WIND DATA REPORT

Harwich

August 1st, 2006 – July 31st 2007

Prepared for

Massachusetts Technology Collaborative
75 North Drive
Westborough, MA 01581

by

Meltem Duran
James F. Manwell
Anthony L. Rogers
Anthony F. Ellis

October 17, 2007

Renewable **E**nergy **R**esearch **L**aboratory
University of Massachusetts, Amherst
160 Governors Drive, Amherst, MA 01003
www.ceere.org/rerl • (413) 545-4359 • rerl@ecs.umass.edu

NOTICE AND ACKNOWLEDGEMENTS

TABLE OF CONTENTS

TABLE OF FIGURES

EXECUTIVE SUMMARY

All the work presented in this Wind Data Report including installation and decommissioning of the meteorological tower and instrumentation, and the data analysis and reporting was performed by the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts, Amherst.

The wind measurement station was installed at Harwich High School, Harwich, MA. Installed in July 2006, the wind monitoring station remained in operation for a little over 12 months. The station was decommissioned on August 14th. The station consisted of two anemometers at 50 m (164 ft) and at 38 m (125 ft), one anemometer at 20 m (66 ft) and wind vanes at the same heights.

During the interval covered by this report, August 01 2006 – July 31 2007, the recorded mean wind speed was 5.68 m/s (12.71 mph) and the prevailing wind direction was from southwest. The gross data recovery percentage (the actual percentage of expected data received) was 99.821% and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 99.557%. These percentages are very high, which is an indication that the sensors and the data logger were performing well.

Additional information about interpreting the data presented in this report can be found in the Fact Sheet, "Interpreting Your Wind Resource Data," produced by RERL and the Massachusetts Technology Collaborative (MTC). This document is found through the RERL website:

http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_6_Wind_resource_interpretation.pdf

* 1 m/s = 2.237 mph.

SECTION 1 - Station Location

The wind assessment station is located in an area mostly used for playing fields, behind the high school, about 4 miles away from the Chatham Municipal Airport. The location of the tower base is 41° - 41.4700' North, 070° - 03.8317' West. Relative to the Mean Low Water Level, the tower is mounted at a height of 15 m (49 ft).

Figure 1 – Site location at Harwich High School

SECTION 2 - Instrumentation and Equipment

The wind monitoring equipment is mounted on a met tower that is 164 feet tall, six inches in diameter, and held up by guy wires. This type of tower sits directly on the ground and no foundation is necessary. All the equipment comes from NRG Systems, and consists of the following items:

- Tower kit, height 50 m NRG tower
- Logger kit: NRG Symphonie Logger
- 5 - #40 Anemometers, standard calibration (Slope – 0.765 m/s, Offset – 0.350 m/s). One anemometer is located at 20 m (66 ft). Two anemometers are located at 38 m (125 ft) and two at 50 m (164 ft).

- 3 - #200P Wind direction vanes. The vanes are located at 20 m (66 ft), 38 m (125 ft), and 50 m (164 ft).

- 1 - #110S Temperature sensor located at 3 m (10 ft).

The data from the Symphonie logger is mailed to the University of Massachusetts, Amherst on a regular basis. The logger samples wind speed and direction once every two seconds. These samples are combined into 10-minute averages and are put into a binary file along with the standard deviation for each 10-minute interval. The binary files are converted to ASCII text files using the NRG software BaseStation®. These text files are then imported into a database software program where they are subjected to quality assurance tests prior to data usage.

SECTION 3 - Data Summary

A summary of the wind speeds and wind directions measured during the reporting period is included in Table 1. Table 1 includes the mean wind speeds measured at each measurement height, the maximum instantaneous wind speed measured at each measurement height and the prevailing wind direction measured at each measurement height. These values are provided for each month of the reporting period and for the whole reporting period.

Table 1. Wind Speed and Direction Data Summary

Date	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction	Mean Wind Speed	Max Wind Speed	Prevailing Wind Direction
Height Units	**50 m [m/s]**	**50 m [m/s]**	**50 m [deg]**	**38 m [m/s]**	**38 m [m/s]**	**38 m [deg]**	**20 m [m/s]**	**20 m [m/s]**	**20 m [deg]**
Aug 2006	4.71	11.29	225	4.24	10.25	225	2.94	8.20	225
Sept 2006	5.00	11.27	247.5	4.45	10.17	225	3.02	8.36	225
Oct 2006	6.12	18.09	247.5	5.48	16.68	225	3.83	13.24	225
Nov 2006	5.44	15.73	225	4.78	14.49	225	3.38	11.18	225
Dec 2006	6.16	16.57	270	5.45	14.34	270	3.96	10.68	270
Jan 2007	6.52	14.81	315	5.79	13.40	315	4.28	10.25	315
Feb 2007	6.29	16.17	292.5	5.67	14.78	270	4.26	11.63	270
Mar 2007	6.89	15.93	225	6.19	14.69	225	4.65	11.18	225
Apr 2007	6.02	19.11	292.5	5.47	17.62	22.5	4.18	13.85	22.5
May 2007	5.40	12.10	225	4.88	11.22	225	3.69	9.21	225
Jun 2007	5.60	11.77	225	5.07	10.75	225	3.81	8.37	225
July 2007	4.86	12.99	225	4.38	11.77	225	3.20	9.13	225
Aug2006 - July 2007	5.75	19.11	225	5.15	17.62	225	3.77	13.85	225

Wind data statistics in the table are reported when more than 90% of the data during the reporting period are valid. In cases when a larger amount of data are missing, the percent of the available data that are used to determine the data statistics is noted.

No measurement of wind speed or direction can be perfectly accurate. Wind speed measurement errors occur due to anemometer manufacturing variability, anemometer calibration errors, the response of anemometers to turbulence and vertical air flow and due to air flows caused by the anemometer mounting system. Every effort is made to reduce the sources of these errors. Nevertheless, the values reported in this report have an expected uncertainty of about ± 2% or ± 0.2 m/s, whichever is greater. Wind direction measurement errors occur due to sensor measurement uncertainty, tower effects, boom alignment measurement errors and twisting of pipe sections during the raising of a pipe tower. Efforts are also made to reduce these errors, but the reported wind directions are estimated to have an uncertainty of +/- 5 degrees.

A summary of the turbulence intensity and mean wind shear measured at each measurement height during the reporting period is included in Table 2. These values are provided for each month of the reporting period and for the whole reporting period. Turbulence Intensity is calculated by dividing the standard deviation of the wind speed by the mean wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. Turbulence intensity varies with wind speed. The average turbulence intensity presented in Table 2 is the mean turbulence intensity when the wind speed at the highest measurement height is between 9.5 and 10.5 m/s.

Shear coefficients provide a measure of the change in wind speed with height. When data at multiple heights are available, shear coefficients, α, have been determined. They can be used in the following formula to estimate the average wind speed, $U(z)$, at height z, when the average wind speed, $U(z_r)$, at height z_r is known:

$$U(z)=U(z_r)\left(\frac{z}{z_r}\right)^{\alpha}$$

The change in wind speed with height is a very complicated relationship related to atmospheric conditions, wind speed, wind direction, time of day and time of year. This formula will not always provide the correct answer at any given site. Nevertheless the calculated shear coefficient, based on measurements at two heights, can be used to characterize the degree of increase in wind speed with height at a site.

The mean wind shear coefficient that is provided here is calculated based on the mean wind speeds in Table 1, where z_{high} and z_{low} are the heights of the higher and lower mean wind speeds used in the calculation and $U\ (z_{low})$ and $U(z_{high})$ are the mean wind speeds at the two heights.

$$\alpha = \log\left(\frac{U(z_{high})}{U(z_{low})}\right) \Big/ \log\left(\frac{z_{high}}{z_{low}}\right)$$

Table 2. Shear and Turbulence Intensity Data Summary

Date	Turbulence Intensity at 10 m/s	Turbulence Intensity at 10 m/s	Turbulence Intensity at 10 m/s	Mean Wind Shear Coefficient, α
Height Units	50 m [-]	38 m [-]	20 m [-]	Between 50 m and 38 m [-]
Aug 2006	0.17	0.19	0.29	0.38
Sept 2006	0.17	0.19	0.29	0.42
Oct 2006	0.19	0.21	0.30	0.40
Nov 2006	0.18	0.20	0.28	0.47
Dec 2006	0.19	0.21	0.28	0.45
Jan 2007	0.20	0.22	0.29	0.43
Feb 2007	0.20	0.21	0.29	0.38
Mar 2007	0.19	0.22	0.28	0.39
Apr 2007	0.20	0.22	0.29	0.35
May 2007	0.18	0.21	0.27	0.37
Jun 2007	0.19	0.21	0.28	0.36
July 2007	0.19	0.22	0.31	0.38
Aug2006 -July 2007	0.19	0.21	0.29	0.40

During the period between August 2006 and July 2007, the average wind speed was 5.75 m/s and the maximum wind speed was 19.11 m/s at a height of 50 m. At this height, the prevailing wind direction was southwest. The turbulence intensity recorded was 0.19 with a shear coefficient of 0.40.

SECTION 4- Capacity Factor

The capacity factor of a wind turbine at a given site depends on the hub height, wind speed distribution at the hub height, the wind turbine power curve and any assumptions about down time and losses due to wake effects from upwind wind turbines, etc. If the hub height wind speed is estimated from data at lower heights, then the capacity factor will also depend on the estimated wind shear and the wind speeds measured at lower heights. No simple estimate of capacity factor at a site could take all of these effects and choices into account. Nevertheless, an estimate of the capacity factor of a wind turbine at this site is provided here to help the reader understand the order of magnitude of the wind resource at this site.

The estimates assume a hub height of 80 m, a 1.8 MW wind turbine with a rotor diameter of 80 m and the mean wind speed at the highest measurement height and the mean wind shear at the site, in order to determine the mean hub height wind speed. The capacity factor (CF) is then estimated from (see G.M. Masters, Renewable and Efficient Electric Power Systems, Wiley, 2004):

$$CF = (0.087)U_{hub} - \frac{P_{rated}}{D^2}$$

where U_{hub} is the mean annual hub height wind speed in m/s, P_{rated} is the rated power of the wind turbine in kW and D is the diameter of the rotor in meters. Based on this equation, the estimated capacity factor of a wind turbine at this site would be about 0.323.

SECTION 5- Graphs

This report contains several types of wind data graphs. Unless otherwise noted, each graph represents data from one year (August 2006 to July 2007). The following graphs are included:

- Time Series – 10-minute average wind speeds are plotted against time. This graph includes all of the collected data, starting on August 1, 2006, Figure 2. The graph represents data at 50 m.

- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. Figure 3 shows wind speeds ranged between 4 m/s (8.9 mph) and 5 m/s (11.2 mph) about 17% of the time and between 5 m/s (11.2 mph) and 6 m/s (13.42 mph) about another 18% of the time. The graph represents data at 50 m.

- Monthly Average – A plot of the monthly average wind speed over a 12-month period. This graph shows the trends in the wind speed over the whole period of data collection. This plot is shown on Figure 4 and represents data collected at 50 m.

- Diurnal – A plot of the average wind speed for each hour of the day. Figure 5 shows that the wind speed varied between 5.9 m/s (13.2 mph) and 6.3 m/s (14.1 mph) throughout the day on average and the highest wind speeds were recorded in the early afternoon. The plot represents data collected at 50 m.

- Turbulence Intensity – A plot of turbulence intensity as a function of wind speed. Turbulence Intensity is calculated as the standard deviation of the wind speed divided by the wind speed and is a measure of the gustiness of a wind resource. Lower turbulence results in lower mechanical loads on a wind turbine. For Harwich, the turbulence intensity was well within the acceptable range. This plot is shown as Figure 6. The plot represents data at 50 m.

- Wind Rose – A plot, by compass direction showing the percentage of time that the wind comes from a given direction and the average wind speed in that direction. The wind blew from southeast approximately 13% of the time at an average speed of approximately 6.0 m/s (13.4 mph). This plot is shown on Figure 7 and represents data collected at 50 m.

Data for the wind speed histograms, monthly and diurnal average plots, and wind roses are included in APPENDIX B.

Wind Speed Time Series

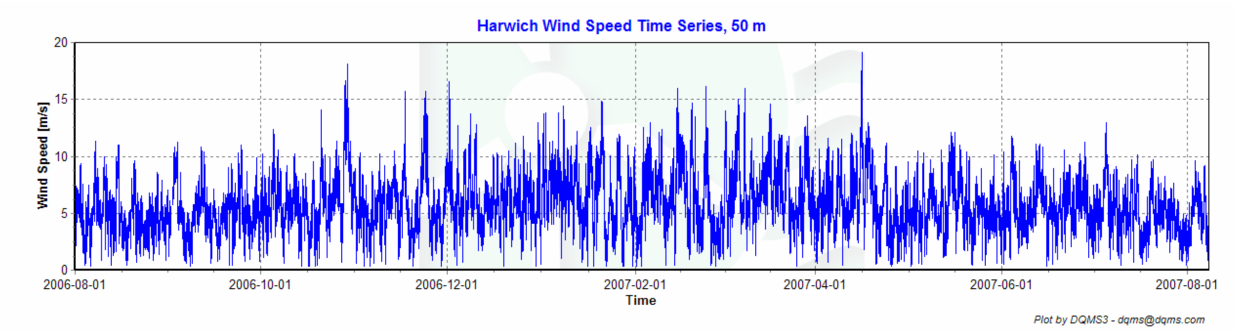

Figure 2 - Wind Speed Time Series, August 2006 – July 2007

Wind Speed Distributions

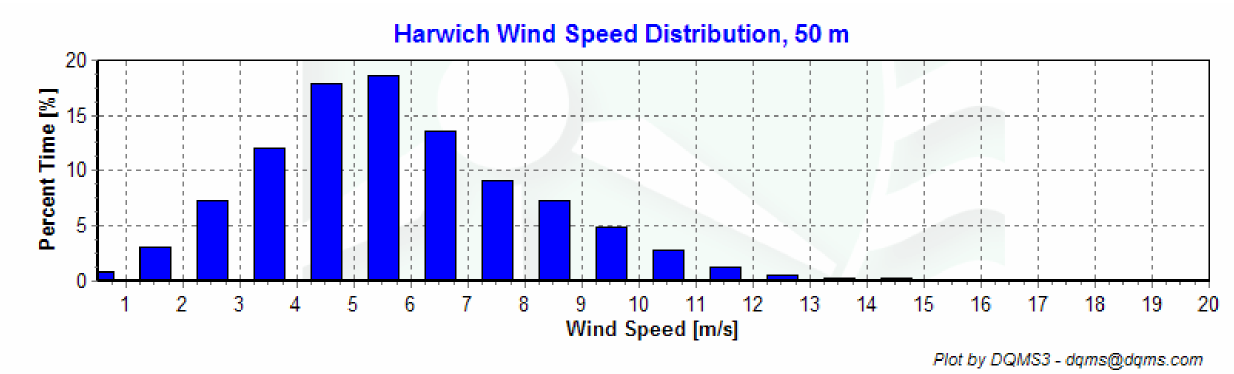

Figure 3 – Wind speed distribution, August 2006 – July 2007

Monthly Average Wind Speeds

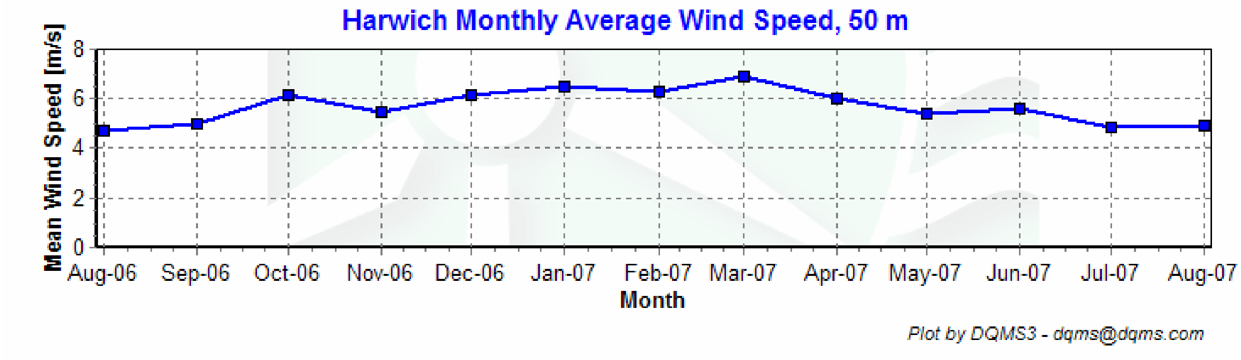

Figure 4 - Monthly Average Wind Speeds, August 2006 – July 2007

Diurnal Average Wind Speeds

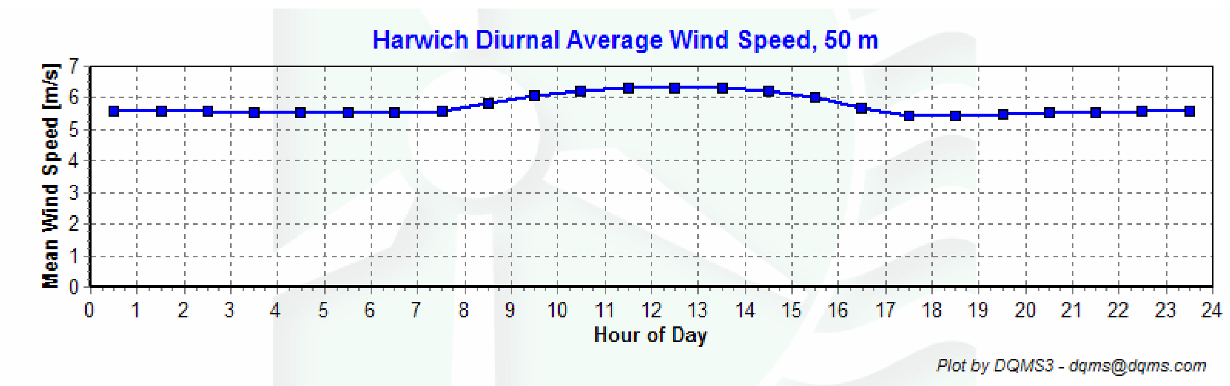

Figure 5 – Diurnal average wind speed, August 2006 – July 2007

Turbulence Intensities

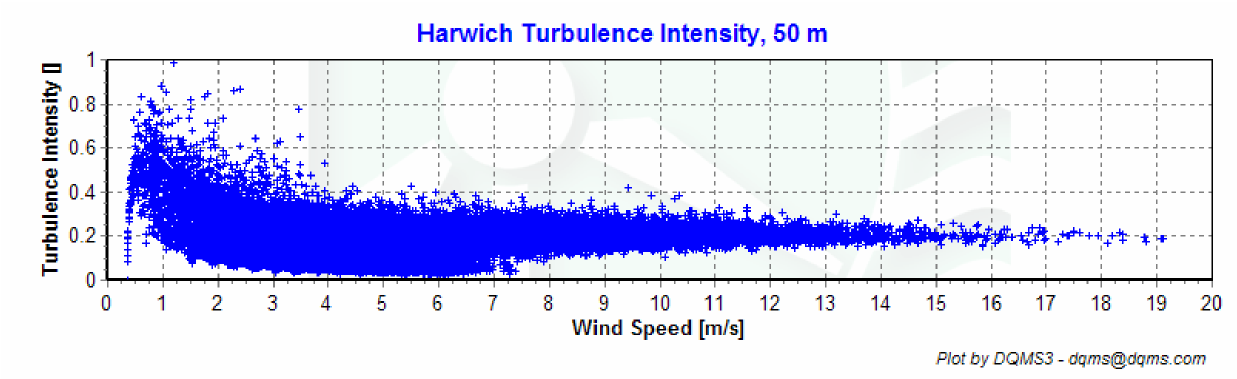

Figure 6 – Turbulence intensity, August 2006 - July 2007

Wind Roses

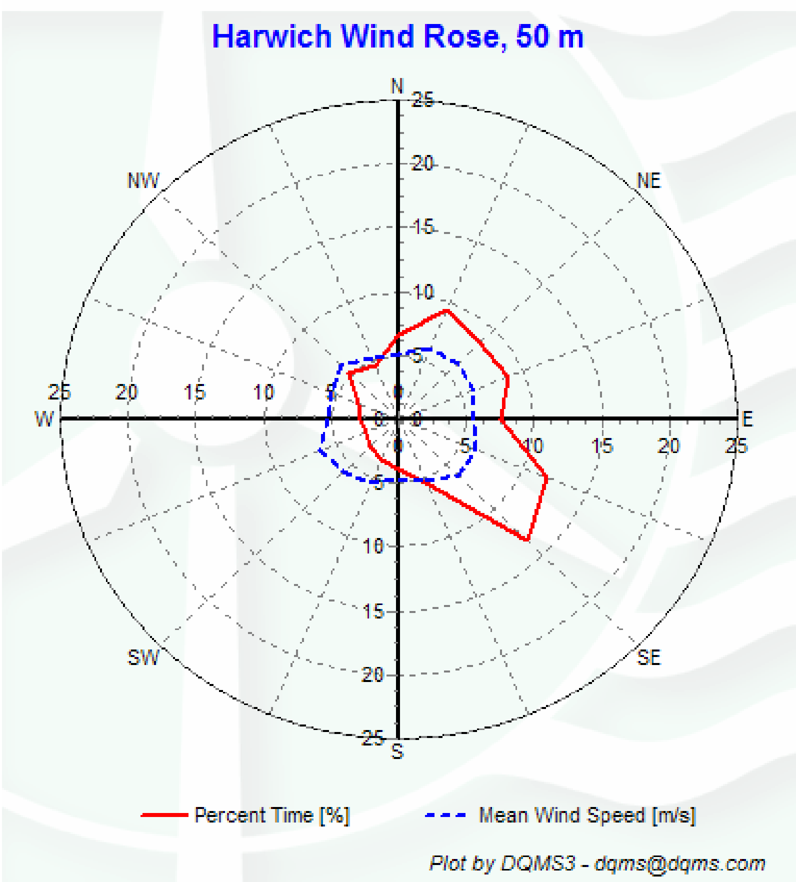

Figure 7 – Wind rose, August 2006 – July 2007

SECTION 6 - Significant Meteorological Events

The year between August of 2006 and July of 2007 experienced, on average, normal winds and precipitation. No major events are shown in the wind speed time series.

Source: http://www.erh.noaa.gov/box/MonthlyClimate2.shtml

SECTION 7 - Data Collection and Maintenance

The following maintenance/equipment problems occurred during the report period, and the following corrective actions taken:

- All sensors worked without any problems for the duration that the wind measuring station was in operation.
- The wind measuring station was decommissioned in August 2007.

SECTION 8 - Data Recovery and Validation

All raw wind data are subjected to a series of tests and filters to weed out data that are faulty or corrupted. Definitions of these quality assurance (QA) controls are given below under Test Definitions and Sensor Statistics. These control filters were designed to automate the quality control process and used many of the previous hand-worked data sets made at UMass to affect a suitable emulation. The gross percentage of data recovered (ratio of the number of raw data points received to data points expected) and net percentage (ratio of raw data points which passed all QA control tests to data points expected) are shown below.

Gross Data Recovered [%]	99.821
Net Data Recovered [%]	99.557

Test Definitions

All raw data were subjected to a series of validation tests, as described below. The sensors tested and the parameters specific to each sensor are given in the Sensor Performance Report which is included in APPENDIX A. Data which were flagged as invalid were not included in the statistics presented in this report.

MinMax Test: All sensors are expected to report data values within a range specified by the sensor and logger manufacturers. If a value falls outside this range, it is flagged as invalid. A data value from the sensor listed in Test Field 1 (TF1) is flagged if it is less than Factor 1 (F1) or greater than Factor 2. This test has been applied to the following sensors (as applicable): wind speed, wind speed standard deviation, wind direction, temperature, and solar insolation.

$$F1 > TF1 > F2$$

MinMaxT Test: This is a MinMax test for wind direction standard deviation with different ranges applied for high and low wind speeds. A wind direction standard deviation data value (TF1) is flagged either if it is less than Factor 1, if the wind speed (TF2) is less than Factor 4 and the wind direction standard deviation is greater than Factor 2, or if the wind speed is greater than or equal to Factor 4 and the wind direction standard deviation is greater than Factor 3.

$$\begin{gathered}(TF1 < F1) \\ \text{or } (TF2 < F4 \text{ and } TF1 > F2) \\ \text{or } (TF2 \geq F4 \text{ and } TF1 > F3)\end{gathered}$$

Icing Test: An icing event occurs when ice collects on a sensor and degrades its performance. Icing events are characterized by the simultaneous measurements of near-zero standard deviation of wind direction, non-zero wind speed, and near- or below-freezing temperatures. Wind speed, wind speed standard deviation, wind direction, and wind direction standard deviation data values are flagged if the wind direction standard deviation (CF1) is less than or equal to Factor 1 (F1), the wind speed (TF1) is greater than Factor 2 (F2), and the temperature (CF2) is less than Factor 3 (F3). To exit an icing event, the wind direction standard deviation must be greater than Factor 4.

$$CF1 \leq F1 \text{ and } TF1 > F2 \text{ and } CF2 < F3$$

CompareSensors Test: Where primary and redundant sensors are used, it is possible to determine when one of the sensors is not performing properly. For anemometers, poor performance is characterized by low data values. Therefore, if one sensor of the pair reports values significantly below the other, the low values are flagged. At low wind speeds (Test Fields 1 and 2 less than or equal to Factor 3) wind speed data are flagged if the absolute difference between the two wind speeds is greater than Factor 1. At high wind speeds (Test Fields 1 or 2 greater than Factor 3) wind speed data are flagged if the absolute value of the ratio of the two wind speeds is greater is greater than Factor 2.

$$\begin{gathered}[\ TF1 \leq F3 \text{ and } TF2 \leq F3 \text{ and } \mathrm{abs}(TF1 - TF2) > F1\ ] \\ \text{or } [\ (TF1 > F3 \text{ or } TF2 > F3) \text{ and } (\mathrm{abs}(1 - TF1 / TF2) > F2 \text{ or } \mathrm{abs}(1 - TF2 / TF1) > F2)\ ]\end{gathered}$$

Sensor Statistics

A summary of the results of the data collection and filtering are given in the Sensor Performance Report which is included in APPENDIX A. The following categories of information, tabulated for each sensor, are included in that report.

Expected Data Points: the total number of sample intervals between the start and end dates (inclusive).

Actual Data Points: the total number of data points recorded between the start and end dates.

% Data Recovered: the ratio of actual and expected data points (this is the *gross data recovered percentage*).

Hours Out of Range: total number of hours for which data were flagged according to MinMax and MinMaxT tests. These tests flag data which fall outside of an expected range.

Hours of Icing: total number of hours for which data were flagged according to Icing tests. This test uses the standard deviation of wind direction, air temperature, and wind speed to determine when sensor icing has occurred.

Hours of Fault: total number of hours for which data were flagged according to CompareSensors tests. These tests compare two sensors (e.g. primary and redundant anemometers installed at the same height) and flag data points where one sensor differs significantly from the other.

% Data Good: the filter results are subtracted from the gross data recovery percentage to yield the *net data recovered percentage*.

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	Test Field1	Test Field2	Test Field3	Calc Field1	Calc Field2	Calc Field3	TestType	Factor 1	Factor 2	Factor 3	Factor 4
1							TimeTest Insert				
10	Anem50aMS						MinMax	0	90		
11	Anem50bMS						MinMax	0	90		
12	Anem38aMS						MinMax	0	90		
13	Anem38bMS						MinMax	0	90		
14	Anem20aMS						MinMax	0	90		
20	AnemSD50aMS						MinMax	0	4		
21	AnemSD50bMS						MinMax	0	4		
22	AnemSD38aMS						MinMax	0	4		
23	AnemSD38bMS						MinMax	0	4		
24	AnemSD20aMS						MinMax	0	4		
30	Vane50aDEG						MinMax	0	359.9		
31	Vane38aDEG						MinMax	0	359.9		
32	Vane20aDEG						MinMax	0	359.9		
50	Turb50zNONE						MinMax	0	2		
51	Turb38zNONE						MinMax	0	2		
52	Turb20zNONE						MinMax	0	2		
60	Wshr0zNONE						MinMax	0	20		
70	Amax50aMS						MinMax	0	90		
71	Amin50aMS						MinMax	0	90		
72	Amax50bMS						MinMax	0	90		
73	Amin50bMS						MinMax	0	90		
74	Amax38aMS						MinMax	0	90		
75	Amin38aMS						MinMax	0	90		
76	Amax38bMS						MinMax	0	90		
77	Amin38bMS						MinMax	0	90		
78	Amax20aMS						MinMax	0	90		
79	Amin20aMS						MinMax	0	90		
80	Vmax50aDEGC						MinMax	0	359.9		
81	Vmin50aDEGC						MinMax	0	359.9		
82	Vmax38aDEGC						MinMax	0	359.9		
83	Vmin38aDEGC						MinMax	0	359.9		
84	Vmax20aDEGC						MinMax	0	359.9		
85	Vmin20aDEGC						MinMax	0	359.9		
200	VaneSD50aDEG	Anem50aMS					MinMaxT	0	100	100	10
201	VaneSD38aDEG	Anem38aMS					MinMaxT	0	100	100	10
202	VaneSD20aDEG	Anem20aMS					MinMaxT	0	100	100	10
300	Anem50aMS	AnemSD50aMS	Vane50aDEG	VaneSD50aDEG	Etmp3aDEGC		Icing	0.5	1	2	2
301	Anem50bMS	AnemSD50bMS	Vane50aDEG	VaneSD50aDEG	Etmp3aDEGC		Icing	0.5	1	2	2
302	Anem38aMS	AnemSD38aMS	Vane38aDEG	VaneSD38aDEG	Etmp3aDEGC		Icing	0.5	1	2	2
303	Anem20aMS	AnemSD20aMS	Vane20aDEG	VaneSD20aDEG	Etmp3aDEGC		Icing	0.5	1	2	2
400	Anem50aMS	Anem50bMS					CompareSensors	1	0.25	3	
401	Anem38aMS	Anem38bMS					CompareSensors	1	0.25	3	

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Etmp3aDEGC	54486	54394	99.831	8.5	0	0	99.738
EtmpSD3aDEGC	54486	54394	99.831	0	0	0	99.831
Anem50aMS	54486	54394	99.831	0.167	18	21.167	99.398
AnemSD50aMS	54486	54394	99.831	0.167	18	16.167	99.453
Anem50bMS	54486	54394	99.831	0.167	18.167	40.667	99.181
AnemSD50bMS	54486	54394	99.831	0.167	18.167	21.333	99.394
Anem38aMS	54486	54394	99.831	0.167	20.167	2.167	99.583
AnemSD38aMS	54486	54394	99.831	0.167	20.167	1	99.596
Anem38bMS	54486	54394	99.831	0.333	0	65.667	99.104
AnemSD38bMS	54486	54394	99.831	0.333	0	29.667	99.501
Anem20aMS	54486	54394	99.831	0	20.333	0	99.607
AnemSD20aMS	54486	54394	99.831	0	20.333	0	99.607
Vane50aDEG	54486	54332	99.717	0.833	18.167	0	99.508
VaneSD50aDEG	54486	54332	99.717	2	18.167	0	99.495
Vane38aDEG	54486	54394	99.831	1.5	20.167	0	99.593
VaneSD38aDEG	54486	54394	99.831	2.333	20.167	0	99.583
Vane20aDEG	54486	54394	99.831	2	20.333	0	99.585
VaneSD120aDEG	54486	54394	99.831	3.333	20.333	0	99.571
Total	**54486**	**54394**	**99.831**	**0.167**	**18**	**0.167**	**99.629**

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent of Time [%]
0.5	0.5
1.5	1.5
2.5	2.5
3.5	3.5
4.5	4.5
5.5	5.5
6.5	6.5
7.5	7.5
8.5	8.5
9.5	9.5
10.5	10.5
11.5	11.5
12.5	12.5
13.5	13.5
14.5	14.5
15.5	15.5
16.5	16.5
17.5	17.5
18.5	18.5
19.5	19.5
20.5	20.5
21.5	21.5
22.5	22.5
23.5	23.5
24.5	24.5

Monthly Average Wind Speed Data

Date	10 min Mean [m/s]
Jul 2006	4.99
Aug 2006	4.71
Sep 2006	5.00
Oct 2006	6.12
Nov 2006	5.44
Dec 2006	4.89
Jan 2007	5.53
Feb 2007	6.38
Mar 2007	6.02
Apr 2007	5.4
May 2007	5.6
June 2007	4.86
July 2007	4.9

Diurnal Average Wind Speed Data

Hour of Day	Average Wind Speed [m/s]
0.5	5.59
1.5	5.60
2.5	5.59
3.5	5.54
4.5	5.52
5.5	5.52
6.5	5.53
7.5	5.57
8.5	5.81
9.5	6.08
10.5	6.23
11.5	6.33
12.5	6.33
13.5	6.32
14.5	6.21
15.5	6.00
16.5	5.70
17.5	5.42
18.5	5.43
19.5	5.49
20.5	5.52
21.5	5.54
22.5	5.56
23.5	5.59

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	6.66	5.08
NNE	4.62	5.26
NE	5.16	6.00
ENE	3.17	5.42
E	2.77	5.22
ESE	2.57	6.35
SE	3.07	5.73
SSE	3.47	5.46
S	3.96	4.63
SSW	5.36	5.14
SW	13.43	6.15
WSW	11.87	6.11
W	7.48	5.52
WNW	8.71	5.96
NW	8.43	6.14
NNW	9.28	6.01