Deering Wind Resource Report

Report by: Douglas Vaught, V3 Energy LLC, Eagle River, Alaska
Date: August 31, 2010

Village of Deering; D. Vaught photo

Contents

Summary

The wind resource measured in Deering is good at high wind power Class 3. The met tower site experiences low turbulence conditions but is subject to storm winds that raise the probability of extreme wind events higher than might otherwise be expected for a Class 3 site. Met tower placement was based on observations of wind patterns in Deering, the relatively high elevation of the site, and proximity to existing roads. The site is thought to have the best developable wind regime near Deering. Other locations near Deering, such as the summit plateau of the high, broad hill east of the village, are likely windier but development costs there would be very high.

Met tower data synopsis

Data dates	August 9, 2008 to August 6, 2010 (24 months)
Wind Power Class	High 3 (fair)
Power density mean, 30 m	322 W/m^2
Wind speed mean, 30 m	6.06 m/s
Max. 10-min wind speed average	25.9 m/s
Maximum wind gust	30.9 m/s (Jan. 2009)
Weibull distribution parameters	k = 1.78, c = 6.72 m/s
Wind shear power law exponent	
Roughness class	0.0 (smooth)
IEC 61400-1, 3rd ed. classification	
Turbulence intensity, mean	0.075 (at 15 m/s)

Community profile

Current Population:	118 (2009 DCCED Certified Population)
Incorporation Type:	2nd Class City
Borough Located In:	Northwest Arctic Borough
Taxes:	Sales: None, Property: None, Special: None
National Flood Insurance Program Participant:	Yes
Coastal Management District:	Northwest Arctic Borough

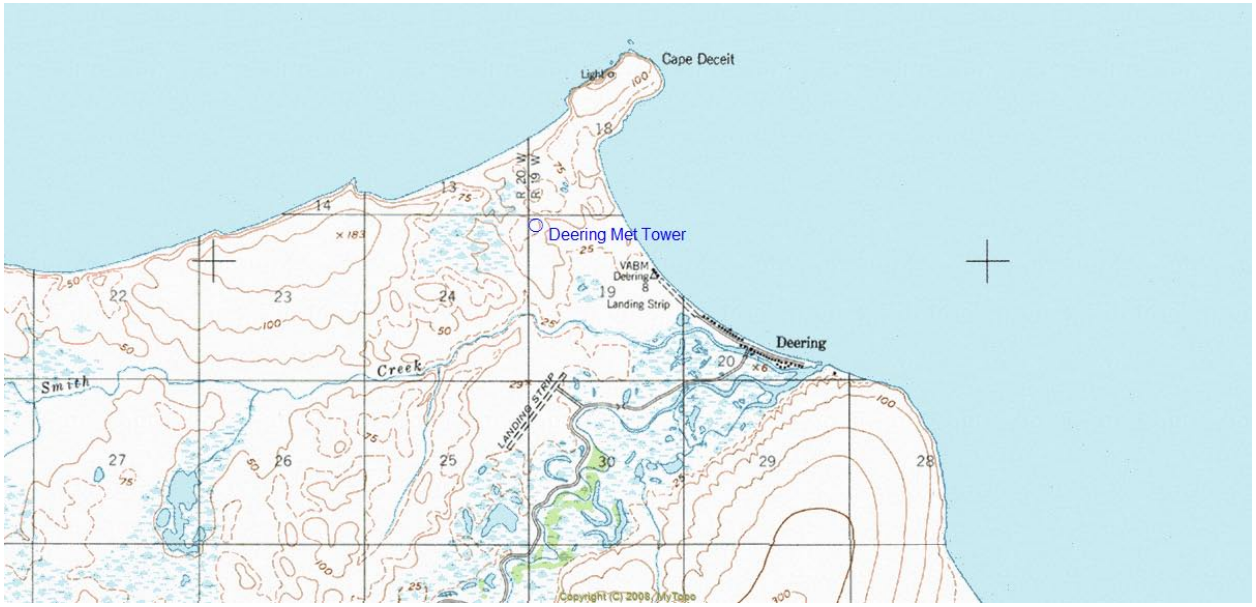
Test Site Location

The met tower is located 1.5 km (0.9 miles ft) from the western edge of the village. The site is south of Cape Deceit on a broad sloping hill overlooking Kotzebue Sound with good exposure to winds from all directions.

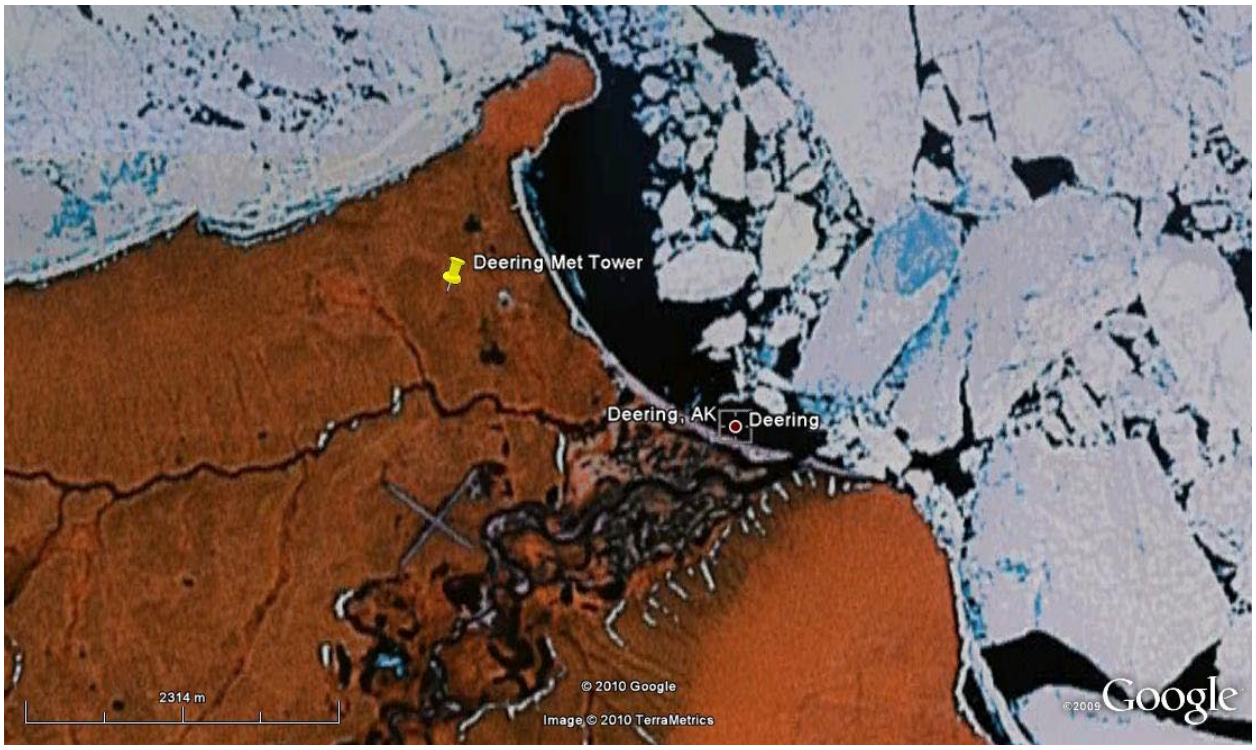
Site information

Site number	7312
Latitude/longitude	N 66° 5.1', W 162° 45.8' (WGS 84)
Site elevation	15 meters
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 30-meter tall tower, 152 mm diameter
Anchor type	Buried plate (configured with plywood and screw-in anchor)

Topographic map image



Google Earth image



Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	29 m (A)	0.765	0.35	WNW
2	NRG #40 anemometer	29 m (B)	0.765	0.35	ENE
3	NRG #40 anemometer	20 m	0.765	0.35	NNW
7	NRG #200P wind vane	29 m	0.351	000	359° T
9	NRG #110S Temp C	3 m	0.136	-86.383	N

Photographs

Deering crew; D. Vaught photo

Installing plate anchors; D. Vaught photo

Deering met tower; D. Vaught photo

Deering crew; D. Vaught photo

Data Recovery

The quality of data from the Deering met tower was acceptable to describe the essentials of the wind resource, but unfortunately there were a number of problems including inoperability of the temperature sensor for the first three months after tower installation (after which the sensor was replaced but data has been suspect) and complete failure of the wind vane that resulted in no recorded wind data. Fortunately, the nearby Deering airport has been equipped with an Automated Surface

Observing System (ASOS) weather station since 1984 and hence wind direction from it is a suitable substitute for the met tower site. Other data problems with the met tower include two long episodes of missing data: 6/30/09 to 8/31/09 and 11/14/09 to 2/3/10. Reportedly, one episode was due to a lost or misplaced data card and the other to failure of the datalogger.

Apparent icing events, characterized by relatively long periods of zero sensor output, non-variant sensor standard deviation, and temperatures near or below freezing, were removed from the data set for quality control purposes. It is apparent from the data that icing events (likely freezing rain/sleet but also possibly hoarfrost conditions) certainly occur frequently during the winter months, but the site is not of sufficient elevation for the highly problematic rime icing conditions.

Data recovery summary table

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)
Speed 29 m A	m/s	29 m	104,717	79,341	75.8
Speed 29 m B	m/s	29 m	104,717	79,229	75.7
Speed 20 m	m/s	20 m	104,717	76,768	73.3
Direction 24 m	°	24 m	104,717	0	0.0
Temperature	°C		104,717	67,853	64.8

Anemometer data recovery

			29 m A		29 m B		20 m	
Year	Month	Possible Records	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)
2008	Aug	3,227	3,227	100.0	3,227	100.0	3,227	100.0
2008	Sep	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2008	Oct	4,464	4,443	99.5	4,439	99.4	4,455	99.8
2008	Nov	4,320	2,365	54.8	2,348	54.4	2,368	54.8
2008	Dec	4,464	4,290	96.1	4,276	95.8	4,331	97.0
2009	Jan	4,464	3,539	79.3	3,511	78.7	3,192	71.5
2009	Feb	4,032	3,615	89.7	3,614	89.6	2,325	57.7
2009	Mar	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Apr	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2009	May	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Jun	4,320	3,906	90.4	3,906	90.4	3,906	90.4
2009	Jul	4,464	0	0.0	0	0.0	0	0.0
2009	Aug	4,464	54	1.2	54	1.2	54	1.2
2009	Sep	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2009	Oct	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Nov	4,320	1,578	36.5	1,578	36.5	1,578	36.5
2009	Dec	4,464	0	0.0	0	0.0	0	0.0
2010	Jan	4,464	0	0.0	0	0.0	0	0.0

2010	Feb	4,032	3,106	77.0	3,245	80.5	2,114	52.4
2010	Mar	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2010	Apr	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2010	May	4,464	4,464	100.0	4,277	95.8	4,464	100.0
2010	Jun	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2010	Jul	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2010	Aug	834	834	100.0	834	100.0	834	100.0
All data		104,717	79,341	75.8	79,229	75.7	76,768	73.3

Wind Speed

Wind data collected from the met tower, from the perspective of mean wind speed and mean wind power density, indicates a good wind resource for wind power development. The cold arctic temperatures of Deering contributed to the high power density. It is problematic, however, analyzing wind data with significant concentrated data loss, such as occurred in Deering during the two data loss episodes. Fortunately, however, with met tower data collection encompassing a two year time period, missing months of data in 2009 and 2010 were duplicated by data collected in 2008 and 2009. Nevertheless, to correct the anemometer data loss problem, synthetic data was inserted in the data gaps to create a more complete wind speed profile. To be sure, long segments of synthetic data introduce uncertainty to the data set, but missing data does as well. With synthetic data inserted to fill in the data gaps, the mean wind annual wind speed and power density decrease slightly from the original data.

Anemometer data summary

	Original Data			Synthesized data		
Variable	Speed 29 m A	Speed 29 m B	Speed 20 m	Speed 29 m A	Speed 29 m B	Speed 20 m
Measurement height (m)	29	29	20	29	29	20
Mean wind speed (m/s)	6.00	6.06	5.96	5.94	6.00	5.82
Max 10-min avg wind speed (m/s)	25.9	25.2	24.4			
Max gust wind speed (m/s)	30.9	29.8	29.8			
Weibull k	1.71	1.74	1.77	1.67	1.69	1.72
Weibull c (m/s)	6.62	6.72	6.55	6.64	6.72	6.52
Mean power density (W/m²)	312	322	301	309	316	285
Mean energy content (kWh/m²/yr)	2,737	2,820	2,635	2,703	2,768	2,493
Energy pattern factor	2.244	2.236	2.183	2.311	2.299	2.268
1-hr autocorrelation coefficient	0.913	0.914	0.915	0.908	0.909	0.91
Diurnal pattern strength	0.013	0.018	0.014	0.025	0.028	0.028
Hour of peak wind speed	15	15	13	13	13	12

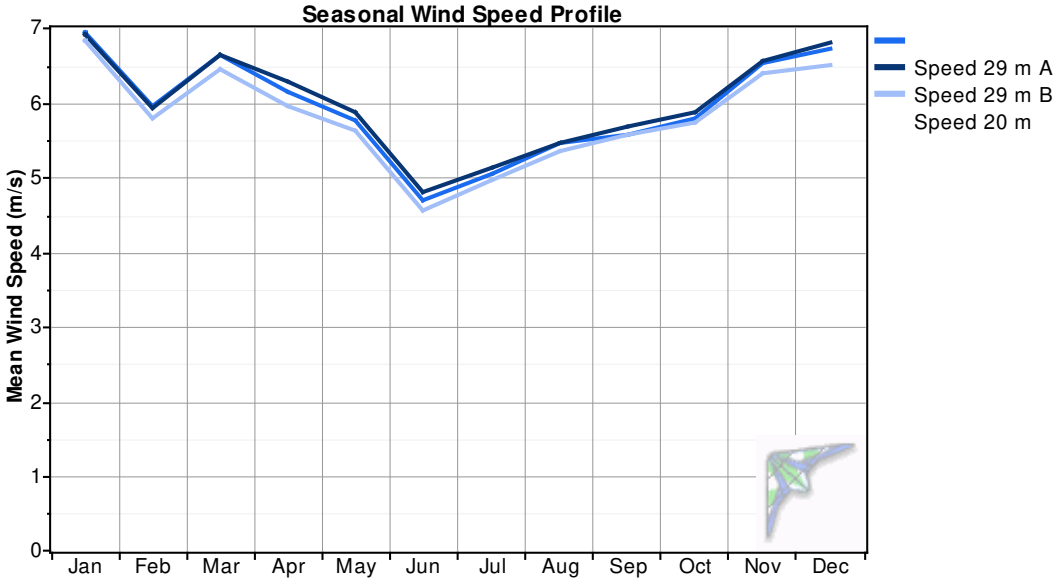
Time Series

Time series calculations indicate moderately wind speed averages during the autumn, winter and spring months, but winds die down during summer. Fortunately, however, seasonal wind speeds correlate to a typical village electric load profile of high winter loads and light summer loads.

29m B anemometer data summary

		Original 29m B Data					Synth Data Added	
Year	Month	Mean (m/s)	Max 10-min avg (m/s)	Max gust (m/s)	Weibull k (-)	Weibull c (m/s)	Mean (m/s)	Ratio: synth to original mean speed (-)
2008	Aug	5.52	15.3	17.6	2.198	6.24	5.52	100.0%
2008	Sep	5.94	13.3	15.3	2.15	6.693	5.94	100.0%
2008	Oct	5.59	15.4	18.7	1.958	6.305	5.57	99.6%
2008	Nov	6.38	13.4	16.1	2.484	7.174	6.01	94.2%
2008	Dec	7.05	20.5	24	1.945	7.913	6.92	98.1%
2009	Jan	7.14	25.1	29.8	1.536	7.963	6.69	93.8%
2009	Feb	7.55	22	25.6	1.586	8.375	6.98	92.3%
2009	Mar	6.76	24.7	27.9	1.609	7.538	6.76	100.0%
2009	Apr	5.50	25.2	29.8	1.593	6.128	5.50	100.0%
2009	May	6.30	19.6	24.8	2.175	7.118	6.30	100.0%
2009	Jun	4.91	15.9	19.5	2.042	5.543	4.91	100.1%
2009	Jul						4.96	
2009	Aug	12.07	16.2	19.9	6.252	12.969	5.68	47.1%
2009	Sep	5.42	14.1	17.2	1.947	6.116	5.42	100.0%
2009	Oct	6.21	16.5	19.5	1.72	6.943	6.21	100.0%
2009	Nov	7.38	20.5	23.7	1.533	8.166	7.10	96.3%
2009	Dec						6.67	
2010	Jan						7.14	
2010	Feb	4.37	12.9	14.1	1.942	4.892	4.89	112.1%
2010	Mar	6.52	15.6	19.5	1.695	7.236	6.52	100.0%
2010	Apr	7.05	20.2	22.6	1.66	7.828	7.05	100.0%
2010	May	5.32	15.6	18.7	1.753	5.936	5.47	102.8%
2010	Jun	4.72	17.8	20.6	1.994	5.329	4.72	100.0%
2010	Jul	5.29	16.4	19.1	1.809	5.95	5.29	100.0%
2010	Aug	4.12	10.1	13.3	2.095	4.648	4.12	100.0%
MMM Annual		6.06	25.2	29.8	1.738	6.716	6.00	98.9%

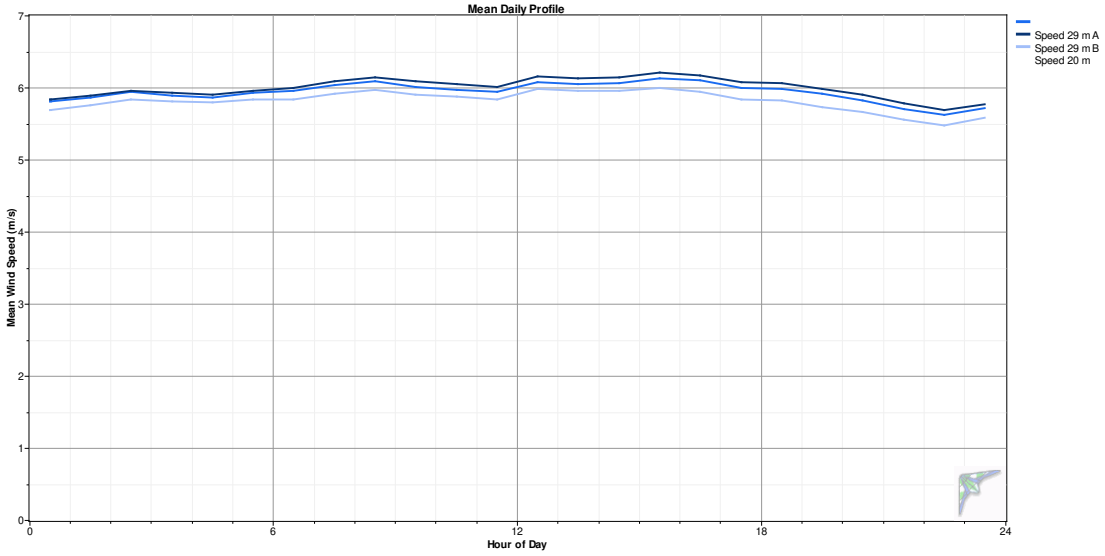
Time series graph (synth. data)



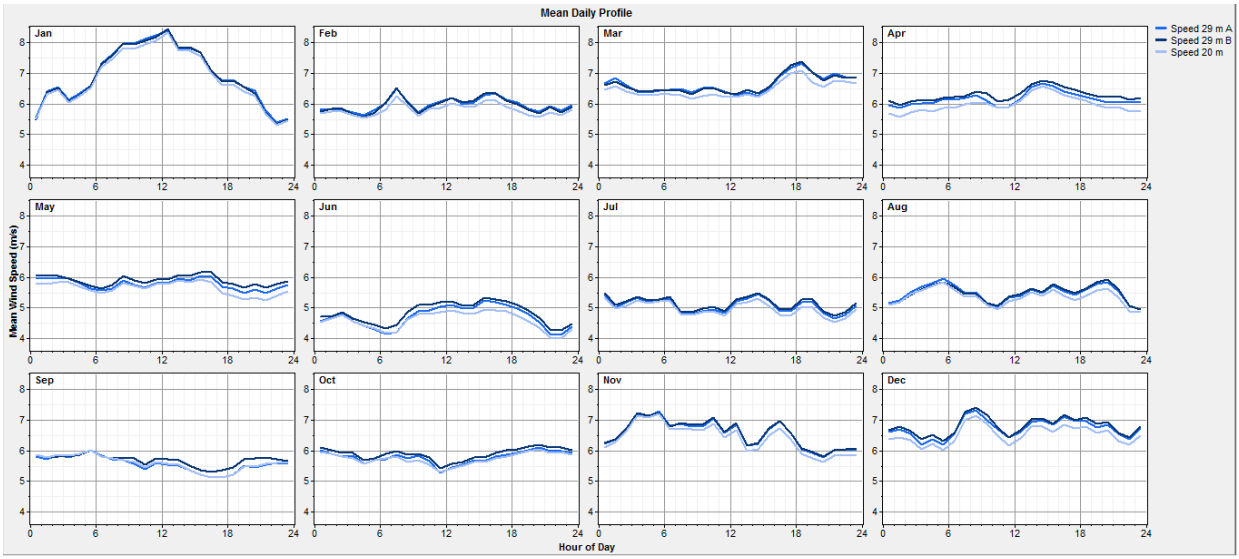
Daily Wind Profile

The average annual daily wind profile in Deering indicates a minor variation of wind speeds throughout the day, with lowest wind speeds during the late night and early morning hours and highest winds during mid to late afternoon. This perspective changes somewhat when considering monthly views of daily profiles as much more variation is observed.

Annual daily wind profile (synth. data)



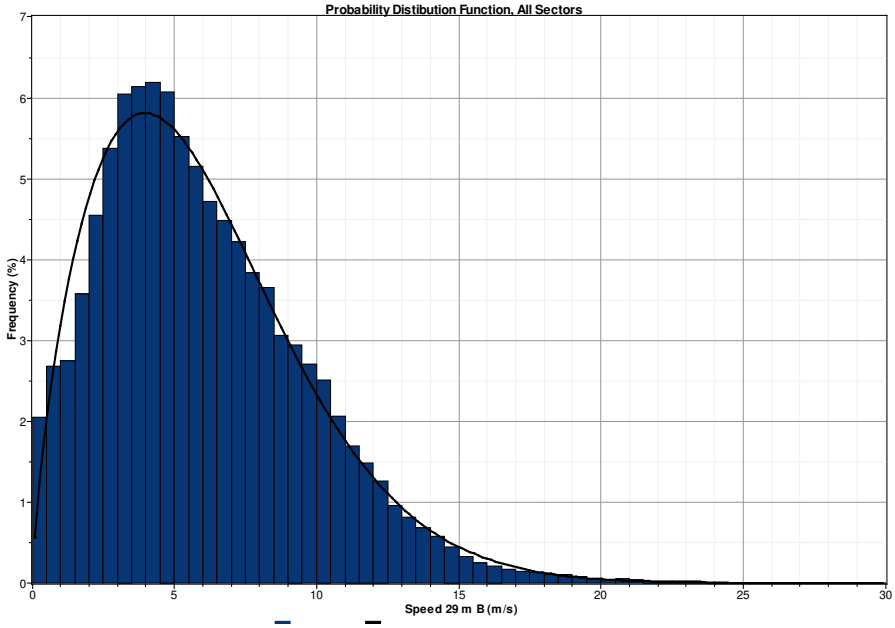
Monthly daily wind profiles (synth. data)



Probability Distribution Function

The probability distribution function (PDF), or histogram, of wind speed indicates wind speed "bins" oriented somewhat toward the lower speeds compared to a normal wind power shape curve of k=2.0, otherwise known as the Raleigh distribution. Note in the cumulate frequency table below that 33 percent of the winds are less than 4 m/s, the cut-in wind speed of most wind turbines.

PDF of 29m B anemometer (synth. data)



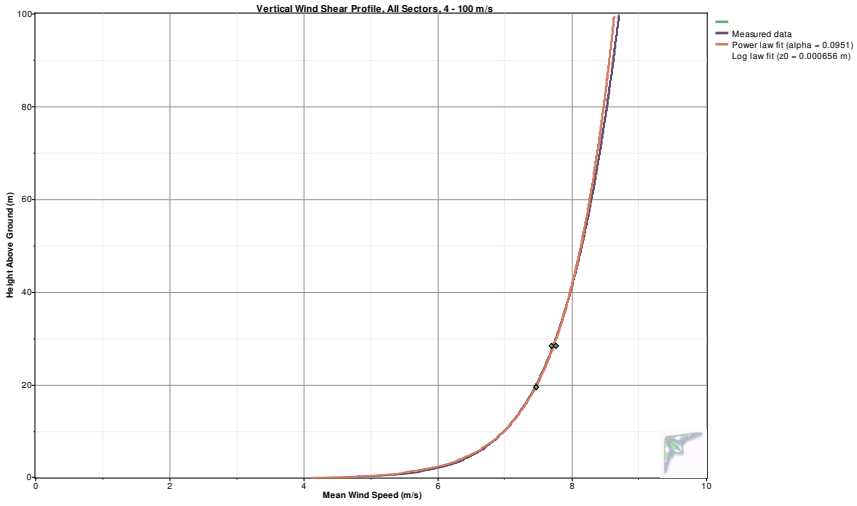
Cumulative frequency table

Bin (m/s)			Freq.	Cum. Freq.	Bin (m/s)			Freq.	Cum. Freq.
Lower	Upper	Occurrences	(%)	(%)	Lower	Upper	Occurrences	(%)	(%)
0	1	4,952	4.73	4.7	15	16	606	0.58	98.7
1	2	6,616	6.32	11.0	16	17	402	0.38	99.1
2	3	10,382	9.91	21.0	17	18	290	0.28	99.4
3	4	12,747	12.17	33.1	18	19	219	0.21	99.6
4	5	12,827	12.25	45.4	19	20	140	0.13	99.7
5	6	11,167	10.66	56.0	20	21	97	0.09	99.8
6	7	9,635	9.20	65.2	21	22	70	0.07	99.9
7	8	8,429	8.05	73.3	22	23	58	0.06	99.9
8	9	7,030	6.71	80.0	23	24	37	0.04	100.0
9	10	5,918	5.65	85.7	24	25	19	0.02	100.0
10	11	4,773	4.56	90.2	25	26	5	0.01	100.0
11	12	3,331	3.18	93.4	26	27	4	0.00	100.0
12	13	2,317	2.21	95.6	27	28	1	0.00	100.0
13	14	1,572	1.50	97.1	28	29	0	0.00	100.0
14	15	1,073	1.03	98.1	29	30	0	0	100.0
						All	104,717	100.00	

Wind Shear and Roughness

A wind shear power law exponent of 0.0951 indicates very low wind shear at the site; hence wind turbine construction at a low hub height may be a desirable option. Related to wind shear, a calculated surface roughness of 0.00002 meters (the height above ground level where wind velocity would be zero) indicates very smooth terrain (roughness description: smooth) surrounding the met tower.

Vertical wind shear profile, wind > 4 m/s



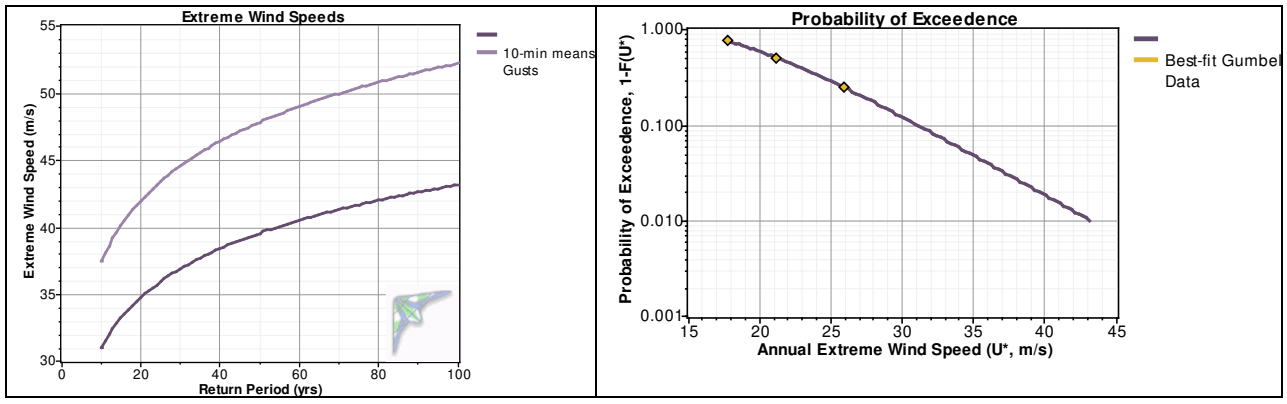
Extreme Winds

The duration of Deering met tower should be considered minimal for calculation of extreme wind probability, but nevertheless, it can be calculated with a moderate level of accuracy. Analysis indicates that Deering experiences sufficiently robust storm wind events to exceed IEC 61400-1, 3rd edition Class III criteria and hence classify as a Class II wind site.

Extreme wind speed probability table

	Extreme Wind Speed (m/s)		IEC 61400-1, 3rd	
Return Period (yr)	10-min means	Gusts	Class	V_{ref}, m/s
20	34.8	42.0	I	50
25	35.9	43.4	II	42.5
50	39.6	47.8	III	37.5
100	43.2	52.2	S	designer-specified

Extreme winds probability graphs



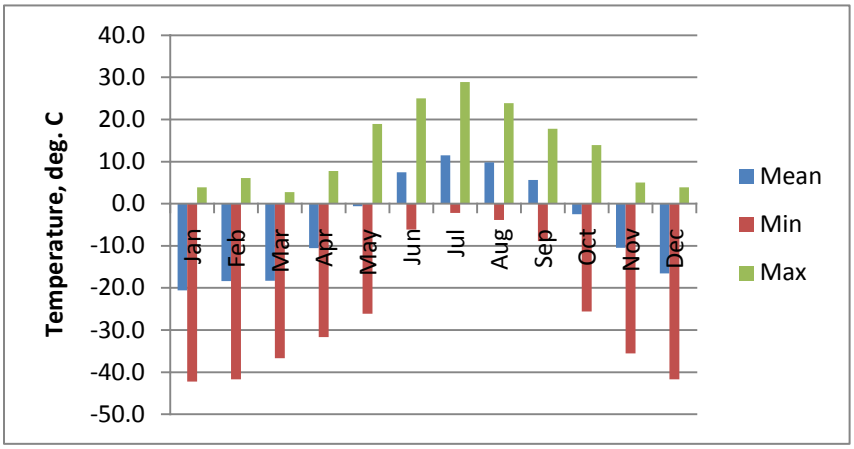
Temperature and Density

In addition to the data loss noted in the Data Recovery section of this report, by examination the met tower temperature data appears faulty. Hence, instead of reporting met tower temperature data, temperature data from the airport ASOS are referenced below. This data represents a long time period: 1984 to the present. Density was not directly measured, but calculated using standard pressure at 15 meters elevation and the ideal gas law. Note that in general Deering is a cool maritime climate characterized by severely cold winters.

Temperature and density table

	Temperature			Air Density		
	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m^3)	Max (kg/m^3)	Min (kg/m^3)
Jan	-20.6	-42.2	3.9	1.395	1.526	1.272
Feb	-18.3	-41.7	6.1	1.383	1.523	1.262
Mar	-18.3	-36.7	2.8	1.383	1.490	1.277
Apr	-10.5	-31.7	7.8	1.342	1.460	1.255
May	-0.6	-26.1	18.9	1.293	1.427	1.207
Jun	7.5	-6.1	25.0	1.256	1.320	1.182
Jul	11.5	-2.2	28.9	1.238	1.301	1.167
Aug	9.8	-3.9	23.9	1.246	1.309	1.186
Sep	5.6	-8.9	17.8	1.264	1.334	1.211
Oct	-2.5	-25.6	13.9	1.302	1.423	1.228
Nov	-10.4	-35.6	5.0	1.342	1.483	1.267
Dec	-16.5	-41.7	3.9	1.374	1.523	1.272
Annual	-4.4	-42.2	28.9	1.318	1.526	1.167

Temperature graph



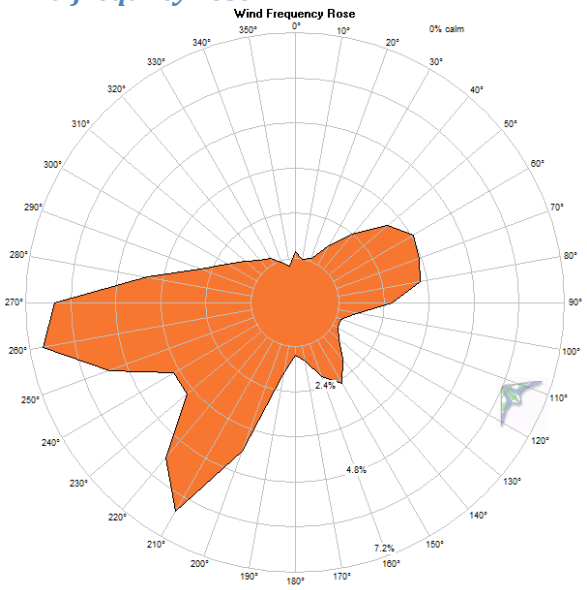
Wind Direction

The met tower wind vane was inoperative during the entire measurement period, with no data return. However, nearby airport ASOS data (1984 to present) is usable for wind direction analysis and presented below.

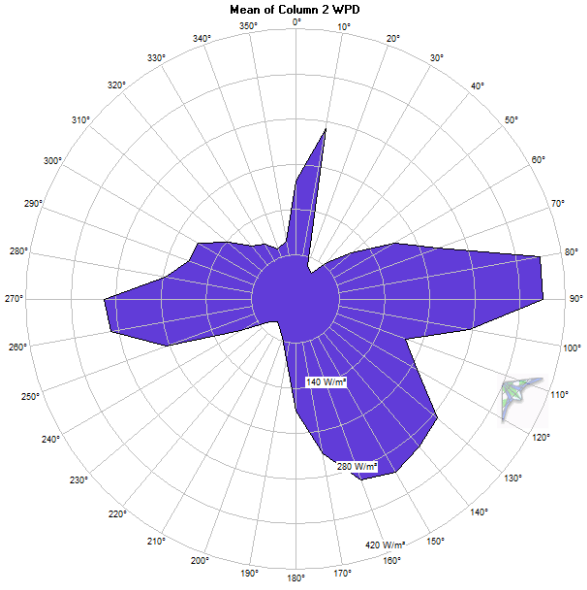
The wind frequency rose for Deering indicates predominately southwesterly to westerly winds with a lesser component of east-northeasterly winds and some southeasterly winds. The mean value rose indicates that when the easterly and southeasterly winds do occur, they tend to be very powerful. Combining the frequency and mean value rose into the total energy rose results in the observation that

the power-producing winds are chiefly westerly. Not critically important, but note that the resolution of the ASOS wind direction data is ten degrees, not one degree as with met tower wind vane sensors.

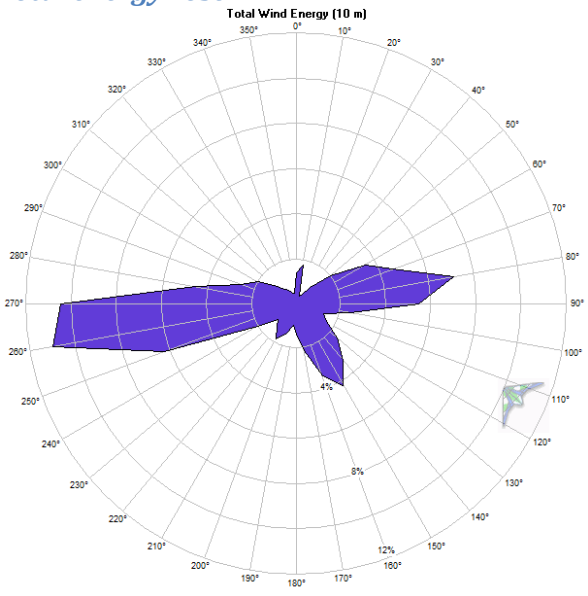
Wind frequncy rose



Mean value rose



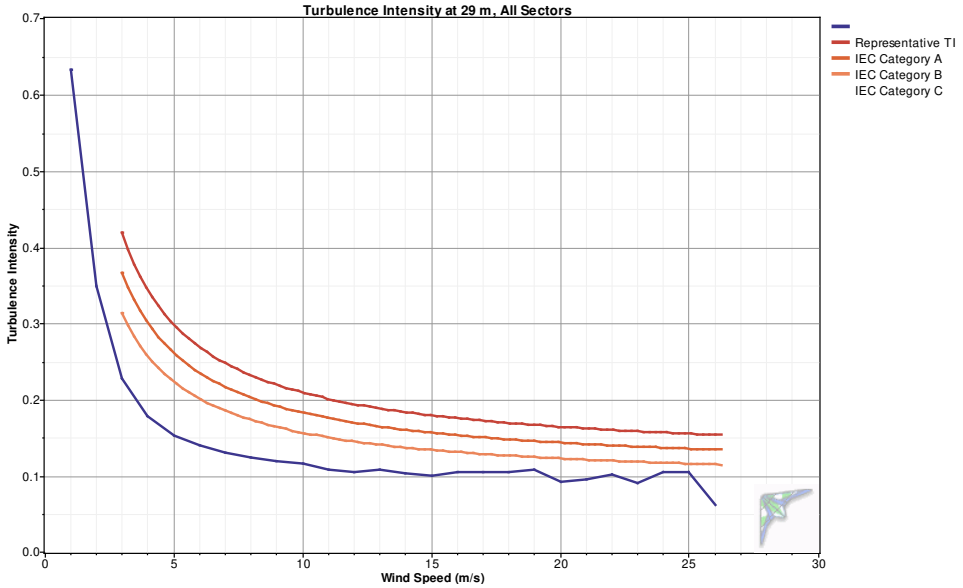
Total energy rose



Turbulence

Turbulence intensity at the Deering test site is well within acceptable standards for wind power development with an International Electrotechnical Commission (IEC) 61400-1, 3rd edition (2005) classification of turbulence category C, which is the lowest defined. Mean turbulence intensity at 15 m/s is 0.075

Turbulence intensity, all wind sectors



Turbulence table

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records In Bin	Mean TI	Standard Deviation of TI	Representative TI	Peak TI
1	0.5	1.5	3,858	0.416	0.170	0.634	1.333
2	1.5	2.5	6,218	0.208	0.110	0.349	0.941
3	2.5	3.5	8,963	0.138	0.070	0.228	0.769
4	3.5	4.5	10,044	0.109	0.054	0.178	0.683
5	4.5	5.5	9,206	0.095	0.045	0.153	0.660
6	5.5	6.5	7,891	0.089	0.040	0.140	0.532
7	6.5	7.5	7,298	0.084	0.036	0.131	0.354
8	7.5	8.5	5,994	0.082	0.034	0.125	0.519
9	8.5	9.5	4,751	0.080	0.031	0.119	0.326
10	9.5	10.5	4,028	0.079	0.029	0.116	0.308
11	10.5	11.5	2,995	0.077	0.024	0.108	0.255
12	11.5	12.5	2,103	0.076	0.023	0.105	0.218
13	12.5	13.5	1,359	0.077	0.025	0.109	0.235
14	13.5	14.5	885	0.075	0.022	0.103	0.200
15	14.5	15.5	539	0.075	0.020	0.101	0.158
16	15.5	16.5	317	0.077	0.021	0.105	0.178
17	16.5	17.5	228	0.078	0.021	0.105	0.164
18	17.5	18.5	151	0.078	0.021	0.105	0.152
19	18.5	19.5	99	0.078	0.024	0.109	0.195
20	19.5	20.5	64	0.071	0.018	0.093	0.128
21	20.5	21.5	38	0.070	0.019	0.095	0.125

22	21.5	22.5	43	0.076	0.020	0.102	0.129
23	22.5	23.5	15	0.071	0.015	0.090	0.099
24	23.5	24.5	17	0.075	0.023	0.105	0.119
25	24.5	25.5	8	0.080	0.020	0.106	0.102
26	25.5	26.5	1	0.062	0.000	0.062	0.062

Airport ASOS Data

Analysis of airport ASOS wind speed data since 1984 confirms the met tower data results. Airport data is collected at an elevation of 10 meters. Shown below, the data was scaled to 29 meters with a power law algorithm using an α (power law exponent) value of 0.095 (measured by the met tower) and 0.14 (typical of tundra terrain). In both cases, average wind speeds measured by the met tower exceed airport wind speeds. This likely is due to the more exposed location of the met tower on higher terrain. In 2005, Alaska Energy Authority analyzed the Deering airport data and predicted a Class 3 wind resource from it. Deering met tower data confirms that classification but adjusted to the high end of the Class 3 range.

Airport/met tower data comparison

	Deering Airport			Met Tower, 29 m B	
	AWOS, 10 m sensor (m/s)	Data adj. to 29 m, α=0.095 (m/s)	Data adj. to 29 m, α=0.14 (m/s)	Collected Data (m/s)	Synth. Data (m/s)
Jan	5.16	5.71	5.99	7.14	6.91
Feb	5.90	6.52	6.84	6.05	5.93
Mar	5.19	5.75	6.03	6.64	6.64
Apr	5.10	5.64	5.92	6.27	6.27
May	4.34	4.80	5.03	5.82	5.88
Jun	3.95	4.37	4.59	4.81	4.82
Jul	4.18	4.63	4.86	5.29	5.12
Aug	4.46	4.93	5.18	5.32	5.47
Sep	4.54	5.02	5.27	5.68	5.68
Oct	4.44	4.91	5.15	5.90	5.89
Nov	4.55	5.03	5.28	6.78	6.56
Dec	5.20	5.76	6.04	7.05	6.80
Annual	4.71	5.21	5.47	6.06	6.00