

OREGON ANEMOMETER LOAN PROGRAM

Wind Resource Evaluation: Fir Mountain 50m Tower Site



Prepared By:
Energy Resources Research laboratory
Oregon State University

August 24, 2009

NOTICE

This publication was prepared as an account of work sponsored by the Energy Trust of Oregon, Inc. Neither the Energy Trust of Oregon, Inc. nor any of their contractors, subcontractors, or their employees make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, usefulness, or reliability of the research data, and conclusions reported herein, or of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. For these reasons and for the reason that the views, opinions, and conclusions contained in this material are those of the contractor.

OREGON ANEMOMETER LOAN PROGRAM

Wind Resource Evaluation: Fir Mountain 50m Tower Site

Prepared by:

**Philip L. Barbour
Stel N. Walker, Ph.D.
Energy Resources Research Laboratory
Department of Mechanical Engineering
Oregon State University
Corvallis, OR 97331**

Sponsor:

**Energy Trust of Oregon, Inc.
733 SW Oak Street, Suite 200
Portland Oregon, 97205**



1.0 *SITE DESCRIPTION*

Site Name:	Fir Mountain 50m
Latitude:	45 36.675 N (WGS 84)
Longitude:	121 28.509 W
Elevation:	2457 ft. (749 m)
County:	Hood River
Tower Height:	50 meter
Types of Sensors:	NRG Maximum #40 wind speed NRG 200 series2 wind vane
Instrumentation:	50m (164 ft.) – Wind Speed (2) 40m (131.2 ft.) – Wind Speed (2) 31.6m (103.6 ft.) – Wind Speed (2) 48m (157.4 ft.) – Wind Direction 38m (124.6 ft.) – Wind Direction
Types of Data:	10 min. average wind speed (mph) 10 min. mean wind direction (deg) 10 min temperature (Deg F) Standard Deviation, maximum and minimum over 10 min. period also available for each data type.
Installation Date:	June 6, 2008
Data Available to:	July 31, 2009

Site Location: The site is located on the edge of a sharp ridge south of the City of Hood River. The Ridge is oriented N-S and extends north to the Columbia River and well to the south. There is good exposure to the west with a wide Valley and Mount Hood to the south-east at a distance. The exact location of the tower with respect to the edge of the ridge is not clear. The approximate tower location is marked on the map included in Appendix A.

Project Description: The landowner is interested in exploring the possibility of a small wind project at the site.

2.0 WIND DATA PROCESSING

NRG equipment was used at this site including #40 anemometers and a Symphony data logger. Data chips were swapped out on roughly a monthly basis by a nearby land owner and sent to the ERRL. Raw NRG Symphony files were read and downloaded from the data cards. NRG Symphony software was used to read these files and produce monthly files of ten minute averages. These files were then converted to hourly averages and converted to an internal ERRL format to accommodate data checking and to perform analysis using existing programs. In this process each level/site combination is assigned a two digit site code. These codes are listed in Table 1.

Table 1: Site codes and information for the Fir Mountain 50m site location.

Site ID	Site Name	Latitude	Longitude	Elev.	Sensor Ht	Period of Record
		dd-mm.mm	dd-mm.mm	(ft)	(ft)	
F1	Fir Mtn.	45 36.675	121 28.509	2457	164.0	June 6,2008 - July 31, 2009
F2	Fir Mtn.	45 36.675	121 28.509	2457	131.2	June 6,2008 - July 31, 2009
F3	Fir Mtn.	45 36.675	121 28.509	2457	103.6	June 6,2008 - July 31, 2009

In addition to the filter available for use with the NRG Symphony software, data files were also scanned manually to identify any additional periods in which ice was might be present and to identify any additional problems. Several significant and sustained icing periods were detected primarily during the months of January and February and 2009.

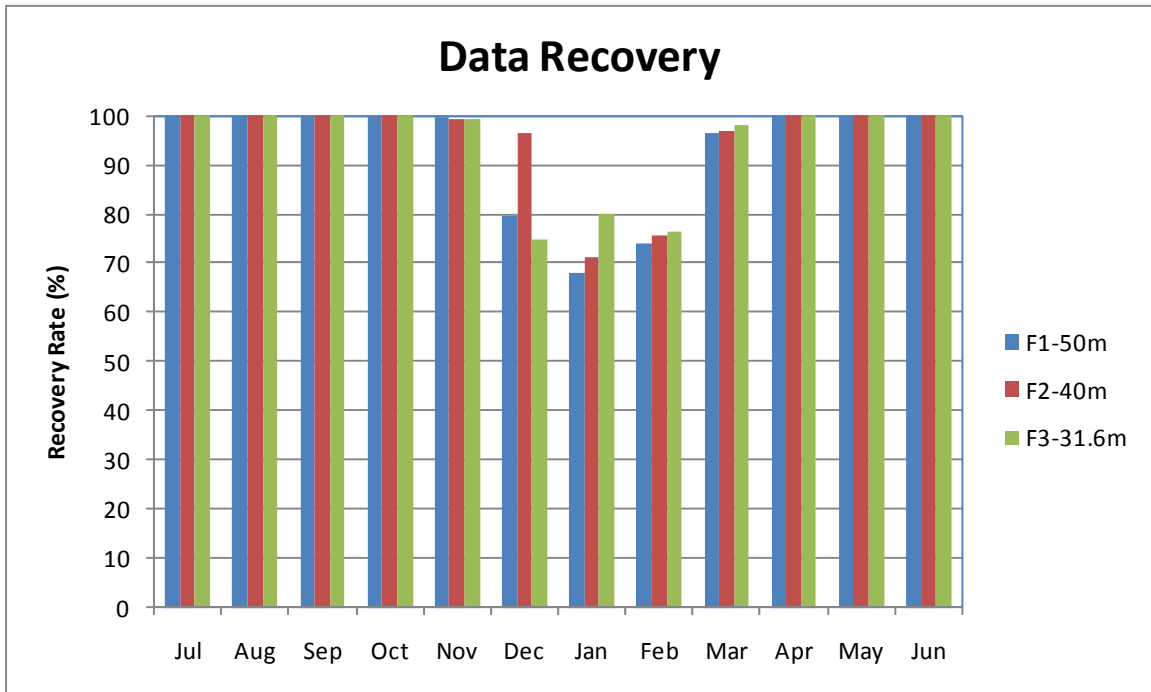


Figure 1: Data recovery for the 3 levels of the Fir Mountain 50m site.

3.0 WIND CHARACTERISTICS

In the following sections, several characteristics of the winds at the Fir Mtn. site are examined and discussed. The goals are to evaluate the characteristics that can help explain the physical processes at work at the site and to highlight the properties that are important to assessing the wind energy potential. These evaluations are done using hourly averaged means that have been constructed using the 10 minute means recorded at the site. This is done so that existing analysis programs can be used and is not expected to have any appreciable influence on the interpretation of data. Plots of various quantities are included in this section and more complete tables can be found in Appendix B.

This analysis is also confined to a single annual period. This is done so that the results are not biased by the addition of data from only a single season or a portion of a year. *The period analyzed here is for July 1, 2008 to June 30 2009.*

Monthly Means:

Table 2: Monthly Mean Wind Speed Values and data recovery rates for the annual study period.

Month	F1 (164')		F2(131')		F3 (104')	
	(mph)	Rec. (%)	(mph)	Rec. (%)	(mph)	Rec. (%)
Jul	15.4	100.00	14.6	100.00	13.0	100.00
Aug	13.6	100.00	13.0	100.00	11.4	100.00
Sep	12.9	100.00	12.3	100.00	10.8	100.00
Oct	11.4	100.00	10.6	100.00	9.4	100.00
Nov	12.3	99.72	11.5	99.17	10.2	99.31
Dec	14.9	79.44	12.8	96.37	12.9	74.73
Jan	17.1	68.15	15.5	71.24	13.0	79.97
Feb	10.6	73.85	9.8	75.57	8.6	76.44
Mar	16.7	96.51	15.8	96.64	14.1	98.12
Apr	15.1	100.00	14.3	100.00	13.0	100.00
May	14.3	100.00	13.6	100.00	12.3	100.00
Jun	17.8	100.00	16.8	100.00	15.4	100.00
ANN	14.3	93.17	13.4	94.97	12.0	94.08

Diurnal Means:

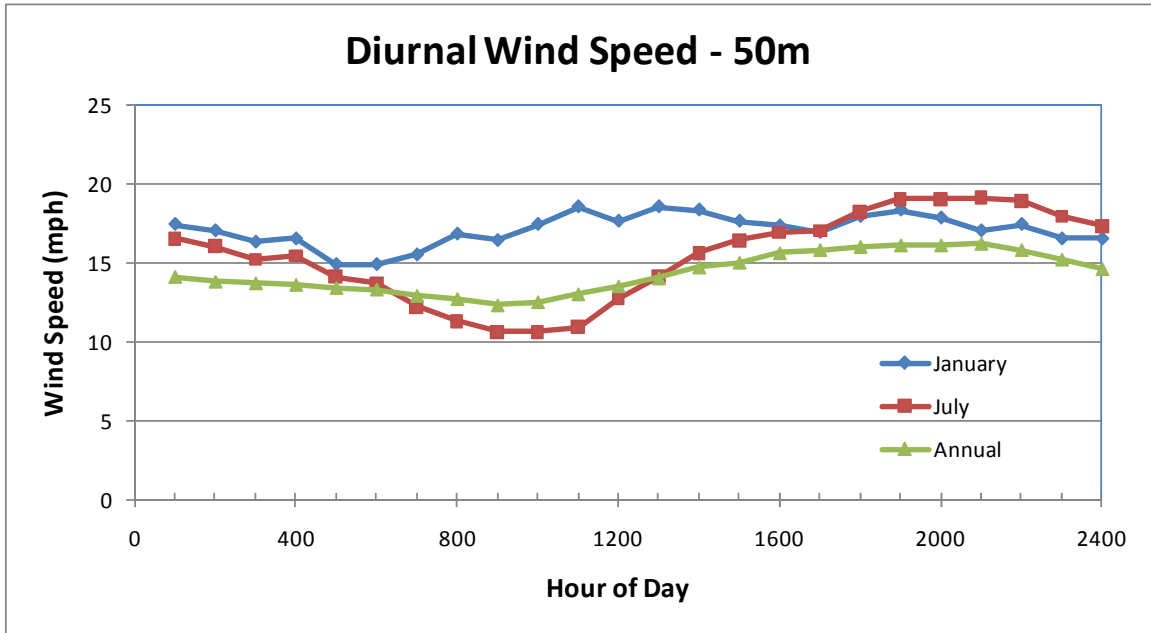


Figure 2: Diurnal mean wind speed values for the 50 m level of the Fir Mtn. 50 meter Site.

Frequency Distribution:

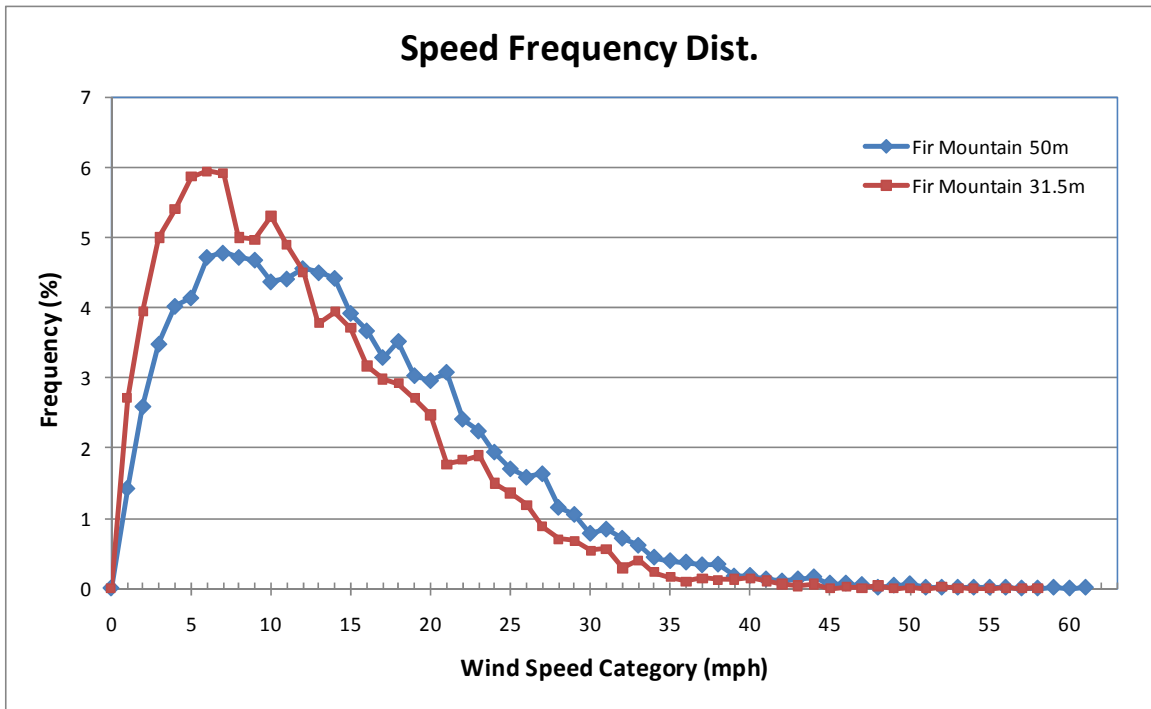


Figure 3: Wind speed frequency distribution for the 50m and 31.5 m levels of the Fir Mtn. 50 meter Site.

Wind Rose:

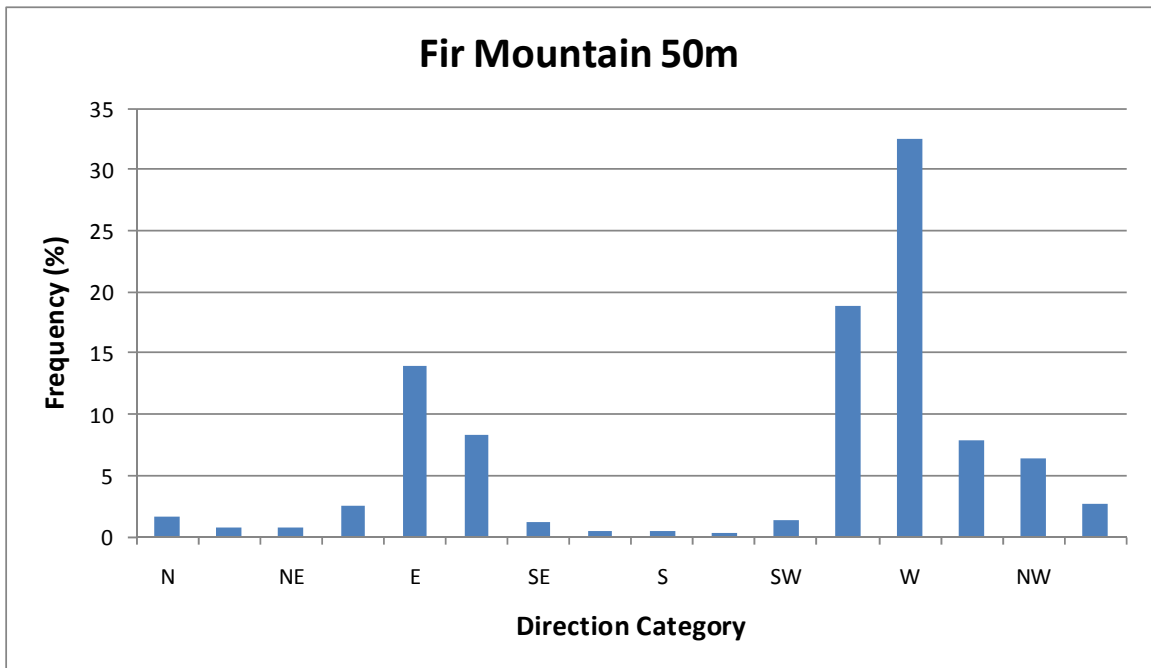
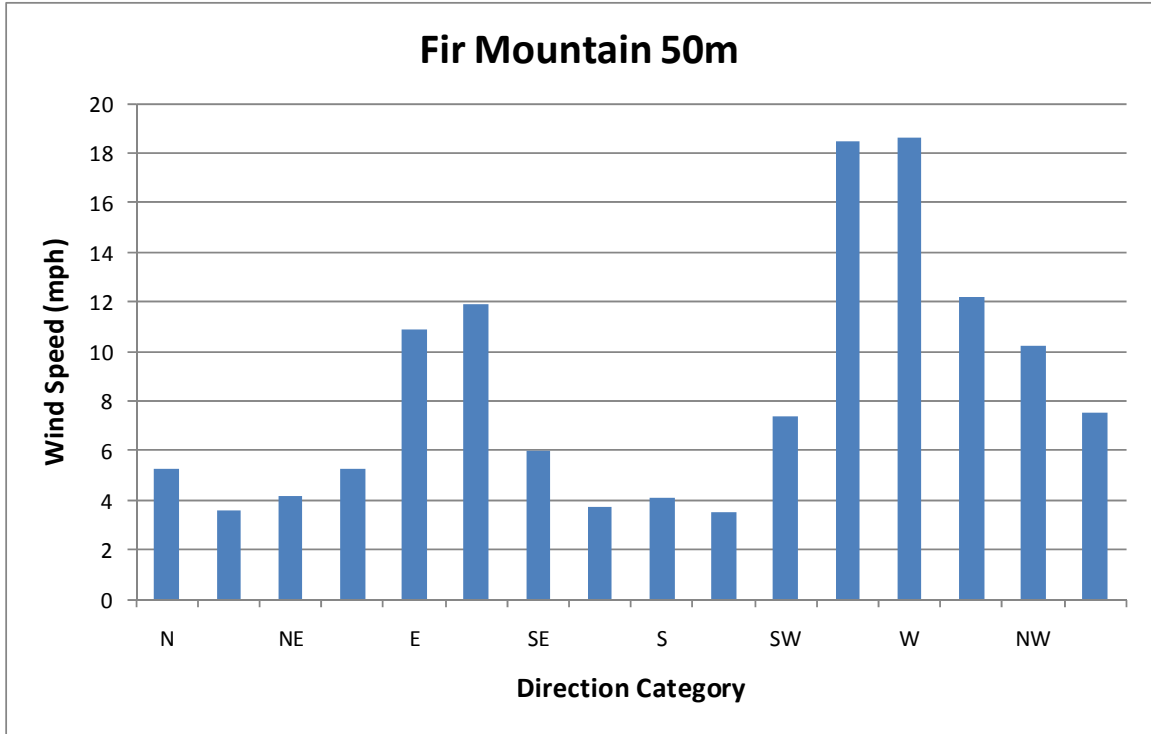


Figure 4a-b: Frequency (%) and average wind speed (mph) for each of 16 wind direction categories from the 50m level of the Fir Mtn. 50 meter Site.

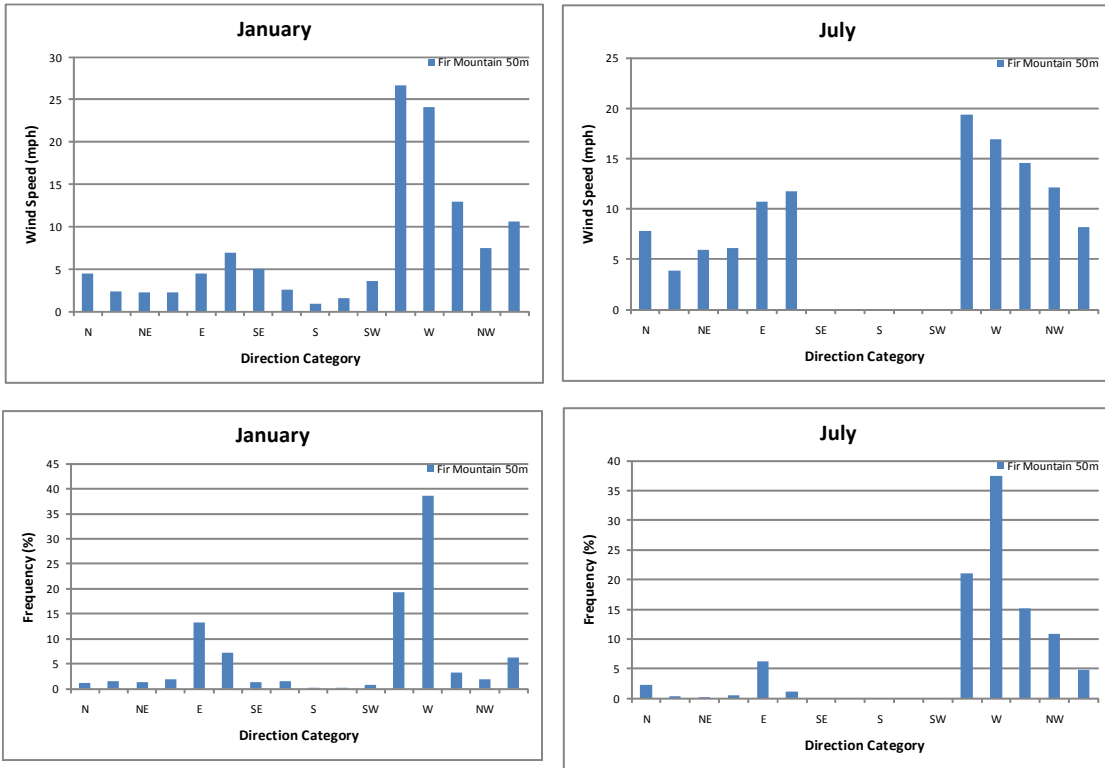


Figure 5a-d: Frequency (%) and average wind speed (mph) for each of 16 wind direction categories for the months of January and July from the 50m level of the Fir Mtn. 50 meter Site.

4.0 CLIMATOLOGICAL ANALYSIS

Measurements taken over a single one-year period can provide a good estimation of the winds and wind energy potential of a site. However, this is a fairly limited period and is only meaningful if we can place the period into a larger climatological context. The difficulty with this is usually finding appropriate long-term sites to base this on. For the current site, the nearest sites with good quality long-term records are two sites within the BPA long-term wind monitoring network. These sites include Sevenmile Hill and Goodnoe Hills. These long-term normals are taken using data from 1980 to 2009.

The wind speed departures show that the winds at both sites were very close to normal for the period as a whole. There were, however, several individual months in which the winds varied significantly from normal. Unfortunately, there is no clear pattern or agreement between these two sites, knowledge of the meteorological conditions in the area would suggest that Sevenmile Hill would best indicate conditions during the spring and summer and Goodnoe Hills would likely be best for the winter months.

Table 3: Monthly mean and departures for winds at two BPA long-term wind sites. Current period is July 2008 to June 2009.

SEVENMILE HILL - BPA				GOODNOE HILLS - BPA			
	Current	Mean	Depart.		Current	Mean	Depart.
Month	(mph)	(mph)	(%)	Month	(mph)	(mph)	(%)
JUL	22.4	21.3	5.2	JUL	16.8	16.6	1.2
AUG	18.5	19.6	-5.6	AUG	9.9	15.5	-36.1
SEP	14.3	15.9	-10.1	SEP	16.0	13.9	15.1
OCT	13.6	12.7	7.1	OCT	15.1	13.2	14.4
NOV	10	9.8	2.0	NOV	15.3	13.1	16.8
DEC	10.9	9.6	13.5	DEC	16.9	11.9	42.0
JAN	14.1	10.5	34.3	JAN	16.3	13.1	24.4
FEB	7.6	10.1	-24.8	FEB	15.5	12.6	23.0
MAR	15.4	13.2	16.7	MAR	11.3	14.3	-21.0
APR	16.7	15.6	7.1	APR	12.0	16.0	-25.0
MAY	15.7	18.8	-16.5	MAY	12.6	16.6	-24.1
JUN	21.9	20.2	8.4	JUN	13.9	17.2	-19.2
ANN	15.1	15.0	0.6	ANN	14.3	14.6	-2.1

In addition to these long-term sites there is a small weather station located to the west of Fir Mountain near another Anemometer Loan Program site on Middle Mountain. This station is part of the RAWS network (Remote automated Weather Stations) managed by the Forest Service and BLM. The station has continuous data but the site is not well suited to accurately evaluate wind variability. The sensor is located near the ground and is surrounded by a number of tall trees. Nevertheless, it is worth examining here.

Middle Mtn. RAWS			
Month	Current (mph)	Mean (mph)	Depart. (%)
JUL	8.9	7.7	16.2
AUG	8.2	7.8	5.3
SEP	7.2	8.9	-18.5
OCT	6.6	8.4	-22.1
NOV	7.1	7.6	-6.1
DEC	8.2	7.5	9.2
JAN	8.1	7.7	5.9
FEB	5.6	8.6	-34.3
MAR	9.0	9.1	-1.3
APR	8.6	9.2	-6.1
MAY	8.2	9.5	-13.0
JUN	9.1	8.6	6.3
ANN	7.9	8.3	-4.8

The Middle Mountain site shows the winds were slightly below normal for this period overall and that several months had winds well below normal (September, October, February). Overall, these three sites suggest the winds were likely close to normal for this annual analysis period.

5.0 SITE POWER CHARACTERISTICS

In order to evaluate the wind power potential at this site a number of quantities were computed using the collected wind data. As with the wind characteristics, hourly wind data was used to complete this work. The power density calculation requires air density. This is estimated assuming a standard atmosphere and the site elevation. The computed quantities include the monthly mean and recovery rate of the hourly values, the maximum one hour average, the available power, the frequency that the wind was observed within a wind speed range (12 mph to 60 mph) and the shear coefficient (alpha). These quantities are shown in Table 5 and reveal a number of things about the potential for generating energy at the site.

Table 5: Observed and computed power quantities for the Fir Mtn. 50 meter Site. Values shown are for the 50m (164 ft.) and 31.2m (104 ft.) levels. The last three columns are for the 50m level.

Month	164 ft.		104 ft.		Shear Factor	Max 1-Hr (mph)	Time in Range (12-60) mph (%)	Available Energy kWh/m**2
	Mean	Recovery	Mean	Recovery				
	(mph)	Rate (%)	(mph)	Rate (%)				
Jul	15.4	100.00	13.0	100.00	0.369	36.7	62.80	231
Aug	13.6	100.00	11.4	100.00	0.398	37.8	52.70	187
Sep	12.9	100.00	10.8	100.00	0.403	37.5	48.60	155
Oct	11.4	100.00	9.4	100.00	0.420	36.6	42.90	119
Nov	12.3	99.70	10.2	99.30	0.419	50.4	41.80	237
Dec	14.9	79.40	12.9	74.70	0.310	43.8	57.90	277
Jan	17.1	68.10	13.0	80.00	0.310	53.3	57.40	566
Feb	10.6	76.50	8.6	79.20	0.458	33.4	34.80	99
Mar	16.7	96.50	14.1	98.10	0.359	54.1	62.30	398
Apr	15.1	100.00	13.0	100.00	0.328	42.2	59.70	256
May	14.3	100.00	12.3	100.00	0.342	37.5	55.00	233
Jun	17.8	100.00	15.4	100.00	0.318	44.3	71.40	362
ANN	14.3	93.40	12.0	94.30	0.383	54.1	54.30	3045

The most significant feature of this table is the high shear factor observed at the site. These values are generally in a range between 0.10 and 0.14 but here exceed 0.400 for every month. This indicates a strong increase in wind speed with height. This is likely a result of two factors. First, the site is located on the edge of a sharp ridge and the flow up and over might be missing the lower levels of the tower in some cases. There are also trees along the leading edge of the ridge that might be contributing to or enhancing this effect. This appears to be an issue at the lower two sensor levels and similar shear factors were found between the 40m and 50m levels (although slightly lower).

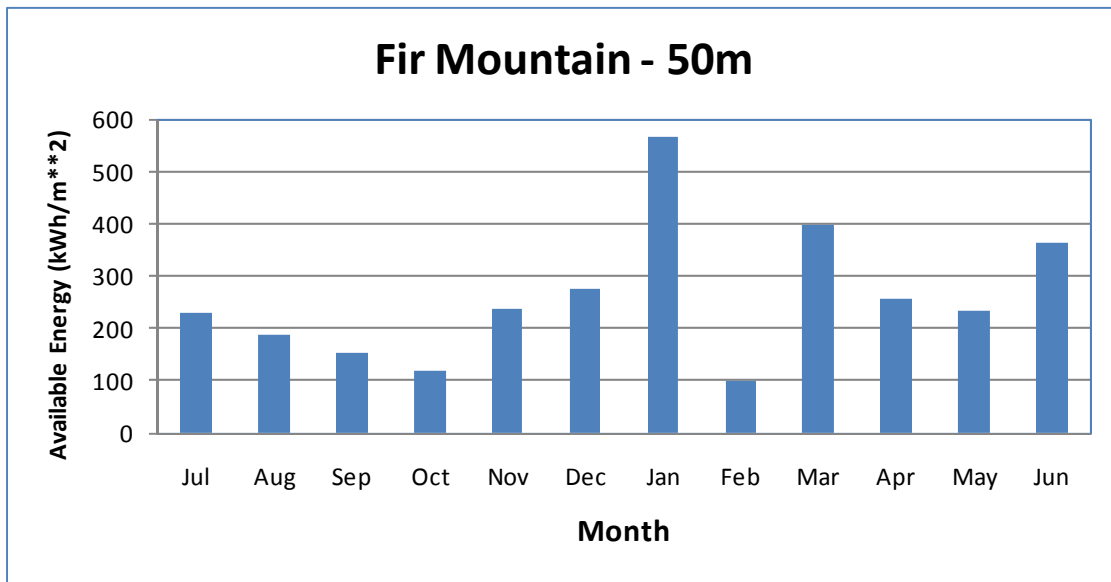


Figure 6: Monthly available power for 50m level of the Fir Mtn. 50 m site.

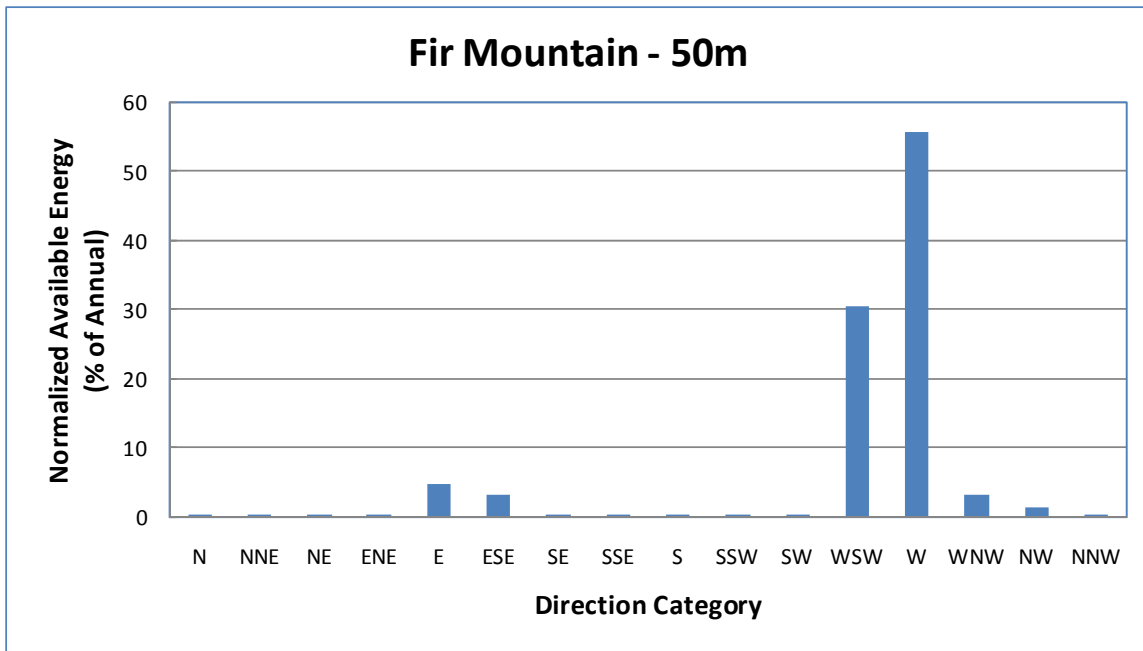


Figure 7: Annual Energy Rose for the 50m level at the Fir Mtn. 50m site.

An analysis program was run to evaluate the energy that could be produced by five separate wind turbine types. This analysis program adjusts the site Weibull distribution using the shear coefficient (alpha) calculated from the hourly values (from 103 ft. to 164 ft.). Density variations are approximated using the site elevation and a standard atmosphere. Five wind turbine types are shown for reference. Table 6 compares the gross capacity factors for each month for the five wind turbines. Net capacity factor estimates would account for array losses, availability losses, electric line and

transmission losses, yaw, turbulence, control, blade soiling, icing and high wind cycling. While these losses would be dependent upon the design of the wind farm, a general estimate is that these losses could be in the range of eleven to fifteen percent.

Table 6: Gross monthly and annual capacity factors for five wind turbine types using observed shear factors.

	Lower Level (104')		Upper Level (164')		Vestas 80	GE 70.5	Nordex 80	Nordex 90	Souzlou 88
	Mean (mph)	%	Mean (mph)	%	2000 kW	1500 kW	2500 kW	2300 kW	2000 kW
Jul	13.0	100.00	15.4	100.00	0.376	0.337	0.330	0.409	0.437
Aug	11.4	100.00	13.6	100.00	0.312	0.276	0.274	0.339	0.365
Sep	10.8	100.00	12.9	100.00	0.285	0.246	0.246	0.311	0.338
Oct	9.4	100.00	11.4	100.00	0.231	0.194	0.197	0.253	0.279
Nov	10.2	99.30	12.3	99.70	0.251	0.223	0.220	0.269	0.288
Dec	12.9	74.70	14.9	79.40	0.331	0.303	0.293	0.357	0.380
Jan	13.0	80.00	17.1	68.10	0.416	0.407	0.392	0.440	0.445
Feb	8.6	79.20	10.6	76.50	0.217	0.182	0.188	0.237	0.259
Mar	14.1	98.10	16.7	96.50	0.428	0.401	0.394	0.455	0.477
Apr	13.0	100.00	15.1	100.00	0.373	0.343	0.331	0.402	0.427
May	12.3	100.00	14.3	100.00	0.338	0.313	0.304	0.366	0.386
Jun	15.4	100.00	17.8	100.00	0.462	0.434	0.418	0.498	0.524
ANN	12.0	94.30	14.3	93.40	0.339	0.307	0.303	0.366	0.390

To obtain these capacity factors the winds at the top level are extrapolated upwards to the turbine hub height using the computed shear value. However, these shear values are large and may not be representative of conditions above the tower height. Using high values can produce unrealistically high capacity factors. To compensate for this unknown we have reproduced the quantities in Table 6 using a conservative shear factor of 0.10. These are provided in Table 7 and should serve as a lower estimate of the gross capacity factors for the site.

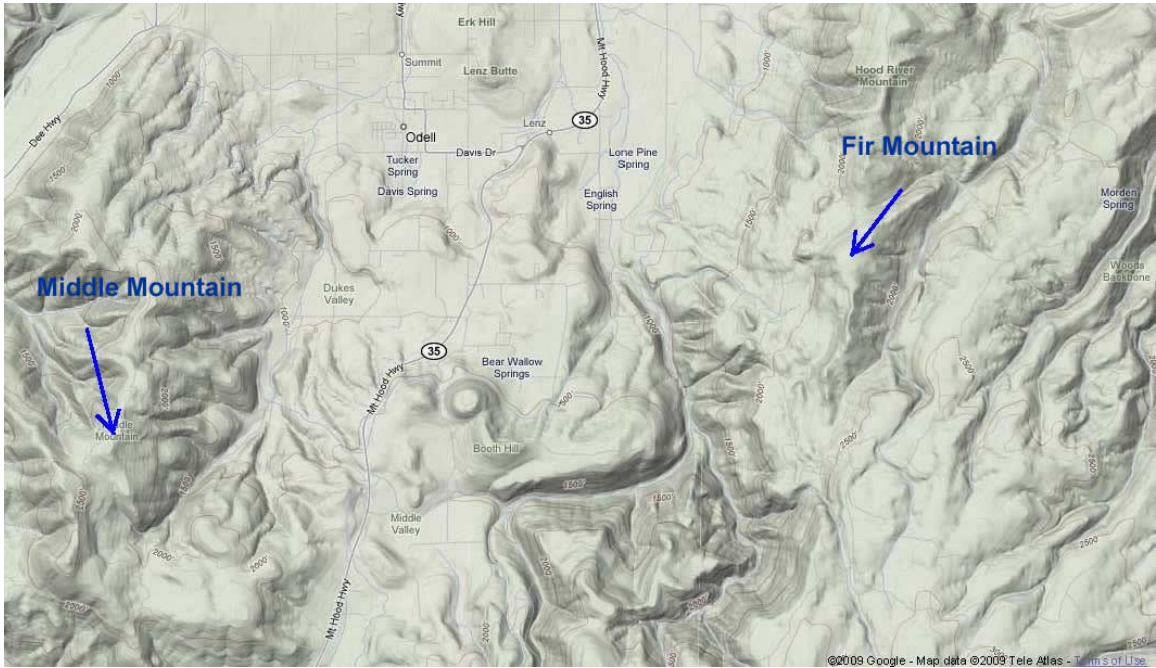
Table 7: Gross monthly and annual capacity factors for five wind turbine types using an assumed shear factor of 0.10.

	Upper Level (164')		Vestas 80	GE 70.5	Nordex 80	Nordex 90	Souzlou 88
	Mean (mph)	%	2000 kW	1500 kW	2500 kW	2300 kW	2000 kW
Jul	15.4	100.00	0.296	0.294	0.252	0.323	0.335
Aug	13.6	100.00	0.239	0.237	0.202	0.261	0.269
Sep	12.9	100.00	0.211	0.207	0.176	0.231	0.239
Oct	11.4	100.00	0.163	0.159	0.134	0.179	0.187
Nov	12.3	99.70	0.195	0.192	0.171	0.210	0.216
Dec	14.9	79.40	0.277	0.275	0.243	0.301	0.310
Jan	17.1	68.10	0.383	0.386	0.355	0.406	0.412
Feb	10.6	76.50	0.151	0.148	0.125	0.166	0.171
Mar	16.7	96.50	0.365	0.368	0.332	0.394	0.402
Apr	15.1	100.00	0.309	0.309	0.268	0.336	0.348
May	14.3	100.00	0.281	0.282	0.244	0.306	0.314
Jun	17.8	100.00	0.395	0.396	0.349	0.429	0.440
ANN	14.3	93.40	0.272	0.271	0.237	0.295	0.304

Summary,

- 1) No problems were detected in the data for this site that might hinder an interpretation of the collected data. Some icing was detected during the winter months and removed from the records prior to performing the analyses presented here.
- 2) The measured shear coefficient between the 30 meter and 48.5 meter levels was 0.385 on an annual basis. This is remarkably high and is likely associated with the towers proximity to the edge of the ridge and the trees present along this rim.
- 3) Winds, especially energy producing winds came almost exclusively from the West and West-Southwest directions.
- 4) Computed gross capacity factors for four sample wind turbine types were found in a range between 27% and about 35%. Estimates of the net capacity factors would be somewhat lower. This wide range reflects the uncertainty associated with the high observed shear.
- 5) A comparison with wind data from a nearby long-term wind monitoring site indicated that the wind observed over the analysis period (July 2008 to June 2009) were very close to long-term mean although several individual months varied significantly.

Appendix A: Topographic map of the general area in which the Fir Mtn. 50m site is located.



Appendix B: Photograph of Fir Mountain and the ridge extending from to the north. Picture was taken from Middle Mountain to the West.



Appendix C: Miscellaneous analysis Tables.

STATION - Fir Mtn. 50m (F1 - 50m)					
WIND SPEED FREQUENCY DISTRIBUTION WITH NORMALIZED AVAILABLE ENERGY					
DATA PERIOD OF RECORD - 7/2008 - 6/2009					
NORMALIZATION PERIOD - ONE YEAR					
AVERAGE WIND SPEED FOR PERIOD: 14.3 MPH					
NORMALIZED AVAILABLE ENERGY: 3049.5 KWH/M**2/YEAR					
TOTAL HOURS OBSERVED: 8184					
SPD	HOURS/				NORMALIZED
MPH	PERIOD	RELFREQ	CUMHRS	CUMRELFREQ	AVAIL. ENERGY
					KWH/M**2/YEAR
0	0	0.00	8184	100.00	0.0
1	116	1.42	8184	100.00	0.0
2	212	2.59	8068	98.58	0.1
3	285	3.48	7856	95.99	0.4
4	329	4.02	7571	92.51	1.1
5	339	4.14	7242	88.49	2.3
6	386	4.72	6903	84.35	4.5
7	391	4.78	6517	79.63	7.3
8	386	4.72	6126	74.85	10.8
9	383	4.68	5740	70.14	15.2
10	358	4.37	5357	65.46	19.5
11	361	4.41	4999	61.08	26.2
12	373	4.56	4638	56.67	35.1
13	368	4.50	4265	52.11	44.0
14	362	4.42	3897	47.62	54.1
15	321	3.92	3535	43.19	59.0
16	300	3.67	3214	39.27	66.9
17	269	3.29	2914	35.61	72.0
18	288	3.52	2645	32.32	91.5
19	248	3.03	2357	28.80	92.7
20	242	2.96	2109	25.77	105.5
21	252	3.08	1867	22.81	127.1
22	197	2.41	1615	19.73	114.3
23	183	2.24	1418	17.33	121.3
24	159	1.94	1235	15.09	119.7
25	139	1.70	1076	13.15	118.3
26	129	1.58	937	11.45	123.5
27	133	1.63	808	9.87	142.6
28	94	1.15	675	8.25	112.4
29	86	1.05	581	7.10	114.2
30	64	0.78	495	6.05	94.1
31	69	0.84	431	5.27	112.0
32	58	0.71	362	4.42	103.5
33	50	0.61	304	3.71	97.9
34	36	0.44	254	3.10	77.1
35	32	0.39	218	2.66	74.7
36	30	0.37	186	2.27	76.2
37	27	0.33	156	1.91	74.5
38	28	0.34	129	1.58	83.7
39	14	0.17	101	1.23	45.2
40	15	0.18	87	1.06	52.3
41	11	0.13	72	0.88	41.3
42	8	0.10	61	0.75	32.3
43	11	0.13	53	0.65	47.6
44	13	0.16	42	0.51	60.3
45	6	0.07	29	0.35	29.8
46	6	0.07	23	0.28	31.8
47	4	0.05	17	0.21	22.6
48	1	0.01	13	0.16	6.0
49	3	0.04	12	0.15	19.2
50	5	0.06	9	0.11	34.0
51	1	0.01	4	0.05	7.2
52	1	0.01	3	0.04	7.7
53	1	0.01	2	0.02	8.1
54	1	0.01	1	0.01	8.6

STATION - **Fir Mtn. 50m (F1 - 50m)**

MONTHLY WIND SPEEDS (MPH)
 DATA PERIOD OF RECORD - 7/2008 - 6/2009

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
2008	0.0	0.0	0.0	0.0	0.0	0.0	15.4	13.6	12.9	11.4	12.3	14.9	4261	13.37	7.81
# OBS	0	0	0	0	0	0	744	744	720	744	718	591			
2009	17.1	10.6	16.7	15.1	14.3	17.8	0.0	0.0	0.0	0.0	0.0	0.0	3923	15.38	9.62
# OBS	507	514	718	720	744	720	0	0	0	0	0	0			

STATION - **Fir Mtn. 50m (F2 - 40m)**

MONTHLY WIND SPEEDS (MPH)
 DATA PERIOD OF RECORD - 7/2008 - 6/2009

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
2008	0.0	0.0	0.0	0.0	0.0	0.0	14.6	13.0	12.3	10.6	11.5	12.8	4383	12.47	7.59
# OBS	0	0	0	0	0	0	744	744	720	744	714	717			
2009	15.5	9.8	15.8	14.3	13.6	16.8	0.0	0.0	0.0	0.0	0.0	0.0	3959	14.47	9.28
# OBS	530	526	719	720	744	720	0	0	0	0	0	0			

STATION - **Fir Mtn. 50m (F3 - 31.6m)**

MONTHLY WIND SPEEDS (MPH)
 DATA PERIOD OF RECORD - 7/2008 - 6/2009

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	# OBS	AVG	SD
2008	0.0	0.0	0.0	0.0	0.0	0.0	13.0	11.4	10.8	9.4	10.2	12.9	4223	11.20	7.04
# OBS	0	0	0	0	0	0	744	744	720	744	715	556			
2009	13.0	8.6	14.1	13.0	12.3	15.4	0.0	0.0	0.0	0.0	0.0	0.0	4041	12.91	8.61
# OBS	595	532	730	720	744	720	0	0	0	0	0	0			

STATION - **Fir Mtn. 50m (F1 - 50m)**
 DIURNAL WIND SPEEDS (MPH)
 DATA PERIOD OF RECORD - 7/2008 - 6/2009

	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	AVG SPD
JAN	17.4	17.0	16.3	16.5	14.9	14.9	15.5	16.8	16.4	17.4	18.5	17.6	18.5	18.3	17.6	17.3	16.9	17.9	18.3	17.8	17.0	17.4	16.5	16.5	17.1
FEB	9.6	8.7	9.2	10.7	11.9	12.2	12.5	10.9	10.6	11.3	10.8	9.9	10.4	10.6	9.9	10.2	9.9	10.7	11.0	10.0	10.4	10.6	11.4	10.9	10.6
MAR	16.2	16.1	16.0	14.9	14.9	15.0	15.1	14.1	14.4	14.5	15.6	16.1	16.9	18.7	18.3	18.4	18.2	17.8	18.2	18.5	18.1	18.3	18.5	17.4	16.7
APR	15.4	15.0	15.3	15.3	15.3	14.9	13.9	13.3	12.8	12.8	13.2	14.0	14.7	14.9	15.5	16.7	16.8	15.2	15.7	15.9	16.1	16.9	16.5	15.9	15.1
MAY	14.2	14.7	13.7	13.2	12.8	12.8	12.0	11.4	11.3	11.6	11.9	12.8	13.4	15.1	15.2	15.6	16.7	17.8	17.1	16.1	17.3	16.7	15.4	15.0	14.3
JUN	18.8	18.0	18.1	17.8	17.3	16.7	15.7	15.2	13.8	13.9	14.6	14.2	15.1	15.8	17.0	18.1	20.3	20.6	20.4	20.9	21.9	21.9	20.8	19.5	17.8
JUL	16.5	16.0	15.2	15.4	14.1	13.7	12.2	11.3	10.6	10.6	10.9	12.7	14.1	15.6	16.4	16.9	17.0	18.2	19.0	19.0	19.1	18.9	17.9	17.3	15.4
AUG	12.8	13.3	13.5	12.5	12.4	11.8	11.1	10.5	10.3	10.5	12.7	14.1	14.6	14.5	14.7	14.9	15.0	15.3	15.7	15.9	16.6	15.7	14.7	14.0	13.6
SEP	12.1	11.0	10.6	10.6	11.1	11.0	11.1	11.0	11.4	11.9	12.7	13.5	13.8	13.7	14.1	14.6	14.6	14.9	15.8	16.4	16.2	14.2	13.0	11.6	12.9
OCT	11.8	11.3	11.3	11.0	11.6	11.5	11.3	11.6	10.4	9.9	9.5	10.6	11.0	11.5	11.5	11.8	11.6	12.3	12.7	12.7	11.7	11.5	10.9	11.5	11.4
NOV	11.7	12.2	12.6	12.4	12.2	12.1	12.1	12.4	12.2	12.0	11.3	11.0	11.3	11.0	12.0	12.7	13.6	14.0	13.8	12.3	12.6	12.8	12.4	11.3	11.6
DEC	13.1	12.2	12.5	12.6	12.5	13.6	13.4	15.0	15.1	15.4	15.4	15.3	15.8	15.8	16.7	18.9	17.3	17.2	16.1	15.9	15.5	14.6	14.8	14.0	14.9
AVG																									
SPD	14.1	13.8	13.7	13.6	13.4	13.3	12.9	12.7	12.3	12.5	13.0	13.5	14.0	14.7	15.0	15.6	15.8	16.0	16.1	16.1	16.2	15.8	15.2	14.6	14.3

STATION - **Fir Mtn. 50m (F1 - 50m)**
WIND ROSE FOR ALL DATA - 8184 OBSERVATIONS
DATA PERIOD OF RECORD - 7/2008 - 6/2009

SPEED CATEGORIES (MPH)

DIR	0		10		13		16		19		22		25		28		31		34		37		40		43		46		49		52		55		TOTAL %	MEAN SPEED (MPH)
	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO	TO		
N	1.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	5.3
NNE	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.6
NE	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	4.2
ENE	2.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	5.3		
E	6.6	2.9	2.0	1.1	0.8	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	10.9		
ESE	3.3	1.7	1.5	1.2	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	11.9		
SE	1.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	6.0		
SSE	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.7		
S	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	4.1		
SSW	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.5		
SW	1.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	7.4		
WSW	3.3	1.9	2.4	2.6	2.7	1.9	1.8	0.9	0.5	0.3	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.9	18.5		
W	6.6	3.5	3.7	3.6	3.7	3.2	2.9	1.9	1.4	0.9	0.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.5	18.6		
WNW	2.9	1.3	1.6	1.1	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	12.2		
NW	3.4	1.4	0.9	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	10.2		
NNW	2.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	7.5		
CALM																																			0.0	
TOTAL	36.8	13.3	12.5	10.3	8.7	5.9	4.9	2.8	1.9	1.2	0.7	0.4	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	14.3		

NOTE: MEAN SPEED OF THE TOTAL IN A WIND ROSE MAY DIFFER FROM THE SPEED FREQUENCY DISTRIBUTION FOR A GIVEN PERIOD DUE TO DATA SELECTION. SPEED FREQUENCY DISTRIBUTIONS REQUIRE ONLY A WIND SPEED OBSERVATION BE PRESENT. WIND ROSES, ON THE OTHER HAND, REQUIRE BOTH SPEED AND DIRECTION BE PRESENT FOR EACH OBSERVATION.

STATION - **Fir Mtn. 50m (F1 - 50m)**
 ENERGY ROSE (TOTALS ARE NORMALIZED AVAILABLE ENERGY (KWH/M**2))
 DATA PERIOD OF RECORD - 7/2008 - 6/2009

MON	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	OBS.
JAN	0.1	0.0	0.0	0.0	1.4	1.8	0.2	0.0	0.0	0.0	0.0	230.6	320.9	3.9	0.5	6.6	566.2	507
FEB	0.1	0.0	0.0	2.0	37.5	12.8	0.7	0.0	0.0	0.1	0.0	27.4	18.1	0.1	0.0	0.1	99.0	514
MAR	0.2	0.0	0.0	0.1	16.2	11.3	0.1	0.0	0.0	0.0	0.0	78.5	282.2	6.6	3.5	0.3	398.9	718
APR	0.0	0.1	0.0	0.1	8.4	11.6	0.0	0.0	0.0	0.0	0.6	63.8	161.4	7.8	2.7	0.3	256.9	720
MAY	0.1	0.0	0.1	0.3	10.3	5.5	0.1	0.0	0.0	0.0	0.0	68.2	136.2	7.2	5.3	0.5	234.0	744
JUN	0.1	0.0	0.0	0.3	3.0	0.7	0.0	0.0	1.3	0.0	0.3	136.6	196.0	18.1	6.0	0.7	363.3	720
JUL	0.5	0.0	0.0	0.1	3.8	0.8	0.0	0.0	0.0	0.0	0.0	83.4	106.7	23.7	10.7	1.3	231.0	744
AUG	0.3	0.0	0.0	0.1	5.6	2.8	0.4	0.0	0.0	0.0	0.0	43.3	110.4	13.7	10.3	0.6	187.4	744
SEP	0.1	0.0	0.0	0.2	18.3	14.8	0.3	0.0	0.0	0.0	0.0	52.1	64.1	3.6	0.9	0.3	154.7	720
OCT	0.3	0.0	0.2	0.1	15.5	9.7	0.2	0.1	0.0	0.0	0.0	40.1	45.4	4.4	1.9	0.5	118.5	744
NOV	0.0	0.0	0.0	0.1	15.7	15.4	0.6	0.0	0.2	0.0	0.2	86.6	112.6	5.2	0.9	0.2	237.6	720
DEC	0.1	0.0	0.0	0.0	16.6	16.2	0.1	0.0	0.0	0.0	7.0	46.2	184.0	3.9	2.0	0.2	276.5	591
TOT	1.9	0.2	0.5	3.4	152.3	103.5	2.7	0.2	1.5	0.2	8.2	956.8	1738.0	98.2	44.9	11.5	3124.1	8184

NOTE: AVAILABLE ENERGY IN AN ENERGY ROSE MAY DIFFER FROM THE SPEED FREQUENCY DISTRIBUTION FOR A GIVEN PERIOD DUE TO DATA SELECTION. SPEED FREQUENCY DISTRIBUTIONS REQUIRE ONLY A WIND SPEED OBSERVATION BE PRESENT. ENERGY ROSES, ON THE OTHER HAND, REQUIRE BOTH SPEED AND DIRECTION BE PRESENT FOR EACH OBSERVATION.