WIND DATA REPORT

Savoy

March 1, 2004 – May 31, 2004

Prepared for

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by

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EXECUTIVE SUMMARY

Wind monitoring equipment was first installed in Savoy on November 8, 2003. Anemometers and wind direction vanes are installed at 20m, 39m, and 50m above the tower base. Data are transmitted to RERL via modem on a weekly schedule.

This is the third quarterly report since the tower installation and the second with an entire quarter's worth of data, from March 1, 2004 to May 31, 2004. The mean recorded wind speed was 6.01 m/s (13.4 mph) at 50 m and the prevailing wind direction was from the WNW. The average wind shear factor of 0.24, calculated from data from the 50 m and 39 m anemometers. The average turbulence intensity at 50m was 0.22, well within the normal values recorded at other sites in eastern MA.

The gross data recovery percentage (the actual percentage of expected data received) was 99.99 % and the net data recovery percentage (the percentage of expected data which passed all of the quality assurance tests) was 87.16 %. The gross data recovery is good but the net data recovered is low because of an anemometer failure that occurred within the first few days of logging and because to recurring problems with some of the wind direction vanes.

SECTION 1 - Station Location

The Savoy, MA station is located on privately owned land on a cleared hilltop. 40-50ft tall trees surround the site in every direction. Several trees were removed to create a clearing for the tower approximately 250 ft in diameter. There is a 1-2ft layer of topsoil above the rock surface. Poor drainage results in the area being very wet, almost boggy. The location of the tower base is 42.6034 N, 072.9699 W (NAD 27).

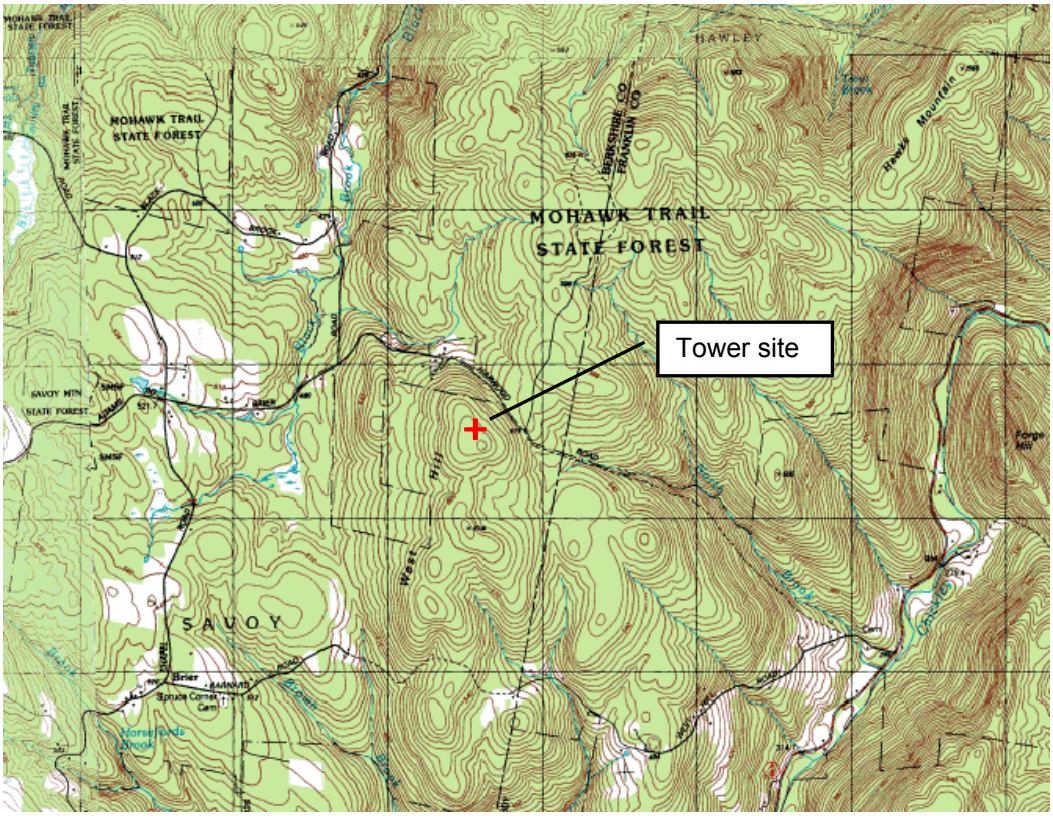

Figure 1 – Map of Savoy site.

Source: www.topozone.com.

SECTION 2 - Instrumentation and Equipment

Wind monitoring equipment is mounted on a standard WindMast™ 50-meter tall 6in diameter tilt-up guyed tower purchased from Second Wind Inc. Four rock anchors were installed and proof tested at 7,400-8,000 lbs load for 10 minutes (equal to 160mph loading without ice). Wind vanes and anemometers are located at three heights on the tower: 20m, 39m, and 50m. Redundant anemometers exist at 39m and 50m. Additional equipment and models:

- NRG model 9300 Cellogger®
- 5 – #40 Anemometers, standard calibration (Slope - 0.765 m/s, Offset – 0.350 m/s)
- 3 - #200P Wind direction vanes
- 3 – Sensor booms, 54" length
- 4 – Rock anchors
- Lightning rod and grounding cable
- Shielded sensor wire

Figure 2 – 50m data tower in Savoy during installation.

SECTION 3 - Data Collection and Maintenance

There have been data transmission problems and sensor problems this quarter. These have been problematic but have not adversely affected the overall data collection effort.

The data logger has had trouble connecting with Umass to download the data each week. This has been addressed by periodic visits to the site to collect the data manually. It is unclear what the source of the problem is.

All anemometers, except one at 50 m, which failed within the first 20 minutes of operation, have been working well. The vanes have evidenced recurring problems but enough data has been available to correctly determine the wind direction. All vanes were working most of the time over the quarter, but the 50 m vane, which had been fairly reliable, seems to have failed irreparably on May 15. All data have been examined and faulty data has been manually flagged.

These problematic sensors will continue to be closely monitored as data arrives at RERL and appropriate actions will be planned if problems persist.

Data Statistics Summary

	Anemometer 50m			Anemometer 39m			Anemometer 20m			10m to 39m	Vane 50m	Vane 39m	Vane 20m
Date	Mean [m/s]	Max [m/s]	Turb. Int. [ ]	Mean [m/s]	Max [m/s]	Turb. Int [ ]	Mean [m/s]	Max [m/s]	Turb. Int. [ ]	Shear [ ]	Prev. Dir	Prev. Dir	Prev. Dir
Mar 2003	6.37	22.98	0.22	6.12	22.14	0.23	4.29	16.22	0.35	0.22	WNW	WNW	WNW
Apr 2004	6.26	18.23	0.21	6.08	18.43	0.22	4.27	12.52	0.33	0.18	WNW	WNW	WNW
May 2004	5.41	15.18	0.23	5.04	13.92	0.25	3.36	10.02	0.39	0.32	NA**	WNW	WNW
Mar – May 04	6.01	22.98	0.22	5.75	22.14	0.23	3.97	16.22	0.36	0.24	NA**	WNW	WNW

** The intermittent vanes failures, prevailing wind directions cannot be accurately reported.

SECTION 4- Significant Meteorological Events

The most significant weather event in this quarter occurred March 16 and 17, when a winter storm struck Berkshire County. Snowfall accumulations ranged from 5 to 10 inches, with 7.0 inches in Pittsfield and 9.5 at Florida, just north of Savoy. In addition, as much as three inches of rain fell between March 31 through April 2 across western

Massachusetts. This rain combined with the last of the snowmelt to produce an excessive runoff of water and local flooding.

Aside from these events the National Climatic Data Center (NCDC) listed no significant storm events for Berkshire County during the first three months of from March through May, 2004 (see their website, http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms)

SECTION 5 - 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 [%]	99.986
Net Data Recovered [%]	87.156

The gross data recovery is good but the net data recovered is low because of the anemometer failure that occurred within the first few days of logging and the occasional vane failures at 20m and 39m. Due to the unusual nature of the vane failures, the standard filters did not catch all the problems and some data were incorrectly counted as recovered data. The data from these vanes is clearly corrupted and all faulty data for this period were manually flagged.

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.

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

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 speed (TF2) is less than or equal to Factor 1 (F1), the wind direction standard deviation (TF1) is less 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.

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

Sensor Statistics

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*.

SECTION 6 - Data Summary

Comment [CNE3]: You can add a summary of trends or comments about specific plots to the paragraph describing that type of plot, or in a paragraph following the descriptions.

This report contains the following types of wind data graphs:

- Time Series – 10-minute average wind speeds are plotted against time.
- Wind Speed Distribution – A histogram plot giving the percentage of time that the wind is at a given wind speed. The distribution peak occurs between 5 and 6 m/s.
- Monthly Average – A plot of the monthly average wind speed during the data collection period. This graph shows the trends in the wind speed over the year.
- Diurnal – A plot of the average wind speed for each hour of the day. This site has a fairly even diurnal distribution, with a slight decrease in wind speeds in the morning hours and a slight increase late in the day.
- 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. The average turbulence intensity was 0.22 at 50 m. This is a typical value for a forested site with rough terrain.
- 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. This graph shows a clear prevailing wind direction from the WNW and show that the mean wind speeds are , in general, greater from the west. .

SECTION 7 - Graphs

Comment [CNE4]: Please use the Insert Caption feature to give all graphs have an auto-numbered caption.

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

Wind Speed Time Series

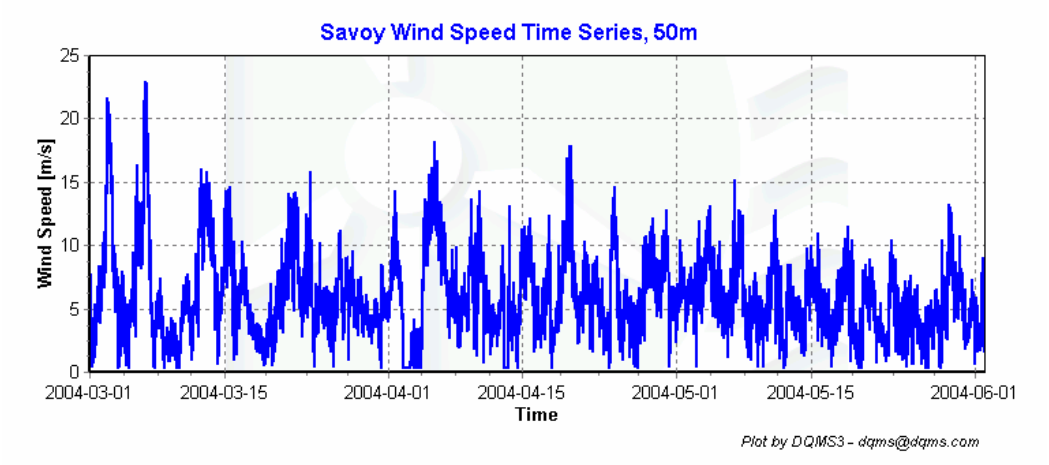

Figure 3 – Wind Speed Time Series, March 1, 2004 – May 31, 2004

Wind Speed Distributions

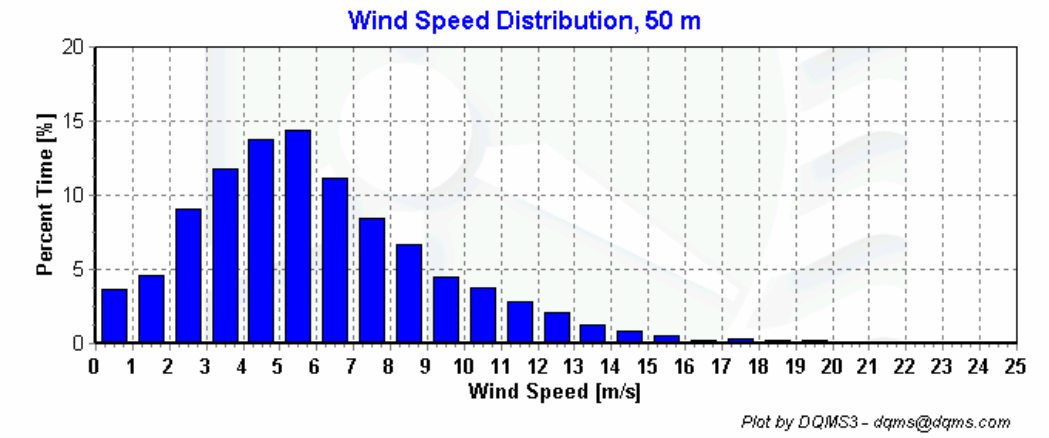

Figure 4 – Wind Speed Distribution, March 1, 2004 – May 31, 2004

Monthly Average Wind Speed

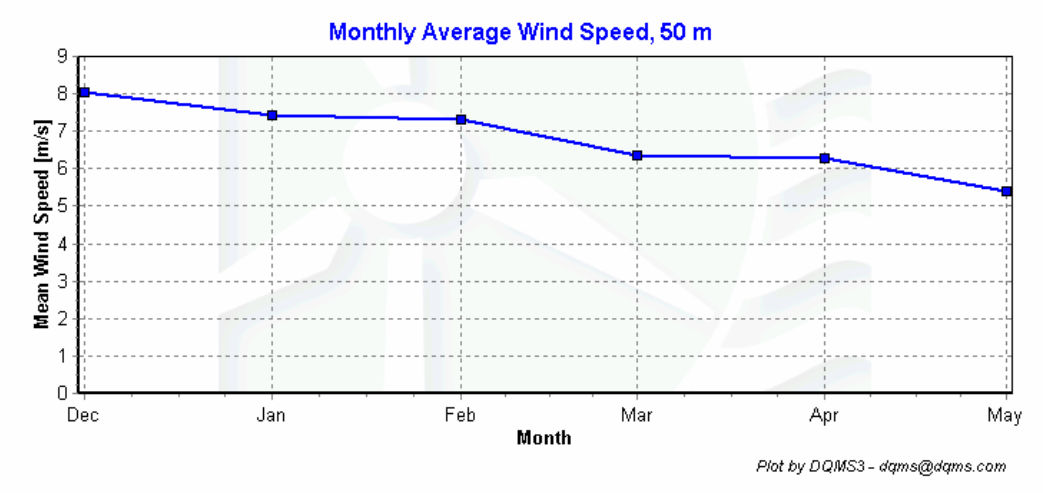

Figure 5 – Monthly Average Wind Speed, December, 2003 – May, 2004

Diurnal Average Wind Speeds

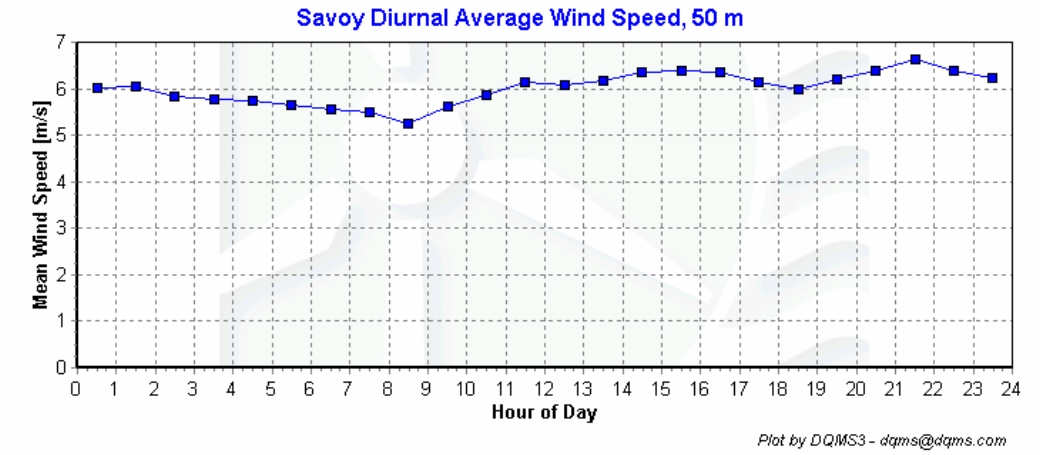

Figure 5 – Diurnal Wind Speed, March 1, 2004 – May 31, 2004

Turbulence Intensities

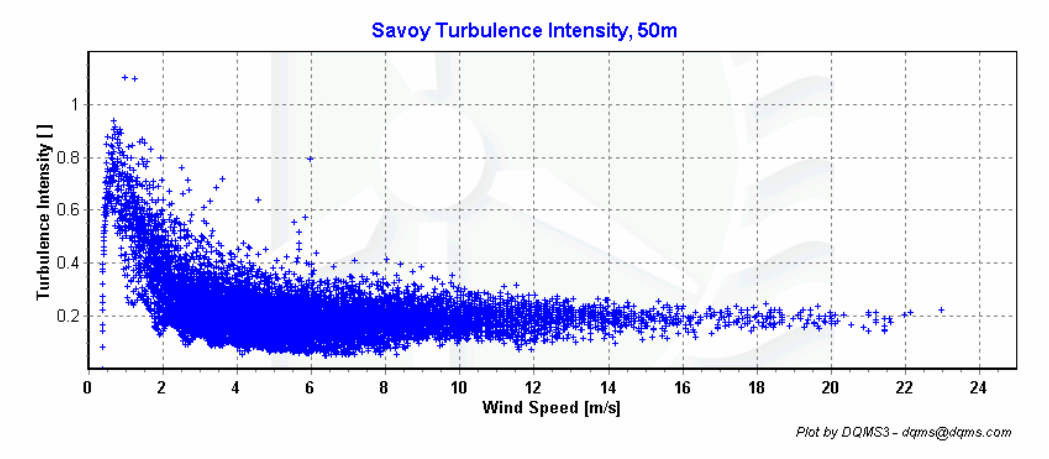

Figure 6 - Turbulence Intensity vs Wind Speed, March 1, 2004 – May 31, 2004

Wind Roses

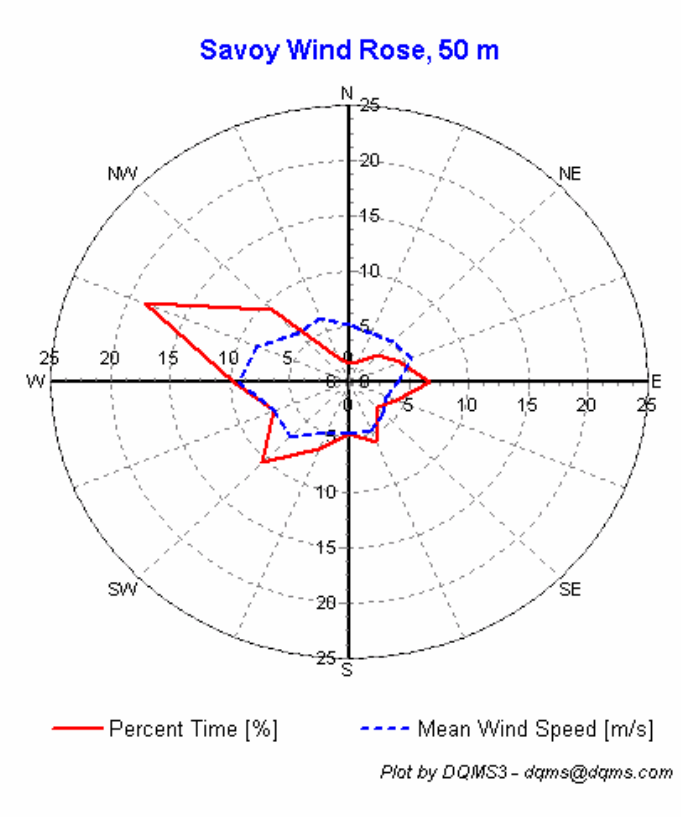

Figure 7 – Wind Rose, March 1, 2004 – May 31, 2004

APPENDIX A - Sensor Performance Report

Test Definitions

Test Order	Test Field1	Test Field2	Test Field3	Calc Field1	Calc Field2	Calc Field3	Test Type	Factor 1	Factor 2	Factor 3	Factor 4
1							TimeTest Insert				
2	Itemp2aDEGC						MinMax	-30	60	0	0
3	Batt2aVDC						MinMax	10.5	15	0	0
4	Etmp2aDEGC						MinMax	-30	60		
5	EtmpSD2aDEGC						MinMax	-30	60		
10	Anem50aMS						MinMax	0	90	0	0
11	Anem50bMS						MinMax	0	90	0	0
12	Anem39aMS						MinMax	0	90	0	0
13	Anem39bMS						MinMax	0	90	0	0
14	Anem20aMS						MinMax	0	90		
20	AnemSD50aMS						MinMax	0	5.5		
21	AnemSD50bMS						MinMax	0	5.5		
22	AnemSD39aMS						MinMax	0	5.5		
23	AnemSD39bMS						MinMax	0	5.5		
24	AnemSD20aMS						MinMax	0	5.5		
30	Vane50aDEG						MinMax	0	359.9		
31	Vane39aDEG						MinMax	0	359.9		
32	Vane20aDEG						MinMax	0	359.9		
200	VaneSD50aDEG	Anem50yMS					MinMaxT	0	100	100	10
201	VaneSD39aDEG	Anem39yMS					MinMaxT	0	100	100	10
202	VaneSD20aDEG	Anem20aMS					MinMaxT	0	100	100	10
300	Anem50aMS	AnemSD50aMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC		Icing	5	10	5	10
301	Anem50bMS	AnemSD50bMS	Vane50aDEG	VaneSD50aDEG	Etmp2aDEGC		Icing	5	10	5	10
302	Anem39aMS	AnemSD39aMS	Vane39aDEG	VaneSD39aDEG	Etmp2aDEGC		Icing	5	10	5	10
303	Anem39bMS	AnemSD39bMS	Vane50aDEG	VaneSD39aDEG	Etmp2aDEGC		Icing	5	10	5	10
304	Anem20aMS	AnemSD20aMS	Vane20aDEG	VaneSD20aDEG	Etmp2aDEGC		Icing	5	10	5	10
400	Anem50aMS	Anem50bMS					CompareSensors	1	0.25	3	0
401	Anem39aMS	Anem39bMS					CompareSensors	1	0.25	3	0
500	Anem50yMS						MinMax	0	90		
501	Anem39yMS						MinMax	0	90		
502	AnemSD50yMS						MinMax	0	5.5		
503	AnemSD39yMS						MinMax	0	5.5		
504	Turb50zNONE						MinMax	0	4		
505	Turb39zNONE						MinMax	0	4		
506	Turb20zNONE						MinMax	0	4		
507	Pwrd50zWMC						MinMax	0	1200		
508	Pwrd39zWMC						MinMax	0	1200		
509	Pwrd20zWMC						MinMax	0	1200		
510	Wshr0zNone						MinMax	-1	4		

Sensor Statistics

Sensor	Expected Data Points	Actual Data Points	% Data Recovered	Hours Out of Range	Hours of Icing	Hours of Fault	% Data Good
Itemp2aDEGC	13248	13246	99.985	0	0	0	99.985
Batt2aVDC	13248	13246	99.985	0	0	0	99.985
Anem50aMS	13248	13248	100	0	0	2208	0
AnemSD50aMS	13248	13248	100	0	0	2208	0
Anem50bMS	13248	13246	99.985	0	0	0	99.985
AnemSD50bMS	13248	13246	99.985	0	0	0	99.985
Anem39aMS	13248	13246	99.985	0	0	12.833	99.404
AnemSD39aMS	13248	13246	99.985	0	0	12.833	99.404
Anem39bMS	13248	13246	99.985	0	0	8.833	99.585
AnemSD39bMS	13248	13246	99.985	0	0	8.833	99.585
Anem20aMS	13248	13246	99.985	0	0	0	99.985
AnemSD20aMS	13248	13246	99.985	0	0	0	99.985
Vane50aDEG	13248	13246	99.985	0	31.667	391.5	80.82
VaneSD50aDEG	13248	13246	99.985	0	31.667	391.5	80.82
Vane39aDEG	13248	13246	99.985	1	46	47.167	95.72
VaneSD39aDEG	13248	13246	99.985	1	46	47.167	95.72
Vane20aDEG	13248	13246	99.985	2.333	44.667	39	96.09
VaneSD20aDEG	13248	13246	99.985	2.333	44.667	39	96.09
Etmp2aDEGC	13248	13246	99.985	0	0	0	99.985
EtmpSD2aDEGC	13248	13246	99.985	0	0	0	99.985
Total	264960	264924	99.986	6.667	244.667	5414.667	87.156

APPENDIX B - Plot Data

Wind Speed Distribution Data

Bin Center Wind Speed [m/s]	Percent
0.5	3.62
1.5	4.62
2.5	9.03
3.5	11.73
4.5	13.72
5.5	14.37
6.5	11.12
7.5	8.41
8.5	6.64
9.5	4.51
10.5	3.78
11.5	2.76
12.5	2.06
13.5	1.2
14.5	0.79
15.5	0.51
16.5	0.25
17.5	0.26
18.5	0.26
19.5	0.16
20.5	0.09
21.5	0.08
22.5	0.02
23.5	0
24.5	0

Table B1: Wind Speed Distribution

Diurnal Average Wind Speed Data

Hour of Day	Wind Speed [m/s]
0	6.02
1	6.04
2	5.83
3	5.77
4	5.73
5	5.66
6	5.55
7	5.5
8	5.24
9	5.62
10	5.87
11	6.14
12	6.07
13	6.17
14	6.35
15	6.37
16	6.36
17	6.15
18	6
19	6.19
20	6.39
21	6.64
22	6.39
23	6.23

Table B3: Diurnal Wind Speed

Wind Rose Data

Direction	Percent Time [%]	Mean Wind Speed [m/s]
N	1.66	5.2
NNE	1.98	4.71
NE	3.34	5.24
ENE	4.56	5.6
E	6.76	4.14
ESE	4.3	3.37
SE	3.32	4.06
SSE	5.88	4.79
S	4.68	4.68
SSW	6.59	4.94
SW	10.36	6.97
WSW	6.86	6.77
W	9.72	9.28
WNW	18.57	8.35
NW	9.14	6.21
NNW	2.27	6.15

Table B4: Wind Rose Time Percentage and Mean Wind Speed