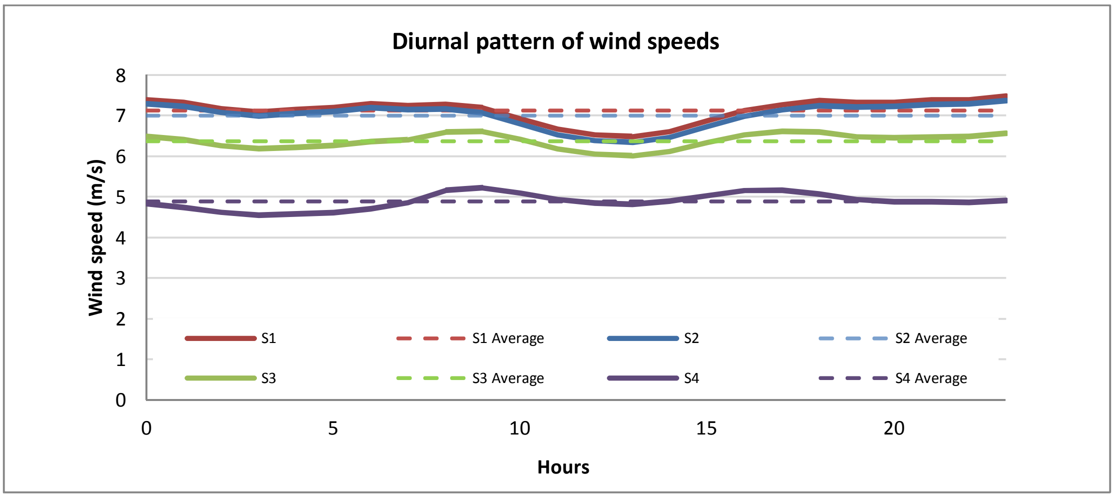

Figure 2-16: Diurnal pattern of wind speeds for 9531

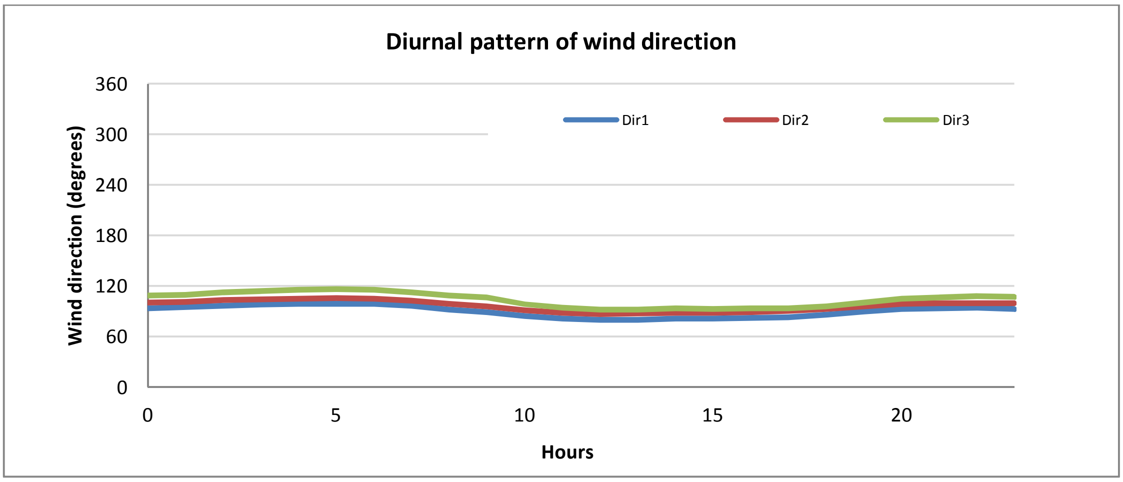

Figure 2-17: Diurnal pattern of wind direction for 9531

The average monthly wind speed at 9531 is shown in Figure 2-18. While there isn't a particularly strong trend, it can be seen that the months of July to October record notably high wind speeds while the months of January, March, May and December record below average wind speeds. When compared to the long term reference site as shown in Figure 3-7, it can be observed that the seasonal wind speed recorded at the 9531 site generally follows the trend of that recorded at the 9420 site.

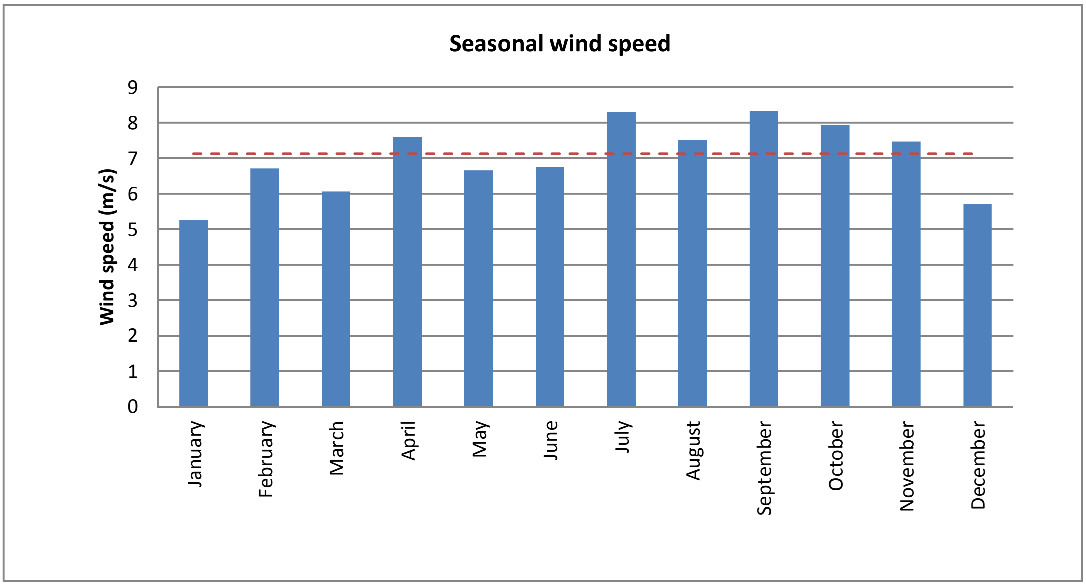

Figure 2-18: Seasonal variation of wind speed for 9531 (S1 anemometer)

The annual mean wind speeds seen in Figure 2-19 indicate that below average wind speeds were measured at the site in 2011, as is the case with 9530. It should be noted that years 2010 and 2012 did not include 12 months of data and therefore the data presented below may not be representative of the actual mean wind speed for the entire year.

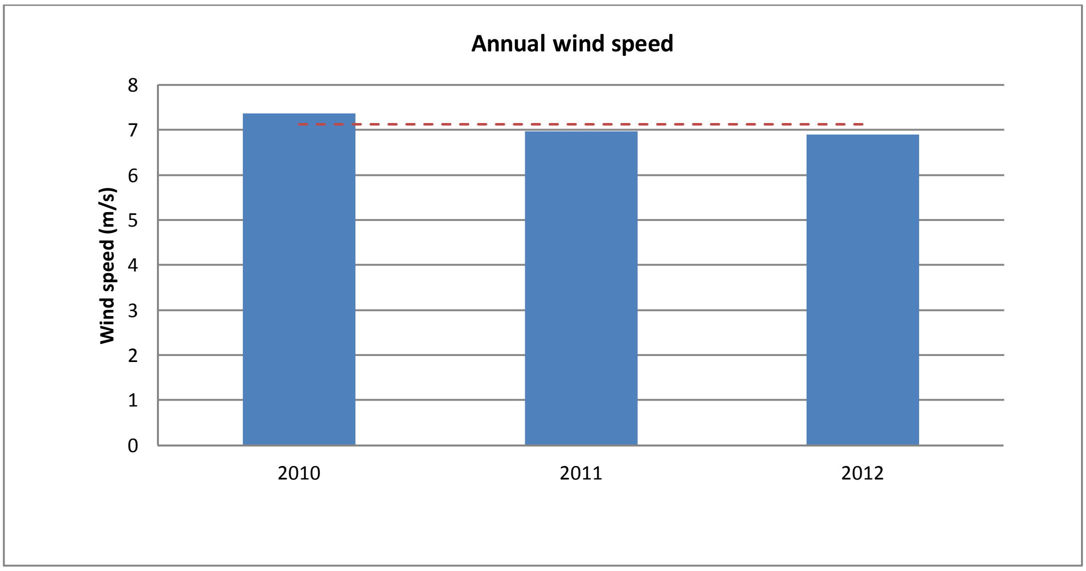

Figure 2-19: Annual mean wind speed for 9531 (S1 anemometer)

3. Longer-term reference data

Wind climates may vary on a number of different time scales, including time scales longer than that for which data has been collected at the MEWF site. Therefore, calculations are performed to predict the on-site data using correlated relationships between the MEWF monitored data and a long term reference site.

Five long term reference sites were evaluated for long term wind speed analysis for the proposed MEWF. These five sites are the 9420 High Road wind monitoring tower, Mareeba Airport Bureau of Meteorology (BoM) Automatic Weather Station (AWS), Cairns Airport BoM AWS and two nodes from the Modern Era Retrospective Analysis for Research and Applications (MERRA) database. The MERRA data source employs atmospheric reanalysis modelling techniques from satellite and ground based observations to produce grid based climate data for the globe. MERRA data is available in 0.5 degree increments in Latitude and 0.66 degree increments of Longitude, and in time increments of 1 hour.

The locations of these five long term reference sources are detailed in Table 3-1 and Figure 3-1.

Table 3-1: Locations of potential longer term reference sites

Longer term reference site locations (UTM WGS84, Zone 54)				
ID	Site Description	Distance from MEWF	Easting	Northing
		km	m	m
9420	High Road Mast	36.3	338823	8066783
N1: 145.34E, 17.00S	MERRA	20.5	323284	8119696
N2: 145.34E, 17.50S	MERRA	36.5	319511	8064326
332745	Mareeba Airport	12.1	332745	8112337
366400	Cairns Airport	50.5	366400	8134003

Figure 3-1: Locations of potential longer term reference sites and MEWF masts (source of background image: © Google Earth 2009, © Cnes Spot Image 2012, © Whereis Sensis Pty Ltd 2012, Data SIO, NOAA, U.S. Navy, GEBCO)

To select the most suitable reference site, Parsons Brinckerhoff conducted a high level correlation study between the on-site monitoring masts and each of the reference sites using unfiltered data in January 2010. The results of this correlation study are summarised below.

Table 3-2: Correlation between on-site masts and long term reference sites

	9420 – High Road	Mareeba Airport	Cairns Airport
	Correlation %	Correlation %	Correlation %
9530 – 80 m	81.3	53.6	61.5
9531 – 50 m	74.9	49.8	53.6

Based on these results, Parsons Brinckerhoff elected to use the 9420 High Road mast as the longer-term reference site based on the strength of its correlation to the 9530 and 9531 monitoring masts. It should be noted that whilst approximately two years of data has become available since the correlation study was undertaken in 2010, Parsons Brinckerhoff does not expect the outcome to be significantly different as the strength of the correlation coefficients between the on-site masts and the 9420 High Road mast are significantly higher than to the Mareeba and Cairns airport BoM sites.

Since this correlation study was undertaken, additional reanalysis data sources have become available for potential use in the assessment. Parsons Brinckerhoff has conducted a high level correlation study with the two closest MERRA nodes using daily filtered data and 9420 High Road. The results of the high level correlation study are summarised below.

Table 3-3: Correlation of on-site masts with MERRA nodes and 9420 High Road

	145.34E, 17.00S	145.34E, 17.50S	9420 High Road
	Correlation %	Correlation %	Correlation %
9530 – 80 m	76.5	68.5	80.1
9531 – 50 m	69.0	65.8	80.3

The results presented above confirm that the appropriateness of 9420 High Road mast as the longer-term reference site; the results of the multi-dimensional correlation study between this mast and the on-site masts using daily filtered data are shown in Table 3-5 in Section 3.2.

3.1 9420 longer-term reference data

The High Road monitoring tower is a 20 m monitoring tower owned and operated by RATCH. The tower is situated on a hilly landscape in cleared pastures at an elevation of 1177 m above sea level. The tower was originally commissioned in December 1998; however it collapsed on the 15th of October 2008. It was re-erected and re-commissioned on the 30th April 2009 with Parsons Brinckerhoff present to verify the installation of new instruments and logging equipment. Parsons Brinckerhoff has collated and evaluated all data recorded from the site since January 1999 and a low recovery rate of data is evident across several years, with the overall recovery rate equal to 59.4%.

Further analysis of the data recovery was performed by Parsons Brinckerhoff to assess the seasonal impact of the lost data. It was found that the months of March, July and November where affected disproportionally when compared to the remaining months. To resolve this issue and achieve an accurate long term seasonal evaluation of the data for High Road, the years of 2004, 2005, 2006 and 2009 (years with less than 75% recovery rate) have been removed from the data. The dataset was also confined to integer number of years to remove any seasonal bias that may otherwise be introduced into the dataset. A summary of the data after processing can be seen in Table 3-4 and the recovery data recovery rate per month can be seen in Figure 3-2.

Table 3-4: 9420 data summary

Wind data characteristics	
Start Date	23/8/1999
End Date	23/8/2012
Recording Interval	10 min
Overall Average (m/s)	7.2
Data Recovery	90.4%

Several periods of non-availability occur between the years of 2000 and 2004 which are each small in duration. Parsons Brinckerhoff considers these periods of non-availability to have an acceptably low effect on the seasonality of the wind data. The final monthly availability of data after processing by Parsons Brinckerhoff can be seen Figure 3-2.

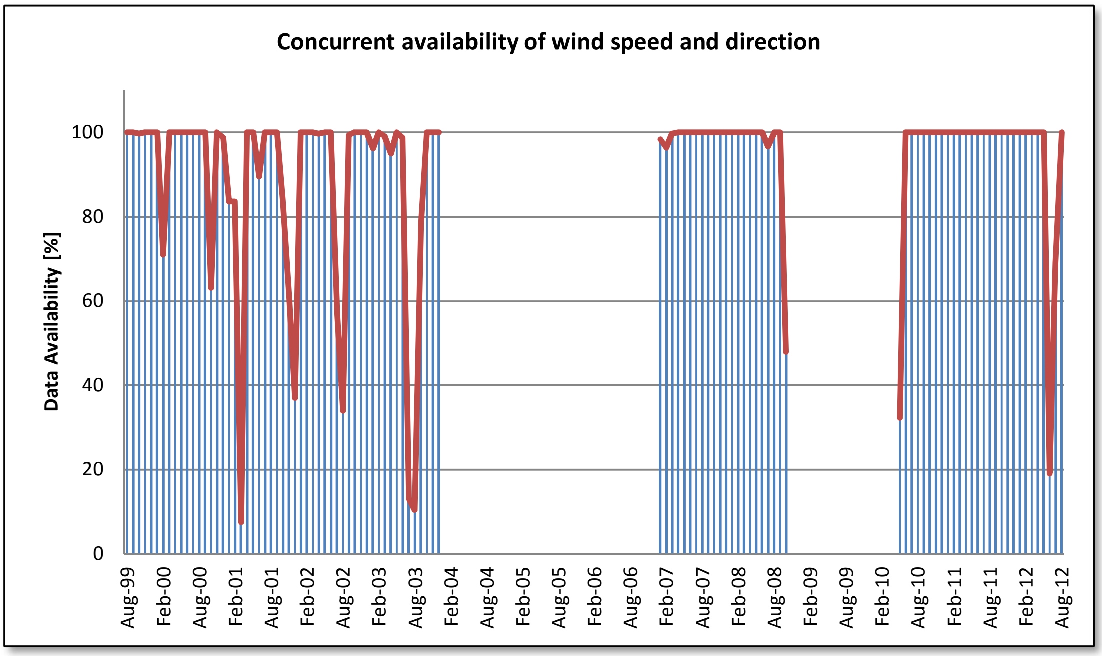

Figure 3-2: Concurrent availability of wind speed and direction data at 9420

The predominant wind direction for 9420 is east, accounting for approximately 50% of the wind experienced at the site. The directional mean wind speed and wind direction distribution can be seen in Figure 3-3.

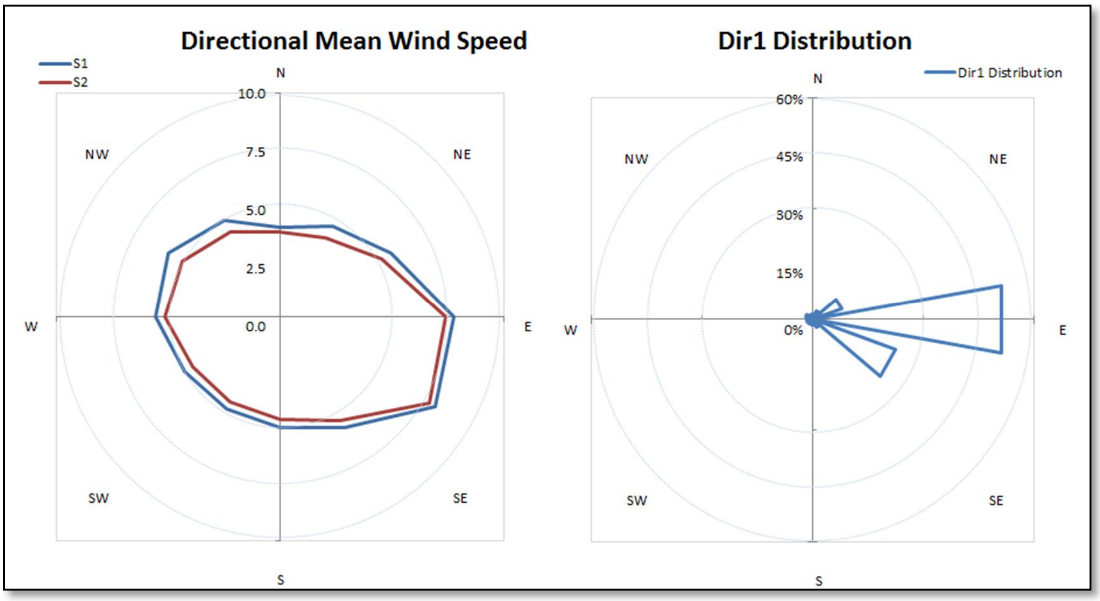

Figure 3-3: Directional wind speed and frequency distributions for 9420

The wind speed distribution for 9420 has been analysed and a Weibull distribution has been fitted. These distributions are shown in Figure 3-4.

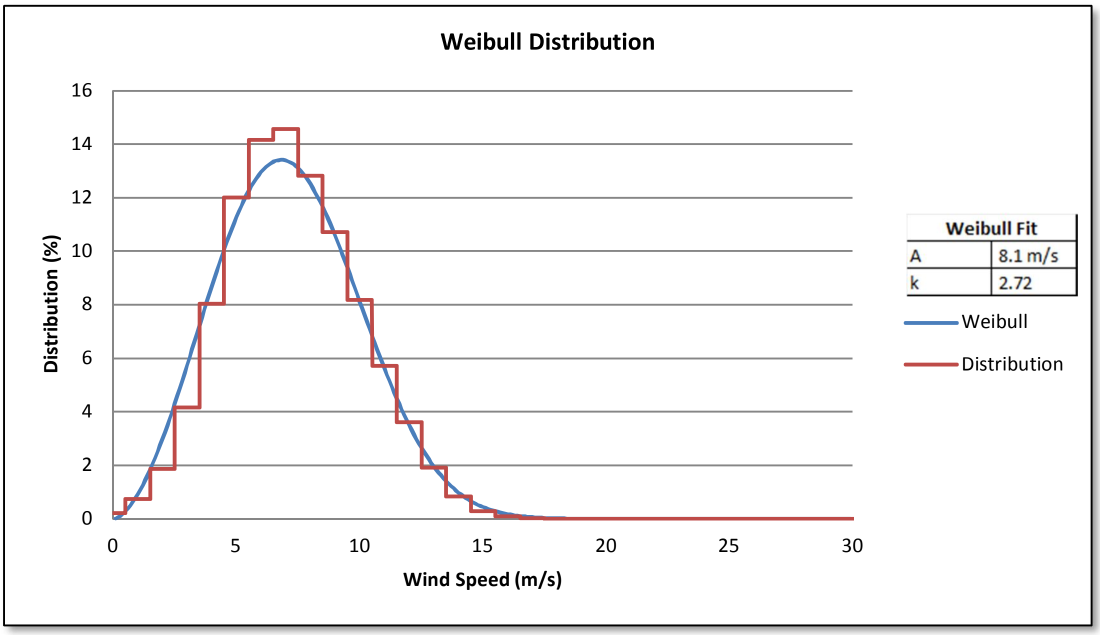

Figure 3-4: Wind speed distribution and Weibull distribution for 9420

The diurnal pattern for wind speed and wind direction at 9420 is shown in Figure 3-5 and Figure 3-6. The diurnal pattern of wind speed shows a similar pattern to the MEWF monitoring towers. The High Road site experiences higher than average wind speeds between the night time hours of 10 pm to 11 am and experiences lower than average during the day time hours of 1 pm to 6 pm.

Parsons Brinckerhoff has used daily filtering at both the reference and the installed masts to remove the daily variations in wind speed before conducting a correlation. This method allows reliable relationships to be constructed between this reference site and the masts installed at MEWF.

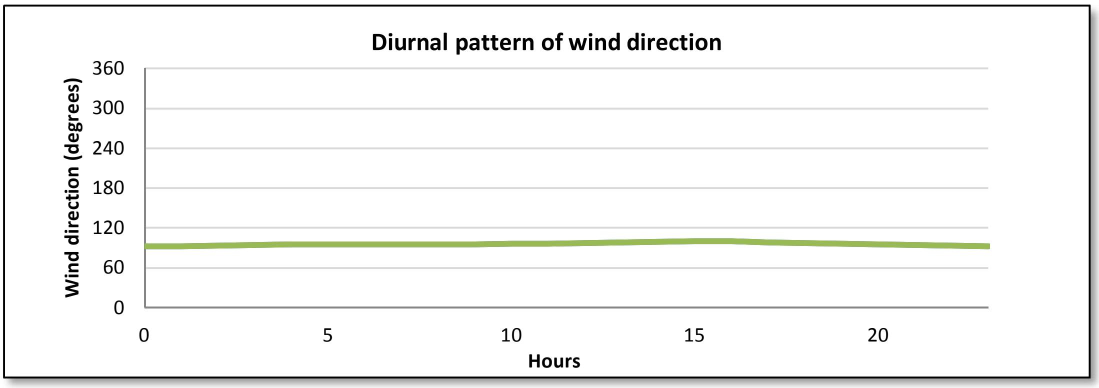

Figure 3-5: Diurnal pattern of wind speed for 9420

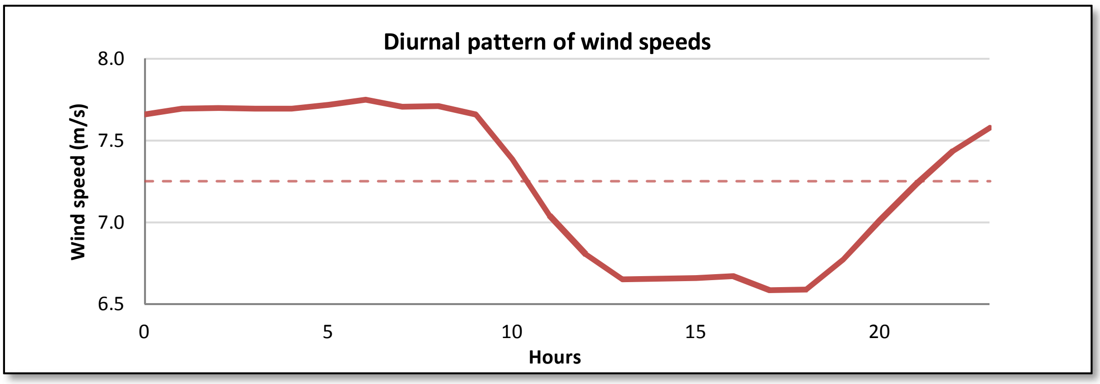

Figure 3-6: Diurnal pattern of wind direction for 9420

The seasonal pattern of wind speed for 9420 has been analysed. The seasonal pattern of wind speed shows above-average wind speeds between the months of March and April, and from September to November. The seasonal pattern of wind speed can be seen in Figure 3-7.

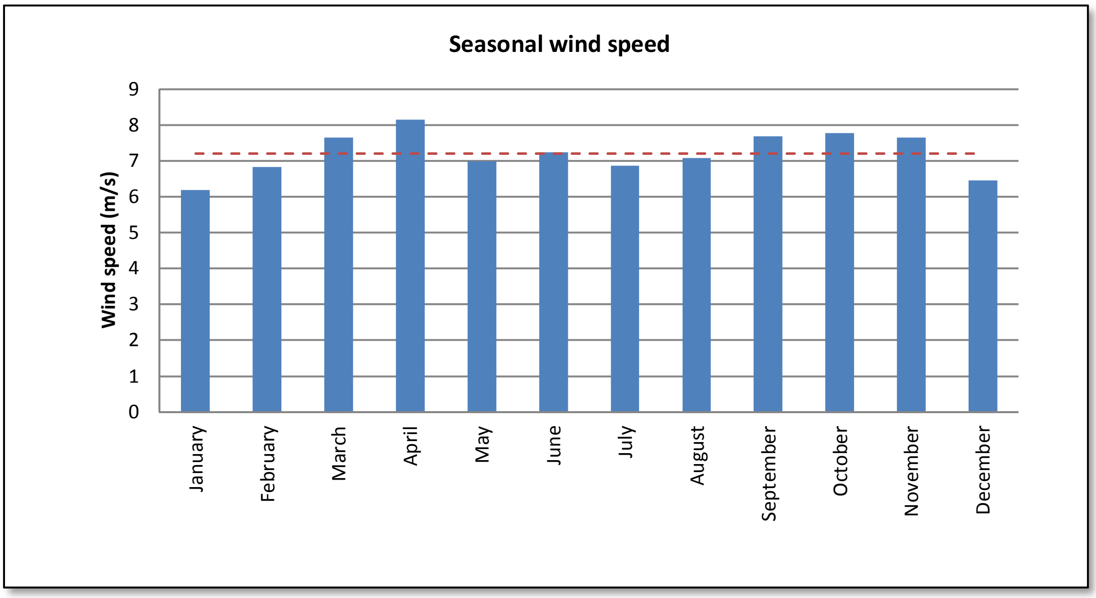

Figure 3-7: Seasonal wind speed pattern for 9420

The annual wind speed variation for 9420 is shown in Figure 3-8. It shows that several years including 2002, and the MEWF monitoring duration of 2011 and 2012 experience below-average wind speeds. This result suggests that these masts recorded below average wind speeds when compared to the longer-term average and has been adjusted by Parsons Brinckerhoff as discussed in Section 3.2.

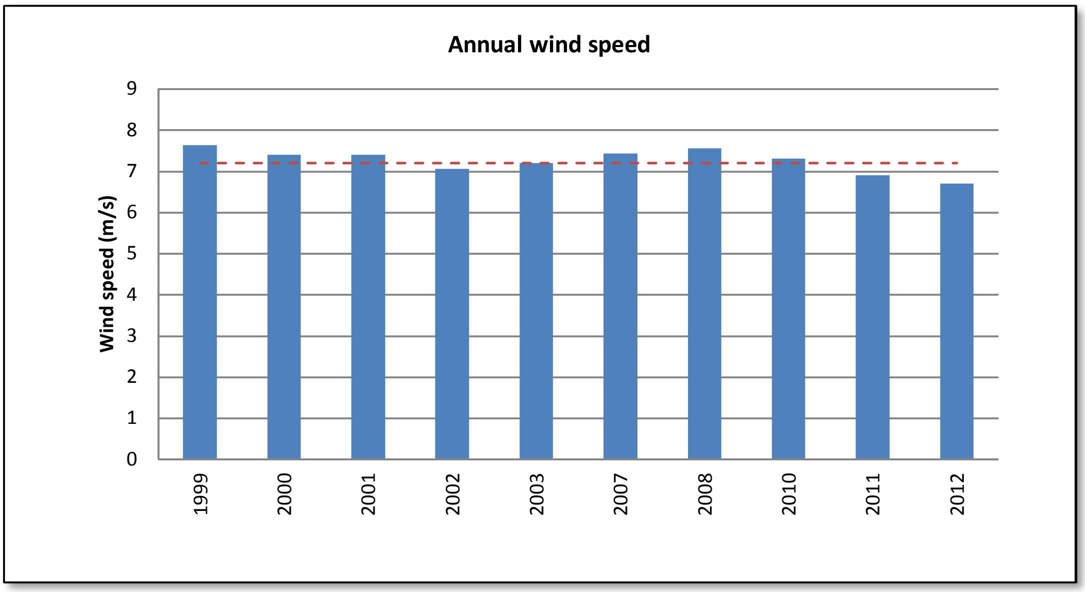

Figure 3-8: Annual variation of wind speed for 9420

3.2 Correlation and wind speed adjustment using longer-term reference data

9420 was correlated to the two monitoring towers at MEWF. The correlation assessment was performed using daily filtering due to the difference in the diurnal pattern between the reference site and the MEWF monitored sites. The daily filtering method removes the fluctuations in wind speed and direction on a daily basis by averaging each recorded sample with the previous 24 hours of data. Parsons Brinckerhoff has used a multi-dimensional linear regression model to assess the long-term reference data against a synthetic reconstruction of the monitored data for the full length of time measured at the reference site. The correlation results for each monitoring tower are shown in Table 3-5.

Table 3-5: Correlation results between 9420 and MEWF monitoring locations

Correlation between MEWF and reference site	
Monitoring tower	Correlation to 9420
	%
9530	90.8
9531	89.7

Parsons Brinckerhoff has applied a scaling factor to all wind speed measurements recorded at MEWF. The scaling factor is derived from a ratio of the synthesised long term site data and the short term monitored data; representing the difference in wind speed between the long-term reference period and the short term period of monitored data. The scaling adjustments made to the data are applied to the data when using whole annual years to account for seasonal effects. The results of the scaled long term wind speeds are shown in Table 3-6.

Table 3-6: Adjusted wind speeds from longer-term reference data

	Monitored site annual average	Longer-term adjusted average
	m/s	m/s
9530	9.1	9.3
9531	7.1	7.4

3.3 Shear extrapolation to turbine hub height

Wind shear is the term used to describe the change in wind speed with height above ground level. Wind shear is accurately modelled at most sites using the power law wind shear model.

The magnitude of wind shear (rate of change of wind speed against height) is known to vary with three main variables:

- Wind direction – the unique topography in each direction has its own influence on wind shear
- Time of day – thermal effects during the day result in a lower wind shear than that experienced at night, and
- Wind speed – turbulence levels and the impact of topographical features depend on wind speed.

Parsons Brinckerhoff has considered these variables by using multi-dimensional time, speed and direction bins to resolve the shear extrapolation for the three monitoring sites.

RATCH has nominated to assess a single hub height. Parsons Brinckerhoff has extrapolated the scaled data from each monitoring site to the to a hub height of 80 m as nominated by RATCH. A summary of the extrapolation is shown in Table 3-7.

Table 3-7: Shear extrapolation of longer-term adjusted wind speeds

Mast ID	Instruments used for shear	Measurement heights	Longer-term adjusted wind speed at measurement height	Extrapolated wind speed at hub height (80 m)	Multi-dimensional wind shear exponent
		mAGL	m/s	m/s	
9530	S1 & S3	81.0 & 50.2	9.3	9.3	0.05
9531	S1 & S3	49.6 & 29.9	7.4	8.2	0.22

4. Energy yield assessment

4.1 Climate and topographical inputs for wind flow modelling

Parsons Brinckerhoff has undertaken, as part of this assessment, a wind flow modelling analysis for the proposed MEWF. The following climate and topographical input data were used in the modelling:

Wind data: Longer-term adjusted hub height annual wind speed and direction datasets from the two monitoring towers located at MEWF.

Air density: Parsons Brinckerhoff has used data recorded by the pressure and temperature sensors at the 9530 mast to calculate the air density at the specific altitude of each turbine. The average air density for the MEWF ranges between 1.063 – 1.089 kg/m^3 at the WTG locations. The WindPro software adjusts the turbine power curve to the relative air density for the local elevation of each turbine location.

Terrain data: Digital topographic contours were supplied by RATCH at an elevation resolution of 10 m and containing an area of 26.8 km east to west and 13.7 km north to south. Parsons Brinckerhoff has supplemented this map using 10 m resolution contour data obtained from the Shuttle Radar Topography Mission (SRTM) database supplied by National Aeronautics and Space Administration (NASA). The final contour map used in the assessment contains an area of 60 km east to west and 60 km north to south. The closest turbine to the boundary of the map is 25.3 km south of the western border of the contour map. This distance is considered acceptable by Parsons Brinckerhoff for wind flow modelling purposes as the industry standard minimum distance is 7 km.

Site roughness map: Parsons Brinckerhoff has created a roughness map based on knowledge of the site, mast installation reports and satellite imagery. The roughness map has classified three different regions of roughness within the boundaries of map, detailed in Table 4-1, and contains an area of 71 km east to west and 47 km north to south. The closest turbine to the boundary of the map is 29.5 km west of the western border of the contour map. This distance is considered acceptable by Parsons Brinckerhoff for wind flow modelling purposes as the industry standard minimum distance is 20 km.

Table 4-1: Roughness classification used in roughness map

Classification	Roughness Class	Description
Water	0.2	Areas of water bodies
Background	2.5	Areas of medium density vegetation
Forest	2.8	Areas of dense forest

4.2 Wind farm layout

The location of each turbine was supplied by RATCH and a map of WTG locations and numbers is detailed in Appendix A. This report only assesses in detail the energy yielded from this layout and a high level assessment of reduced WTG layout options is discussed further in Section 6. This report does not assess alternative re-location strategies, or the appropriateness of the layout provided.

The predicted energy values for each WTG model is based on the wind farm layouts provided by RATCH. It is noted the wake losses for all layouts are notably higher than typical wind farm layouts seen in other projects. An inter-WTG spacing of 5 rotor diameters in the predominant wind direction and 2.5 rotor diameters perpendicular to the predominant wind direction appears to have been applied. It is assumed that RATCH has considered a sensitivity analysis to evaluate the net annual energy yield against the installed Capex and annual Opex for each layout – as well as the impact of higher turbulence on the fatigue life of the WTGs.

4.3 Energy prediction

Parsons Brinckerhoff utilised the industry standard WindPro model (using WAsP) to predict the energy at turbines across the MEWF. In the model, Parsons Brinckerhoff predicted each turbine using its distance relationship to each respective monitoring tower i.e. turbines close to 9530 were largely predicted using the 9530 monitoring tower. The location of each turbine relative to the monitoring towers is detailed in Appendix A.

The modelling software used to for this assessment was WindPro (including WAsP).

4.3.1 Turbine power curve

RATCH has specified the use of, and has provided power and thrust curves for the following WTGs:

1. Siemens SWT3.0-101 3 MW
2. Acciona AW3000-100 3 MW
3. REpower 3.4-104 3.37 MW

Parsons Brinckerhoff has used these power curves with modification to account for turbine hysteresis effects.

Wind turbine manufacturers place varying qualifications on their guaranteed power curve (e.g. turbulence limits, wind shear limits, etc). Parsons Brinckerhoff has not assessed the power curve against site conditions, however we recommend that RATCH seek clarification on any limitations the given turbine manufacturer may wish to place on a guaranteed power curve at the MEWF site, and assess whether these limitations will have any significant impact on the ability of the turbine to produce power in accordance with the supplied power curve. Alternatively, the wind turbine manufacturer should confirm the conditions for which the power curve has been calculated and tested by the turbine manufacturer are appropriate for the MEWF site.

Parsons Brinckerhoff has not assessed the ability of the wind turbine to operate at the power curve provided by RATCH (e.g. through review of independent power curve test results) as it is not within the scope of this assessment.

Turbine hysteresis is the effect of differing energy production between predicted values and real production for a given power curve and wind dataset due to turbine control logic at the cut-out wind speed. Different turbine models behave differently when the cut-out wind speed is reached, for example, by only cutting in when the wind speed is below a low wind speed for a certain period of time. This may not be represented using a standard power curve and 10 minute wind dataset.

The power and thrust curves supplied by RATCH and used in the energy yield assessment are detailed in Appendix B.

4.4 Energy losses

The losses included in the net annual energy output of the MEWF are derived from two sources, either calculated losses or estimation, based on general technical knowledge of typical wind farm losses. Table 4-2 details the included losses further.

Table 4-2: Wind farm losses

Item	Comment	Loss amount	Source
Wake losses	These are due to the impact of internal and neighbouring WTGs reducing the available kinetic energy in the wind. WindPro and WAsP are used to calculate the wake losses. No neighbouring wind WTGs have been included in the MEWF assessment	WTG dependent – refer to Table 4-3	Calculated by Parsons Brinckerhoff
WTG miscellaneous loss	These are estimated miscellaneous losses due typically to ramping up of availability, minor impact from blade contamination and environmental factors	1.0%	Estimated by Parsons Brinckerhoff
On-site electrical losses	These occur in the wind farm electrical infrastructure including WTG transformers, cable systems and the substation transformer. Transmission losses have not been assumed in this assessment.	3.0%	Estimated by Parsons Brinckerhoff
Long-term WTG availability loss	These loss assumptions are based on are based on an assumed warranted time availability of 97% for unscheduled maintenance	3.0%	Estimated by Parsons Brinckerhoff
Scheduled maintenance availability loss	These loss assumptions are based on an assumed scheduled maintenance allowance of 50 hours per annum. This assumption is based on Parsons Brinckerhoff estimate of a reasonable scheduled maintenance allocation for modern WTGs of this size	0.6%	Estimated by Parsons Brinckerhoff
Balance of Plant availability loss	These loss assumptions are based on an assumed Balance of Plant unavailability of 17.5 hours per annum; including substation. This assumption is based on Parsons Brinckerhoff estimate of Balance of Plant maintenance for a wind farm of this size.	0.2%	Estimated by Parsons Brinckerhoff

Hysteresis losses for the wind farm have been accounted for by modification of the power curve at and near the cut-out wind speed. Parsons Brinckerhoff considers this method more accurate than applying a single loss factor for hysteresis effects, due to the inclusion of wind speed distribution in the hysteresis loss.

4.5 Energy results

Table 4-3 summarises the performance of each of the WTG models. A breakdown of energy results by individual WTG in each layout scenario is presented in Appendix C.

Table 4-3: Energy production

MEWF Energy production			
WTG	**Siemens SWT3.0-101**	**REpower 3.4M-104**	**Acciona AW3000-100**
Capacity (kW)	3000	3370	3000
Nominal hub height	80 m		
Wind farm losses (%)			
Wake (calculated)	15.3	15.1	14.5
Electrical losses (estimated)	3.0	3.0	3.0
Others	1.0	1.0	1.0
Non-availability of WTGs (unscheduled)	3.0	3.0	3.0
Non-availability of Scheduled maintenance	0.6	0.6	0.6
Balance of Plant availability	0.2	0.2	0.2
Overall Losses	21.7	21.5	21.0
Energy Output			
Gross Annual Energy Output (GWh)	674.1	693.8	606.9
Gross Annual Energy Output minus wake loss (GWh)	570.9	589.1	518.6
Net Annual Energy Output (GWh)	527.7	544.5	479.4
Net Capacity Factor	28.7%	26.4%	26.1%

5. Energy uncertainty

5.1 Estimated energy uncertainty

There is uncertainty in the predicted performance of a wind farm due to two main factors: uncertainty in the measurements and predictions, and the natural variability of some of the parameters. The main sources of uncertainty and variability are given in Table 5-1.

Table 5-1: Sources of uncertainty and variability in predicted wind farm performance

Uncertainty	Variability
Primary site wind speed measurement (anemometer calibration, sheltering, etc)	Wind resource (e.g. annual average/distribution)
Extrapolation to hub height (wind shear profile)	WTG availability
Cross-correlation process	Power production (degradation, etc)
Long-term average (calculated from historical data)	
Wind flow analysis – wind speeds over the site (terrain, roughness, model)	
Power production (power curve, hysteresis, air density, degradation, etc)	

Parameters such as anemometer calibration are uncertain but have no variability. Most of these parameters could, in principle, be determined exactly with additional measurements and/or once actual performance is known. Parameters such as annual averages have natural variations, even if all the inputs (e.g. long-term average) are known. Parameters with variability are usually also influenced by uncertainty.

The effect that the uncertainties and variability have on wind speeds and energy production are analysed using the Monte Carlo method. In this method, rather than explicitly deriving the results, a model is run many times with the inputs allowed to vary randomly. For each simulation, a random number is picked for each of the inputs, selected from defined probability distributions. Each simulation produces a different result, and these results are analysed to determine their variability. This method allows for any form of input probability distribution, and any relationship between inputs and the output. It is necessary to run a sufficient number of simulations to obtain convergence in the results. The uncertainty parameters used in this uncertainty analysis are detailed in the following Table 5-2.

Table 5-2: Uncertainty parameters used in the uncertainty analysis

Item	Comment	Uncertainty	Source
Wind speed annual variation	Annual variability of the wind speeds, based on the synthetic long term dataset.	0.3 m/s	Calculated by Parsons Brinckerhoff
Correlation Uncertainty	This is the uncertainty due to the cross-correlations carried out to predict the site wind speed datasets at the two masts and to predict the long term wind speed.	2.0%	Estimated by Parsons Brinckerhoff
Anemometer calibration uncertainty	This is the uncertainty in the anemometer wind speed measurements.	0.2 m/s	Manufacturer documentation / Parsons Brinckerhoff
Flow modelling uncertainty	This is the uncertainty in the wind flow modelling, which is estimated based upon the distance between the monitoring masts and the wind WTGs, the number of masts used to calculate the wind farm energy predictions, the size of the wind farm for which the wind flow has to be modelled and the complexity of the terrain.	2.0%	Estimated by Parsons Brinckerhoff
Shear uncertainty	This is the uncertainty related to the instrument heights, shear analysis and the wind speed extrapolation to hub height.	3.3%	Calculated by Parsons Brinckerhoff
Availability uncertainty	This is the uncertainty related to the wind WTG availability. Parsons Brinckerhoff has assumed fixed loss unavailability as applied to the net energy production and therefore, no uncertainty has been applied.	0%	Estimated by Parsons Brinckerhoff

The uncertainty and probability of exceedance in net energy yield for certainty levels of 50%, 75%, 80%, 90%, 95% and 99% are given below for one, ten and twenty year return periods for each of the two WTGs included in the energy assessment.

Table 5-3: Uncertainty and probability of exceedance for the Siemens SWT3.0-101 WTG

Siemens SWT3.0-101 80m hub height		Probability of Exceedance				
	Long-term Average (P50)	75%	80%	90%	95%	99%
Net Energy (GWh/y), 1 year period	527.7	501.5	494.9	477.8	463.7	437.2
Net Energy (GWh/y), 10 year period	527.7	505.9	500.5	486.3	474.6	452.5
Net Energy (GWh/y), 20 year period	527.7	506.2	500.8	486.8	475.2	453.5

Table 5-4: Uncertainty and probability of exceedance for the REpower 3.4-104 WTG

REpower 3.4-104 80m hub height		Probability of Exceedance				
	Long-term Average (P50)	75%	80%	90%	95%	99%
Net Energy (GWh/y), 1 year period	544.5	515.0	507.7	488.5	472.6	442.9
Net Energy (GWh/y), 10 year period	544.5	520.0	513.9	497.9	484.7	459.9
Net Energy (GWh/y), 20 year period	544.5	520.3	514.3	498.5	485.4	460.9

Table 5-5: Uncertainty and probability of exceedance for the Acciona AW3000-100 WTG

Acciona AW3000-100 80m hub height		Probability of Exceedance				
	Long-term Average (P50)	75%	80%	90%	95%	99%
Net Energy (GWh/y), 1 year period	479.4	453.3	446.8	429.8	415.8	389.4
Net Energy (GWh/y), 10 year period	479.4	457.7	452.4	438.2	426.6	404.7
Net Energy (GWh/y), 20 year period	479.4	458.0	452.7	438.8	427.2	405.6

5.2 Recommendations on reducing uncertainty

As discussed in Section 5.1, the uncertainty in the estimated energy production is caused by several factors. Parsons Brinckerhoff has identified three factors which are within the control of RATCH that would potentially lead to a reduction in uncertainty, as discussed below. It should be noted that all three factors can be addressed by installing a strategically located and specified, additional monitoring tower(s) at the MEWF site.

5.2.1 Additional monitoring tower

The flow modelling uncertainty is directly influenced by the number of masts across the site. Parsons Brinckerhoff notes that the average extrapolated long term wind speeds recorded at the masts are significantly different; installing an additional tower (and therefore decreasing the necessary horizontal extrapolation of wind speeds) will contribute towards reducing the uncertainty in the flow modelling, which is currently estimated to be 2%. Parsons Brinckerhoff will then be able to use the measured data as an input to create an updated resource grid, using as little as three months of measured data at the new site.

5.2.2 Hub height measurement

The shear uncertainty relates to the uncertainty in vertical extrapolation based on two measurement points to hub height. Only one of two of the monitoring towers currently installed on site measure wind speed at hub height; Parsons Brinckerhoff recommends that an additional monitoring tower which measures wind speed at - or as close to - the nominated hub height is installed to reduce the shear uncertainty.

5.2.3 Use of first class measuring instruments

The anemometers currently being used at the MEWF site are NRG #40C anemometers, which are Class 2 sensors. Parsons Brinckerhoff recommends that if an additional mast is installed, Class1 sensors such as the Thies First Class Advanced Wind Transmitter are used on site. This effectively reduces the anemometer uncertainty from 0.2 m/s to 0.14 m/s, which translates to approximately 1% in energy.

6. Layout scenario modelling

RATCH has requested for multiple layout scenarios to be simulated in order to understand the effect the total number of WTGs would have on the net AEP and capacity factor. The Siemens SWT3.0-101 3 MW WTG has been used as the sample WTG in this exercise as this WTG produced the highest capacity factor amongst the list of WTGs shortlisted by RATCH. Parsons Brinckerhoff has used the 70 WTG layout supplied by RATCH and has iteratively reduced the layout by removing the lowest performing WTGs (for energy production) in five-WTG increments, eventually arriving at a layout of 30 WTGs. Table 6-1 and Figure 6-1 summarises these incremental reductions and the results of this assessment.

Table 6-1: Net AEP and capacity factors of decreasing layout sizes (using Siemens SWT3.0-101 WTG)

Number of WTGs	Net AEP	Net capacity factor
	GWh	%
70	527.7	28.7
65	506.8	29.7
60	482.5	30.6
55	455.1	31.5
50	424.9	32.3
45	392.2	33.2
40	357.4	34.0
35	320.3	34.8
30	282.7	35.9

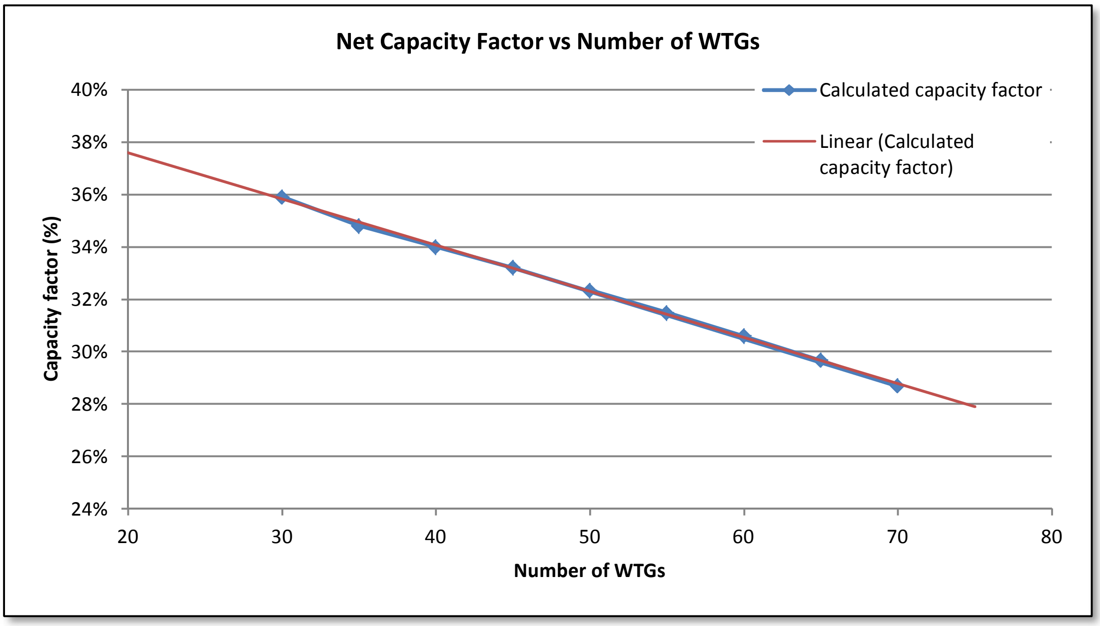

Figure 6-1: Net capacity factor vs. number of WTGs (using Siemens SWT3.0-101 WTG)

As observed in Figure 6-1, it can be seen that the relationship between the increase in layout size and the decrease in the resulting net capacity factor is approximately linear. Whilst the above results are based on the Siemens SWT3.0-101 3 MW WTG, a similar trend is expected with the other WTG models discussed in this report, assuming identical layouts are used. It is expected that other affects, outside the scope of this assessment, such as reduced wake induced loading, is expected to occur from reducing WTG numbers in the layout. Parsons Brinckerhoff has presented this information for consideration by RATCH for further cost benefit and operational assessment. An optimisation was undertaken on the layout by Parsons Brinckerhoff and is discussed in Section 7.

7. Layout optimisation

Parsons Brinckerhoff was requested by RATCH to undertake a layout optimisation using the Repower 3.4M 3.37 MW WTG, with the following constraints (provided by RATCH) taken into consideration:

- Visual impact
- Radio communications impact
- Noise
- Penetration altitude below 1179.5 mASL

Parsons Brinckerhoff commenced the layout development process by optimising solely for the highest possible energy production whilst maintaining the industry standard spacing of 5 rotor diameters in the predominant wind direction and 3 rotor diameters perpendicular to the predominant wind direction. The locations of the surrounding houses were then taken into consideration and were used as a noise constraint input in the optimisation process. Some WTGs were then manually relocated to comply with Air Services Australia requirements of a tip height of less than 1179.5 mASL, and to avoid encroaching into the telecommunication links that intercept the wind farm area. Whilst a minimum standard spacing of three rotor diameters was kept where possible, some WTGs were placed within a closer spacing to take advantage of higher wind speed locations. The layout developed by Parsons Brinckerhoff in consultation with RATCH is summarised in Table 7-1.

Table 7-1: Optimised layout

WTG ID	Easting	Northing	Elevation	Gross Minus Wake AEP	Wake efficiency	Mean wind speed
	m	m	mASL	GWh/yr	%	m/s
1	325,769	8,103,857	879.9	13.6	93.3	9.4
2	329,159	8,100,383	897.6	13.2	95.4	9.1
3	329,883	8,100,887	803.7	11.2	98.8	8.1
4	329,013	8,098,569	1,047.0	11.6	90.9	8.7
5	329,229	8,100,077	904.8	12.4	93.8	8.8
6	329,269	8,100,651	861.4	11.8	93.4	8.6
7	328,130	8,102,855	813.2	9.3	82.7	7.9
8	329,644	8,101,427	805.0	11.9	97.2	8.4
9	325,479	8,101,497	858.9	9.8	80.0	8.3
10	329,609	8,098,191	1,045.7	11.0	93.8	8.3
11	325,969	8,103,497	845.9	10.6	86.5	8.3
12	325,879	8,100,807	877.6	9.7	81.2	8.2
13	329,199	8,100,962	866.1	10.3	85.8	8.3
14	328,819	8,098,897	990.1	9.7	84.6	8.1
15	325,659	8,101,147	870.0	9.1	79.3	8.0
16	328,819	8,100,257	885.6	9.4	82.4	8.1
17	329,584	8,101,137	810.0	10.3	89.1	8.1
18	328,802	8,102,827	772.7	10.9	95.5	8.0
19	329,754	8,099,322	907.3	10.3	92.4	7.9
20	328,835	8,102,516	816.6	10.0	89.6	7.9
21	328,850	8,100,608	890.0	8.2	76.2	7.8

WTG ID	Easting	Northing	Elevation	Gross Minus Wake AEP	Wake efficiency	Mean wind speed
	m	m	mASL	GWh/yr	%	m/s
22	328,782	8,101,933	805.5	8.5	83.7	7.5
23	328,459	8,098,737	1,000.0	8.7	85.4	7.7
24	328,903	8,102,206	810.0	8.7	82.3	7.7
25	329,168	8,099,792	876.1	9.9	88.3	7.9
26	325,349	8,101,847	840.7	7.7	75.3	7.6
27	328,129	8,098,987	967.0	8.2	81.1	7.6
28	327,554	8,102,354	823.0	7.9	78.6	7.5
29	328,645	8,100,878	870.0	7.7	76.4	7.5
30	327,069	8,099,587	878.6	8.8	87.3	7.5
31	327,583	8,102,052	831.3	7.5	75.4	7.4
32	326,149	8,100,507	863.1	7.4	75.2	7.5
33	328,353	8,099,447	900.0	8.4	82.9	7.5
34	330,149	8,098,017	1,025.0	10.4	99.6	7.7
35	325,259	8,102,197	837.5	7.2	74.1	7.4
36	326,159	8,103,107	794.7	8.4	87.6	7.3
37	328,502	8,102,276	806.2	7.7	76.8	7.4
38	326,368	8,101,610	833.5	7.7	84.1	7.2
39	325,919	8,101,617	850.0	7.3	75.2	7.4
40	326,149	8,100,997	865.9	8.2	83.3	7.4
41	329,749	8,098,447	960.2	9.7	95.0	7.6
42	329,349	8,098,927	915.0	9.4	90.8	7.6
43	328,530	8,101,183	846.0	8.4	80.5	7.6
44	326,709	8,099,947	841.8	7.1	77.8	7.1
45	326,209	8,102,767	787.8	7.9	85.2	7.2
46	325,309	8,102,517	809.7	6.7	75.1	7.1
47	325,794	8,101,947	830.8	7.2	79.1	7.2
48	327,511	8,102,628	800.0	7.4	78.4	7.3
49	325,749	8,102,637	794.9	7.0	81.4	7.0
50	328,940	8,099,182	884.3	7.7	82.2	7.2
51	329,349	8,102,222	758.7	9.7	96.9	7.5
52	328,639	8,099,667	849.2	7.6	83.8	7.1
53	329,658	8,100,700	830.3	12.1	98.4	8.5
54	329,777	8,099,623	854.2	9.7	96.1	7.5
55	328,525	8,101,495	832.8	8.9	85.7	7.6
56	328,386	8,102,019	818.3	7.4	74.7	7.5
57	326,519	8,100,277	836.5	6.9	80.0	7.0
58	327,499	8,100,356	830.0	6.7	81.8	6.8
59	328,248	8,102,544	798.9	7.6	75.9	7.4
60	326,379	8,103,367	775.2	7.9	89.8	7.0
61	326,519	8,100,617	840.0	6.7	81.7	6.9
62	328,719	8,099,988	824.7	7.6	79.8	7.2
63	328,568	8,101,731	825.0	9.5	88.1	7.8
64	325,824	8,102,246	813.4	7.3	82.2	7.1
65	326,229	8,101,307	817.2	7.0	84.1	6.9
66	327,199	8,099,867	837.8	7.0	83.5	6.9
67	328,035	8,101,755	835.0	6.7	73.8	7.2
68	326,581	8,101,870	843.1	8.0	84.6	7.3
69	329,999	8,099,042	879.5	9.4	98.8	7.3
70	329,162	8,101,942	793.4	9.7	93.3	7.6

Table 7-2 summarises the performance of layout optimised by Parsons Brinckerhoff and Figure 7-1 shows the layout with the receptors and known radio communications links that intersect the site.

Table 7-2: Energy results of optimised layout

MEWF Energy production	
WTG	**Repower 3.4M 104**
Capacity (kW)	3370
Nominal hub height	80
Wind farm losses (%)	
Wake (calculated)	14.5%
Electrical losses (estimated)	3.0%
Others	1.0%
Non-availability of WTGs (unscheduled)	3.0%
Non-availability of Scheduled maintenance	0.6%
Balance of Plant availability	0.2%
Overall Losses	21.0%
Energy Output	
Gross Annual Energy Output (GWh)	728.4
Gross Annual Energy Output minus wake loss (GWh)	622.6
Net Annual Energy Output (GWh)	575.5
Net Capacity Factor	27.8%

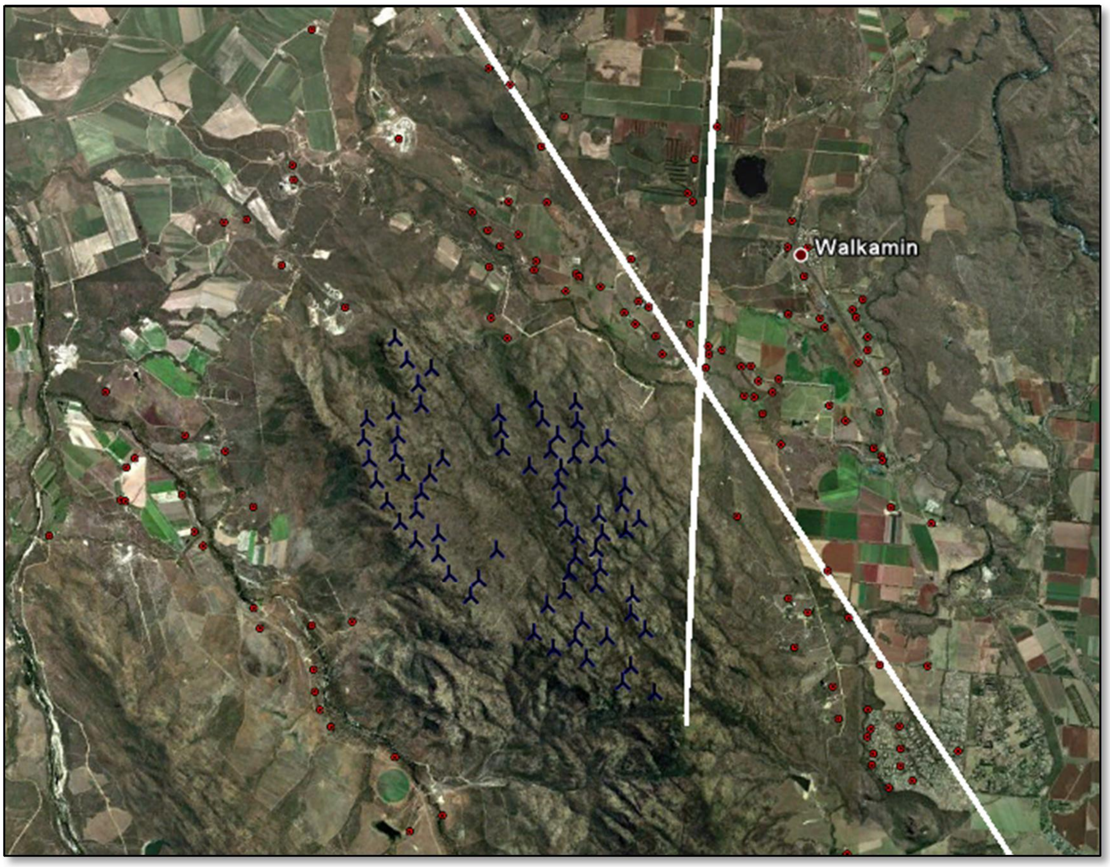

Figure 7-1: Optimised WTG layout (blue symbols), noise receptors (red symbols) and known intersecting radio communications links (white lines)

8. Bibliography

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Appendix A

WTG Layouts

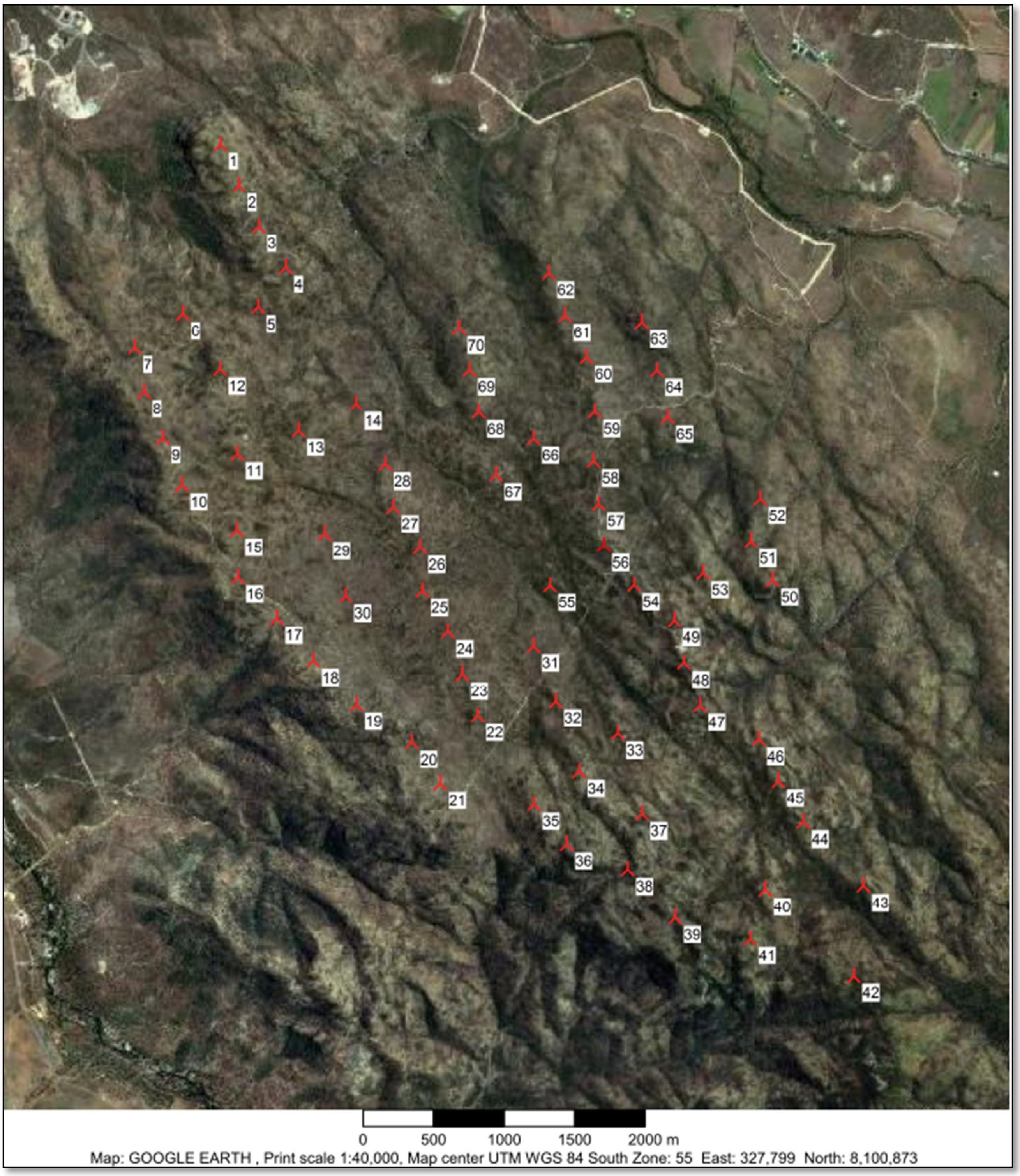

Figure A-1: WTG layout provided by RATCH

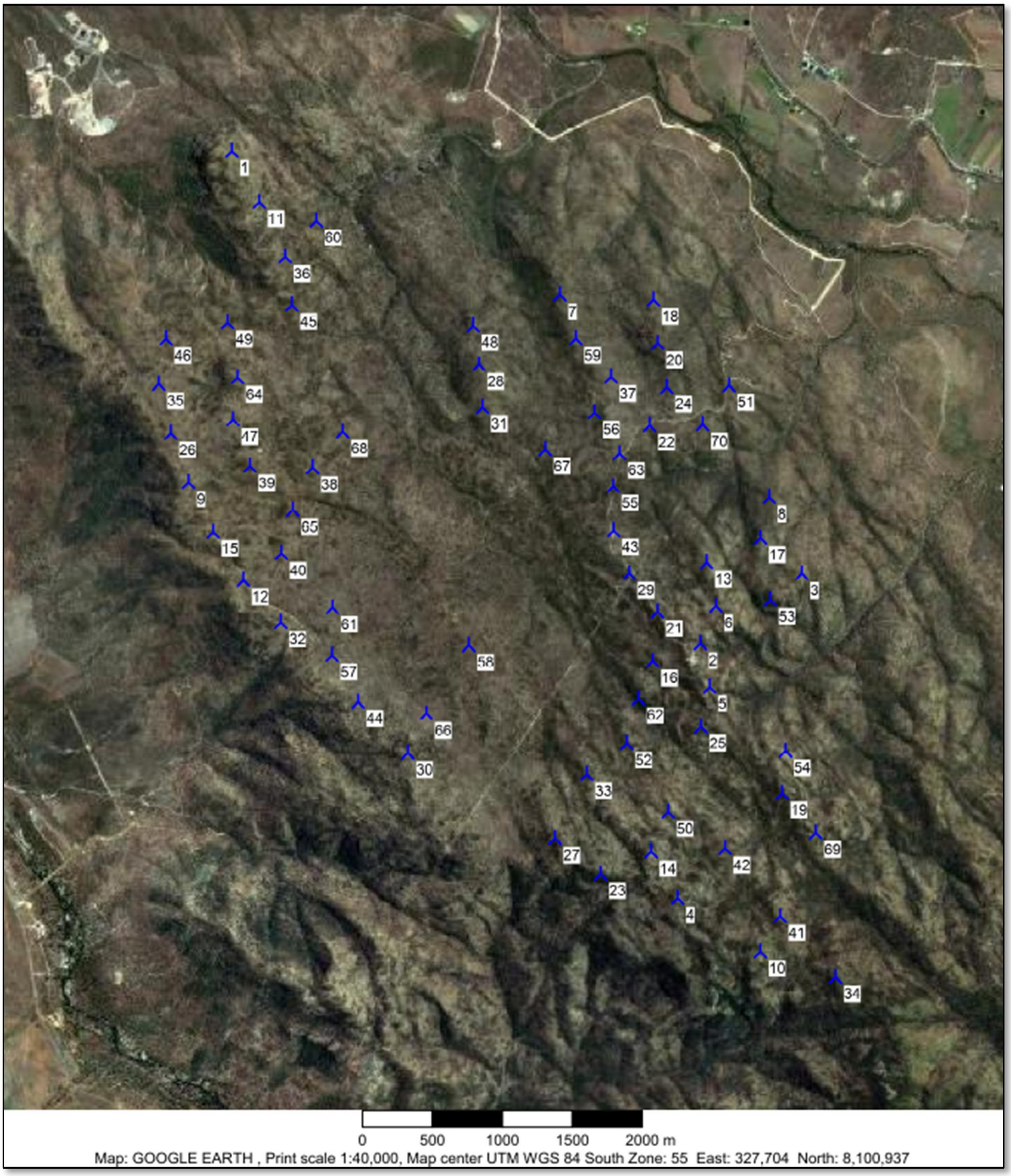

Figure A-2: WTG layout optimised by Parsons Brinckerhoff

Appendix B

Power curves (supplied by RATCH and modified for hysteresis by Parsons Brinckerhoff)

Table B-8-1: Power curve for the REpower 3.4-104 WTG at 1.09 kg/m^3 air density (adjusted by Parsons Brinckerhoff for hysteresis)

Wind Speed	Power	C_t
m/s	kW	
0	0	0.00
1	0	0.00
2	0	0.00
3	0	0.00
4	65	0.91
5	210	0.79
6	409	0.76
7	683	0.76
8	1054	0.76
9	1518	0.76
10	2037	0.71
11	2565	0.66
12	3034	0.57
13	3298	0.40
14	3362	0.31
15	3370	0.25
16	3370	0.20
17	3370	0.17
18	3370	0.14
19	3370	0.12
20	3370	0.11
21	3370	0.09
22	3370	0.08
23	3370	0.07
24	1685	0.06
25	0	0.06

Table B-8-2: Power curve for the Siemens SWT3.0-101 WTG at 1.09 kg/m^3 air density (adjusted by Parsons Brinckerhoff for hysteresis)

Wind Speed	Power	C_t
m/s	kW	
0	0	0.00
1	0	0.00
2	0	0.00
3	43	0.85
4	117	0.84
5	241	0.84
6	431	0.85
7	695	0.84
8	1047	0.84
9	1489	0.82
10	2011	0.75
11	2531	0.69
12	2871	0.63
13	2981	0.45
14	2998	0.34
15	3000	0.27
16	3000	0.22
17	3000	0.18
18	3000	0.16
19	3000	0.13
20	3000	0.11
21	3000	0.10
22	3000	0.09
23	3000	0.08
24	1500	0.07
25	0	0.06

Table B-8-3: Power curve for the Acciona AW3000-100 WTG at 1.09 kg/m^3 air density (adjusted by Parsons Brinckerhoff for hysteresis)

Wind Speed	Power	C_t
m/s	kW	
0	0	0.00
1	0	0.00
2	0	0.00
3	0	0.00
4	36	0.98
5	166	0.86
6	346	0.79
7	593	0.80
8	928	0.80
9	1338	0.74
10	1798	0.68
11	2274	0.63
12	2670	0.56
13	2886	0.43
14	2969	0.33
15	2997	0.26
16	2999	0.21
17	3000	0.18
18	3000	0.15
19	3000	0.13
20	3000	0.11
21	3000	0.09
22	3000	0.08
23	3000	0.07
24	1500	0.06
25	0	0.06

Appendix C

Individual WTG Energy Yield (WTG coordinates supplied by RATCH)

Table C-1: Individual WTG net AEP for the REpower 3.4-104 WTG

WTG ID	Label	Easting	Northing	Gross Minus Wake AEP	Wake efficiency	Mean wind speed
		m	m	GWh/yr	%	m/s
1	3.4-104-1	325,792	8,103,791	13.6	94.0	9.3
2	3.4-104-2	325,927	8,103,500	12.2	92.8	8.7
3	3.4-104-3	326,071	8,103,211	9.2	89.5	7.6
4	3.4-104-4	326,263	8,102,926	8.2	86.9	7.2
5	3.4-104-5	326,071	8,102,642	7.3	82.7	7.0
6	3.4-104-6	325,535	8,102,589	6.8	77.3	7.0
7	3.4-104-7	325,197	8,102,351	7.2	76.9	7.3
8	3.4-104-8	325,266	8,102,037	7.7	77.5	7.5
9	3.4-104-9	325,402	8,101,713	8.8	79.8	7.9
10	3.4-104-10	325,539	8,101,383	9.5	80.3	8.2
11	3.4-104-11	325,930	8,101,603	7.7	78.5	7.4
12	3.4-104-12	325,803	8,102,201	7.1	79.4	7.1
13	3.4-104-13	326,364	8,101,775	7.5	77.6	7.4
14	3.4-104-14	326,771	8,101,965	6.3	77.0	6.8
15	3.4-104-15	325,931	8,101,065	9.2	79.6	8.1
16	3.4-104-16	325,941	8,100,734	9.0	78.4	8.0
17	3.4-104-17	326,222	8,100,448	6.6	74.2	7.1
18	3.4-104-18	326,484	8,100,150	7.1	77.1	7.2
19	3.4-104-19	326,793	8,099,845	6.7	75.9	7.1
20	3.4-104-20	327,187	8,099,577	7.5	80.1	7.2
21	3.4-104-21	327,392	8,099,290	6.6	84.6	6.7
22	3.4-104-22	327,652	8,099,773	6.5	78.4	6.9
23	3.4-104-23	327,542	8,100,066	6.1	75.9	6.7
24	3.4-104-24	327,436	8,100,361	6.1	74.4	6.8
25	3.4-104-25	327,254	8,100,649	5.5	73.5	6.6
26	3.4-104-26	327,232	8,100,956	5.8	77.2	6.5
27	3.4-104-27	327,039	8,101,238	5.4	75.1	6.5
28	3.4-104-28	326,982	8,101,539	5.0	74.8	6.3
29	3.4-104-29	326,556	8,101,046	5.6	72.5	6.7
30	3.4-104-30	326,708	8,100,606	5.6	71.7	6.7
31	3.4-104-31	328,045	8,100,267	6.4	79.7	6.7
32	3.4-104-32	328,206	8,099,881	6.8	77.9	7.0
33	3.4-104-33	328,648	8,099,655	7.9	86.3	7.1
34	3.4-104-34	328,376	8,099,384	8.4	82.9	7.5
35	3.4-104-35	328,058	8,099,149	7.6	79.5	7.4
36	3.4-104-36	328,292	8,098,872	7.8	84.5	7.3
37	3.4-104-37	328,824	8,099,088	8.5	87.7	7.4
38	3.4-104-38	328,726	8,098,695	9.4	87.4	7.9
39	3.4-104-39	329,067	8,098,362	9.4	89.5	7.8
40	3.4-104-40	329,705	8,098,561	9.3	92.7	7.6
41	3.4-104-41	329,600	8,098,212	11.0	95.1	8.3
42	3.4-104-42	330,338	8,097,956	10.0	99.5	7.6
43	3.4-104-43	330,401	8,098,594	9.2	98.8	7.3
44	3.4-104-44	329,970	8,099,041	9.0	94.6	7.3
45	3.4-104-45	329,790	8,099,328	10.5	93.5	8.0
46	3.4-104-46	329,648	8,099,620	9.0	92.0	7.4

WTG ID	Label	Easting	Northing	Gross Minus Wake AEP	Wake efficiency	Mean wind speed
		m	m	GWh/yr	%	m/s
47	3.4-104-47	329,228	8,099,859	10.5	89.9	8.1
48	3.4-104-48	329,113	8,100,157	12.1	92.7	8.7
49	3.4-104-49	329,043	8,100,457	13.0	94.2	9.1
50	3.4-104-50	329,738	8,100,745	12.6	98.6	8.8
51	3.4-104-51	329,581	8,101,021	10.3	93.3	7.9
52	3.4-104-52	329,644	8,101,320	12.2	98.6	8.4
53	3.4-104-53	329,242	8,100,793	10.8	92.2	8.1
54	3.4-104-54	328,753	8,100,703	8.6	81.2	7.7
55	3.4-104-55	328,157	8,100,695	6.8	81.0	6.9
56	3.4-104-56	328,537	8,100,981	8.5	81.9	7.6
57	3.4-104-57	328,498	8,101,272	8.9	86.2	7.6
58	3.4-104-58	328,458	8,101,575	9.2	88.6	7.6
59	3.4-104-59	328,466	8,101,926	8.8	86.4	7.6
60	3.4-104-60	328,402	8,102,310	8.3	83.3	7.4
61	3.4-104-61	328,248	8,102,601	8.2	81.9	7.5
62	3.4-104-62	328,130	8,102,902	10.2	89.4	8.0
63	3.4-104-63	328,792	8,102,560	10.8	95.4	8.0
64	3.4-104-64	328,903	8,102,219	10.2	95.1	7.7
65	3.4-104-65	328,983	8,101,892	9.9	93.5	7.7
66	3.4-104-66	328,031	8,101,732	6.8	76.3	7.1
67	3.4-104-67	327,768	8,101,472	6.4	76.9	6.8
68	3.4-104-68	327,640	8,101,915	6.2	71.7	7.0
69	3.4-104-69	327,574	8,102,211	8.5	80.9	7.7
70	3.4-104-70	327,496	8,102,505	7.5	79.6	7.2

Table C-2: Individual WTG net AEP for the Siemens SWT3.0-101 WTG

WTG ID	Label	Easting	Northing	Gross minus wake AEP	Wake efficiency	Mean wind speed
		m	m	GWh/yr	%	m/s
1	SWT3.0-101-1	325,792	8,103,791	12.9	94.0	9.3
2	SWT3.0-101-2	325,927	8,103,500	11.7	92.7	8.7
3	SWT3.0-101-3	326,071	8,103,211	8.9	89.5	7.6
4	SWT3.0-101-4	326,263	8,102,926	8.0	87.0	7.2
5	SWT3.0-101-5	326,071	8,102,642	7.2	82.8	7.0
6	SWT3.0-101-6	325,535	8,102,589	6.7	77.2	7.0
7	SWT3.0-101-7	325,197	8,102,351	7.0	76.7	7.3
8	SWT3.0-101-8	325,266	8,102,037	7.5	77.3	7.5
9	SWT3.0-101-9	325,402	8,101,713	8.5	79.6	7.9
10	SWT3.0-101-10	325,539	8,101,383	9.2	80.1	8.2
11	SWT3.0-101-11	325,930	8,101,603	7.5	78.4	7.4
12	SWT3.0-101-12	325,803	8,102,201	7.0	79.4	7.1
13	SWT3.0-101-13	326,364	8,101,775	7.3	77.5	7.4
14	SWT3.0-101-14	326,771	8,101,965	6.2	77.0	6.8
15	SWT3.0-101-15	325,931	8,101,065	8.9	79.4	8.1
16	SWT3.0-101-16	325,941	8,100,734	8.6	78.3	8.0
17	SWT3.0-101-17	326,222	8,100,448	6.5	74.1	7.1
18	SWT3.0-101-18	326,484	8,100,150	6.9	77.0	7.2
19	SWT3.0-101-19	326,793	8,099,845	6.6	75.6	7.1
20	SWT3.0-101-20	327,187	8,099,577	7.3	79.9	7.2
21	SWT3.0-101-21	327,392	8,099,290	6.5	84.5	6.7
22	SWT3.0-101-22	327,652	8,099,773	6.4	78.2	6.9
23	SWT3.0-101-23	327,542	8,100,066	6.0	75.8	6.7
24	SWT3.0-101-24	327,436	8,100,361	6.0	74.3	6.8
25	SWT3.0-101-25	327,254	8,100,649	5.5	73.5	6.6
26	SWT3.0-101-26	327,232	8,100,956	5.7	77.3	6.5
27	SWT3.0-101-27	327,039	8,101,238	5.4	75.2	6.5
28	SWT3.0-101-28	326,982	8,101,539	5.0	74.9	6.3
29	SWT3.0-101-29	326,556	8,101,046	5.6	72.5	6.7
30	SWT3.0-101-30	326,708	8,100,606	5.6	71.6	6.7
31	SWT3.0-101-31	328,045	8,100,267	6.3	79.6	6.7
32	SWT3.0-101-32	328,206	8,099,881	6.6	77.6	7.0
33	SWT3.0-101-33	328,648	8,099,655	7.7	86.2	7.1
34	SWT3.0-101-34	328,376	8,099,384	8.1	82.6	7.5
35	SWT3.0-101-35	328,058	8,099,149	7.3	79.2	7.4
36	SWT3.0-101-36	328,292	8,098,872	7.6	84.1	7.3
37	SWT3.0-101-37	328,824	8,099,088	8.2	87.5	7.4
38	SWT3.0-101-38	328,726	8,098,695	9.1	87.2	7.9
39	SWT3.0-101-39	329,067	8,098,362	9.1	89.3	7.8
40	SWT3.0-101-40	329,705	8,098,561	9.0	92.5	7.6
41	SWT3.0-101-41	329,600	8,098,212	10.6	94.9	8.3
42	SWT3.0-101-42	330,338	8,097,956	9.8	99.5	7.6
43	SWT3.0-101-43	330,401	8,098,594	9.0	98.8	7.3
44	SWT3.0-101-44	329,970	8,099,041	8.8	94.6	7.3
45	SWT3.0-101-45	329,790	8,099,328	10.1	93.4	8.0
46	SWT3.0-101-46	329,648	8,099,620	8.8	92.0	7.4

WTG ID	Label	Easting	Northing	Gross minus wake AEP	Wake efficiency	Mean wind speed
		m	m	GWh/yr	%	m/s
47	SWT3.0-101-47	329,228	8,099,859	10.0	89.7	8.1
48	SWT3.0-101-48	329,113	8,100,157	11.5	92.4	8.7
49	SWT3.0-101-49	329,043	8,100,457	12.2	94.1	9.1
50	SWT3.0-101-50	329,738	8,100,745	12.0	98.5	8.8
51	SWT3.0-101-51	329,581	8,101,021	9.8	93.1	7.9
52	SWT3.0-101-52	329,644	8,101,320	11.6	98.6	8.4
53	SWT3.0-101-53	329,242	8,100,793	10.3	92.0	8.1
54	SWT3.0-101-54	328,753	8,100,703	8.2	80.8	7.7
55	SWT3.0-101-55	328,157	8,100,695	6.7	80.8	6.9
56	SWT3.0-101-56	328,537	8,100,981	8.2	81.7	7.6
57	SWT3.0-101-57	328,498	8,101,272	8.6	86.0	7.6
58	SWT3.0-101-58	328,458	8,101,575	8.9	88.5	7.6
59	SWT3.0-101-59	328,466	8,101,926	8.5	86.1	7.6
60	SWT3.0-101-60	328,402	8,102,310	8.0	83.1	7.4
61	SWT3.0-101-61	328,248	8,102,601	7.9	81.5	7.5
62	SWT3.0-101-62	328,130	8,102,902	9.8	89.2	8.0
63	SWT3.0-101-63	328,792	8,102,560	10.4	95.4	8.0
64	SWT3.0-101-64	328,903	8,102,219	9.8	95.0	7.7
65	SWT3.0-101-65	328,983	8,101,892	9.5	93.4	7.7
66	SWT3.0-101-66	328,031	8,101,732	6.7	76.0	7.1
67	SWT3.0-101-67	327,768	8,101,472	6.2	76.6	6.8
68	SWT3.0-101-68	327,640	8,101,915	6.1	71.6	7.0
69	SWT3.0-101-69	327,574	8,102,211	8.2	80.6	7.7
70	SWT3.0-101-70	327,496	8,102,505	7.3	79.4	7.2

Table C-3: Individual WTG net AEP for the Acciona AW3000-100 WTG

WTG ID	Label	Easting	Northing	Gross minus wake AEP	Wake efficiency	Mean wind speed
		m	m	GWh/yr	%	m/s
1	AW3000-100-1	325,792	8,103,791	12.0	94.2	9.3
2	AW3000-100-2	325,927	8,103,500	10.8	93.1	8.7
3	AW3000-100-3	326,071	8,103,211	8.1	90.0	7.6
4	AW3000-100-4	326,263	8,102,926	7.2	87.5	7.2
5	AW3000-100-5	326,071	8,102,642	6.4	83.5	7.0
6	AW3000-100-6	325,535	8,102,589	6.0	78.1	7.0
7	AW3000-100-7	325,197	8,102,351	6.4	77.6	7.3
8	AW3000-100-8	325,266	8,102,037	6.8	78.4	7.5
9	AW3000-100-9	325,402	8,101,713	7.8	80.7	7.9
10	AW3000-100-10	325,539	8,101,383	8.5	81.1	8.2
11	AW3000-100-11	325,930	8,101,603	6.8	79.3	7.4
12	AW3000-100-12	325,803	8,102,201	6.3	80.2	7.1
13	AW3000-100-13	326,364	8,101,775	6.6	78.5	7.4
14	AW3000-100-14	326,771	8,101,965	5.6	77.7	6.8
15	AW3000-100-15	325,931	8,101,065	8.2	80.5	8.1
16	AW3000-100-16	325,941	8,100,734	8.0	79.3	8.0
17	AW3000-100-17	326,222	8,100,448	5.8	74.9	7.1
18	AW3000-100-18	326,484	8,100,150	6.3	77.9	7.2
19	AW3000-100-19	326,793	8,099,845	5.9	76.6	7.1
20	AW3000-100-20	327,187	8,099,577	6.6	80.9	7.2
21	AW3000-100-21	327,392	8,099,290	5.8	85.0	6.7
22	AW3000-100-22	327,652	8,099,773	5.7	79.1	6.9
23	AW3000-100-23	327,542	8,100,066	5.3	76.7	6.7
24	AW3000-100-24	327,436	8,100,361	5.4	75.2	6.8
25	AW3000-100-25	327,254	8,100,649	4.9	74.3	6.6
26	AW3000-100-26	327,232	8,100,956	5.1	77.9	6.5
27	AW3000-100-27	327,039	8,101,238	4.8	75.9	6.5
28	AW3000-100-28	326,982	8,101,539	4.4	75.5	6.3
29	AW3000-100-29	326,556	8,101,046	4.9	73.3	6.7
30	AW3000-100-30	326,708	8,100,606	4.9	72.4	6.7
31	AW3000-100-31	328,045	8,100,267	5.7	80.4	6.7
32	AW3000-100-32	328,206	8,099,881	5.9	78.6	7.0
33	AW3000-100-33	328,648	8,099,655	6.9	86.9	7.1
34	AW3000-100-34	328,376	8,099,384	7.4	83.6	7.5
35	AW3000-100-35	328,058	8,099,149	6.7	80.1	7.4
36	AW3000-100-36	328,292	8,098,872	6.8	85.0	7.3
37	AW3000-100-37	328,824	8,099,088	7.5	88.2	7.4
38	AW3000-100-38	328,726	8,098,695	8.3	87.9	7.9
39	AW3000-100-39	329,067	8,098,362	8.3	89.9	7.8
40	AW3000-100-40	329,705	8,098,561	8.2	92.9	7.6
41	AW3000-100-41	329,600	8,098,212	9.7	95.3	8.3
42	AW3000-100-42	330,338	8,097,956	8.8	99.5	7.6
43	AW3000-100-43	330,401	8,098,594	8.1	98.8	7.3
44	AW3000-100-44	329,970	8,099,041	7.9	94.8	7.3
45	AW3000-100-45	329,790	8,099,328	9.2	93.8	8.0
46	AW3000-100-46	329,648	8,099,620	7.9	92.2	7.4

WTG ID	Label	Easting	Northing	Gross minus wake AEP	Wake efficiency	Mean wind speed
		m	m	GWh/yr	%	m/s
47	AW3000-100-47	329,228	8,099,859	9.2	90.3	8.1
48	AW3000-100-48	329,113	8,100,157	10.7	92.9	8.7
49	AW3000-100-49	329,043	8,100,457	11.4	94.4	9.1
50	AW3000-100-50	329,738	8,100,745	11.1	98.7	8.8
51	AW3000-100-51	329,581	8,101,021	9.0	93.5	7.9
52	AW3000-100-52	329,644	8,101,320	10.7	98.7	8.4
53	AW3000-100-53	329,242	8,100,793	9.5	92.5	8.1
54	AW3000-100-54	328,753	8,100,703	7.6	81.8	7.7
55	AW3000-100-55	328,157	8,100,695	6.0	81.7	6.9
56	AW3000-100-56	328,537	8,100,981	7.5	82.6	7.6
57	AW3000-100-57	328,498	8,101,272	7.8	86.8	7.6
58	AW3000-100-58	328,458	8,101,575	8.1	89.1	7.6
59	AW3000-100-59	328,466	8,101,926	7.8	86.9	7.6
60	AW3000-100-60	328,402	8,102,310	7.3	83.9	7.4
61	AW3000-100-61	328,248	8,102,601	7.2	82.4	7.5
62	AW3000-100-62	328,130	8,102,902	9.0	89.7	8.0
63	AW3000-100-63	328,792	8,102,560	9.5	95.6	8.0
64	AW3000-100-64	328,903	8,102,219	8.9	95.3	7.7
65	AW3000-100-65	328,983	8,101,892	8.7	93.7	7.7
66	AW3000-100-66	328,031	8,101,732	6.0	77.1	7.1
67	AW3000-100-67	327,768	8,101,472	5.6	77.6	6.8
68	AW3000-100-68	327,640	8,101,915	5.4	72.5	7.0
69	AW3000-100-69	327,574	8,102,211	7.5	81.6	7.7
70	AW3000-100-70	327,496	8,102,505	6.6	80.2	7.2