# Wyandotte Municipal Services

# Community Wind Energy Project

# Wind Resouce Assessment

ANNUAL REPORT

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Black & Veatch Project: 144374

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# Contents



## Tables



## Figures

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# 1.0 Executive Summary

Wyandotte Municipal Services (WMS) is currently evaluating the feasibility of developing one or more community wind energy projects. WMS has retained Black & Veatch to perform a wind resource assessment campaign for their perspective wind energy projects which are located within the city of Wyandotte, Michigan, near the United States border with Canada. The duration of this report is from the time when each of the towers was commissioned to February 29, 2008. This report covers a brief summary of wind data measured at two meteorological (met) towers and an update of their operational status. Long-term wind speeds and energy production estimates for the GE 1.5MW xle, Vestas V82 1.65MW and Gamesa G87 2.0MW, wind turbine models are also included in this report to provide information on the anticipated performance for the projects.

This report documents Task 3 & 4 of the overall work plan. Black & Veatch's findings are summarized below and described in detail in this report.

**Wind Resource –** Based on the data from two met towers, Black & Veatch estimates the long-term average wind speeds at 80 meters (262 feet) above ground level at the BASF met location to be 6.2 m/s (13.8 mph) and 5.8 m/s (13.0 mph) at the Central Avenue met location. This means the City of Wyandotte has, on average, a Class 1 wind resource.

**Production Estimates –** Black & Veatch estimated the production potential of each project area using the three wind turbine models mentioned above. Turbines near the BASF met location could achieve a net capacity factor of 27.1 percent, producing approximately 4,752 MWh annually and turbines near the Central Ave met location could achieve a net capacity factor of 23.9 percent, producing approximately 4,186 MWh annually.

# 2.0 Site Wind Resource

The wind energy resource of a potential project site is the single most critical aspect to understand, and is one of the few that cannot be overcome with technical solutions. This section discusses the various sources of wind resource information available for the study, and combines them into an estimate of the wind resource for WMS.

## 2.1 Wind Data

Black & Veatch reviewed several data sources to estimate the wind resource potential for WMS. These data sources were:

- Wind data collected by Black & Veatch from two met towers located with the City of Wyandotte *(December, 2006 through February, 2008)*
- Wind Data Collected by the Detroit Metro Airport ASOS station *(January, 1985 – February, 2008)*
- Wind Data Collected by the Detroit Willow Run Airport ASOS station *(January, 1997 – February, 2008)*

### *2.1.1 Met Tower Data*

Black & Veatch procured two 60 meter (196 foot) tall met towers for WMS, and installed them on land within the City Wyandotte. Each tower was an Ohmega 60m tubular, tilt-up tower with a SecondWind Nomad2 datalogger, and wind speed sensors placed at 60, 30, and 10 meters above ground level. Additionally, wind direction sensors were placed at the 59 and 29 meter levels. The Central Avenue met tower was also equipped with temperature and pressure sensors. The locations of all these towers and their respective equipment are listed in Table 2-1. Installation records are located in Appendix A.

The locations of the met towers, their proximity to the international border and a national wildlife refuge are presented are shown in Figure 2-1. The Central Avenue met tower is located in a densely populated urban environment with various sized structures throughout the local area. The BASF met tower is located within the vicinity of the BASF manufacturing plant. The met towers at both sites are generally free from obstructions within 1,000 – 2,000 feet, with the nearest buildings no more than 2-3 stories tall.

Black & Veatch reviewed data from each of the two met towers; all data was validated through a process of visual inspections of the time series data, along with the comparison of wind speed measurements at different heights on the same tower and between towers. The monthly statistics for each tower are shown in Table 2-2. Figure 2-2 and Figure 2-3 show the cumulative diurnal and frequency distribution patterns for each of the met tower locations. Monthly plots of this data are provided at Appendix B.

**Table 2-1. Met Tower Sites and Equipment Summary.**

| | | |
|---|---|---|
| **Met Tower Number:** | 02539 | 02540 |
| **Met Tower Name:** | BASF | Central Avenue |
| **Type:** | 60m Tubular; 8”- 6- 4.5” O.D | 60m Tubular; 8”- 6 - 4.5” O.D |
| **Manufacturer** | Ohmega | Ohmega |
| **Data Transfer Method** | CDMA Modem | CDMA Modem |
| **Wind Speed Sensor Type** | NRG #40 | NRG #40 |
| **Monitoring Heights Orientation** | 60m, 30m, 10m; SE&NW | 60m, 30m, 10m; SE&NW |
| **Wind Direction Sensor Type** | NRG #200P | NRG #200P |
| **Monitoring Heights & Orientation** | 49m, 29m; SW | 49m, 29m; SW |
| **Sensor Boom Length** | 60.5” | 60.5” |
| **Sensor Boom O.D** | 1.0” | 1.0” |
| **Sensor Rise above Boom** | 22” | 22” |
| **Temperature Sensor** | | SWI |
| **Monitoring Height** | | 3m |
| **Pressure Sensor** | | Setra 276 |
| **Monitoring Height** | | 3m |
| **Latitude (WGS84):** | 42º 13' 6" N | 42º 11' 21.42" N |
| **Longitude (WGS84):** | 83º 8' 33.06" W | 83º 9' 46.86" W |
| **Elevation (meters):** | 174 | 175 |
| **Installation date:** | March 21, 2007 | December, 22 2006 |
| **Dataset Ongoing?** | Yes | Yes |
| **Last Maintenance Date:** | October 17, 2007 | October 17, 2007 |
| **Decommission Date:** | | |

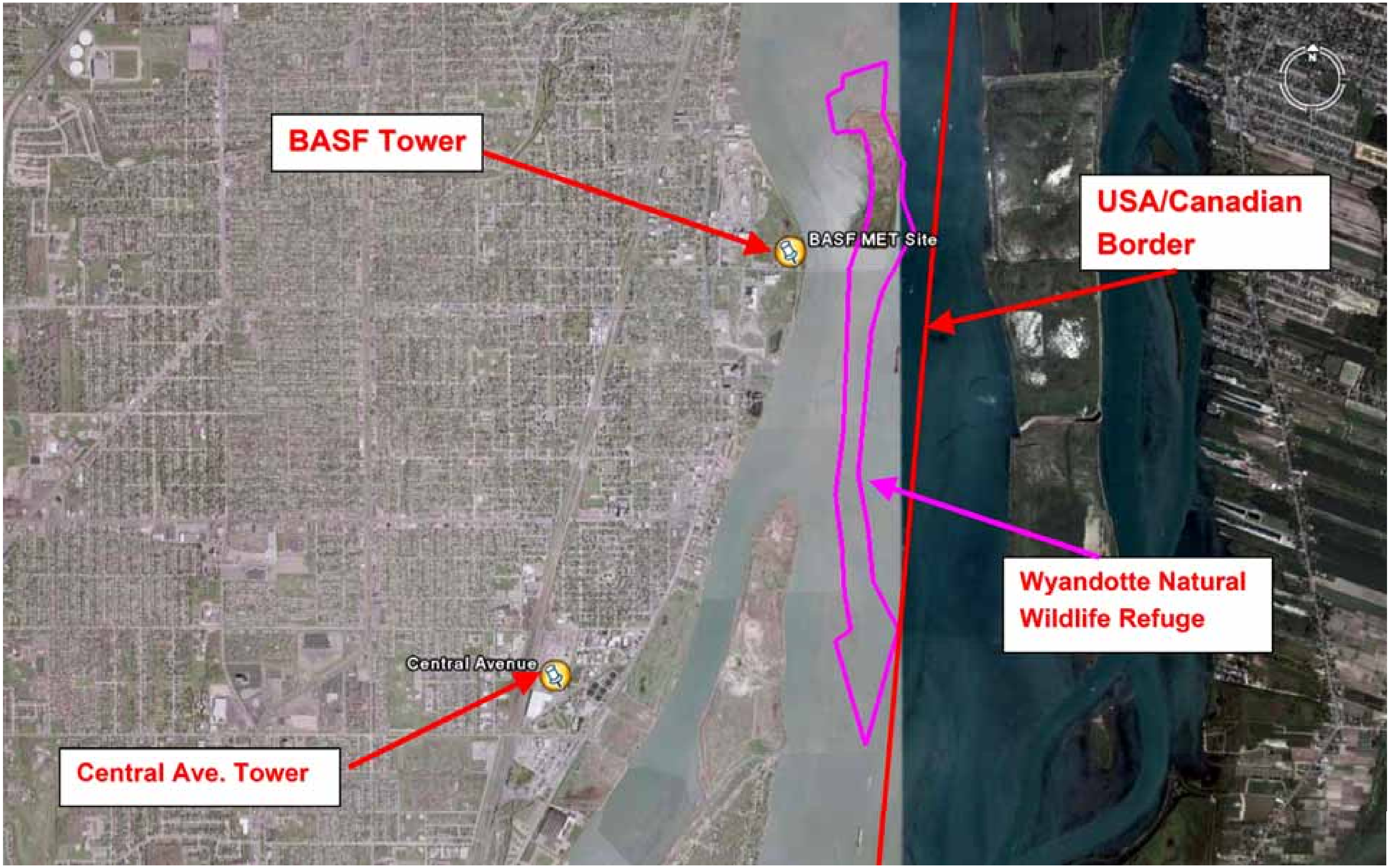


**Figure 2-1. Met tower locations.**

# Table 2-2. Wind Data Collection Summary.

| | Year | 2006 | 2007 | | | | | | | | | | | | 2008 | | Annual Average | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Month | Dec | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | m/s | Mph |
| 10m Average Wind Speed (m/s) | Central Ave | 3.34 | 3.59 | 4.11 | 4.15 | 4.23 | 2.99 | 2.74 | 2.82 | 2.56 | 2.50 | 3.16 | 3.51 | 3.38 | 4.15 | 3.45 | **3.31** | 7.40 |
| | BASF | **3.77** | **4.01** | **4.57** | **4.67** | 4.72 | 3.51 | 3.19 | 3.39 | 3.00 | 3.05 | 3.68 | 3.94 | 3.66 | 4.47 | 3.64 | **3.77** | 8.43 |
| 30m Average Wind Speed (m/s) | Central Ave | 4.64 | 4.80 | 5.26 | 5.34 | 5.32 | 3.92 | 3.57 | 3.72 | 3.49 | 3.44 | 4.38 | 4.53 | 4.44 | 5.38 | 4.51 | **4.35** | 9.73 |
| | BASF | **4.93** | **5.04** | **5.47** | **5.61** | 5.67 | 4.37 | 3.88 | 3.96 | 3.77 | 3.76 | 4.75 | 4.85 | 4.75 | 5.66 | 4.81 | **4.66** | 10.43 |
| 60m Average Wind Speed (m/s) | Central Ave | 5.54 | 5.63 | 6.07 | 6.32 | 6.25 | 4.69 | 4.24 | 4.32 | 4.01 | 4.22 | 5.34 | 5.39 | 5.17 | 6.23 | 5.35 | **5.15** | 11.52 |
| | BASF | **5.77** | **5.76** | **6.21** | **6.56** | 6.41 | 5.00 | 4.48 | 4.56 | 4.27 | 4.48 | 5.71 | 5.72 | 5.49 | 6.52 | 5.45 | **5.40** | 12.08 |
| 60m Max 3-sec Wind Gust (m/s) | Central Ave | 17.56 | 27.72 | 25.21 | 24.83 | 24.06 | 30.95 | 19.86 | 23.3 | 30.18 | 19.09 | 24.45 | 21.39 | 25.21 | 27.89 | 23.3 | **24.30** | 54.35 |
| | BASF | **19.0** | **29.7** | **24.3** | **26.8** | 23.7 | 29.4 | 22.9 | 25.2 | 24.8 | 21.4 | 21.4 | 22.5 | 27.1 | 27.5 | 24.5 | **24.52** | 54.85 |
| 30m to 60m Average Wind Shear | Central Ave | 0.273 | 0.251 | 0.22 | 0.28 | 0.24 | 0.296 | 0.275 | 0.236 | 0.236 | 0.334 | 0.311 | 0.246 | 0.238 | 0.220 | 0.275 | **0.266** | |
| | BASF | **0.256** | **0.230** | **0.20** | **0.26** | 0.20 | 0.246 | 0.262 | 0.242 | 0.223 | 0.304 | 0.299 | 0.249 | 0.233 | 0.217 | 0.195 | **0.246** | |
| Mean 60m Turbulence Intensity @ 15 m/s – All Directions | Central Ave | | 17.9% | 16.6% | 17.0% | 15.1% | | | | 33.2% | | | 16.1% | 17.5% | 18.2% | 16.5% | **19.1%** | |
| | BASF | | **16.9%** | **11.4%** | **19.4%** | 16.7% | | 13.2% | 17.5% | | 17.4% | 16.9% | 14.1% | 14.7% | 16.6% | 16.3% | **16.1%** | |
| Average Temperature (ºC) | Central Ave | 4.10 | -0.54 | -6.69 | 4.43 | 8.44 | 16.75 | 22.01 | 23.53 | 24.70 | 20.15 | 15.46 | 4.92 | -0.84 | -1.52 | -1.41 | **11.412** | |
| | BASF | **4.10** | **-0.54** | **-6.69** | **4.43** | 8.44 | 16.75 | 9.71 | 23.53 | 24.70 | 20.15 | 15.46 | 4.92 | -0.84 | -1.52 | -1.41 | **10.387** | |
| Average Air Density (kg/m^3) | Central Ave | 1.25 | 1.27 | 1.30 | 1.25 | 1.23 | 1.20 | 1.25 | 1.17 | 1.16 | 1.18 | 1.20 | 1.20 | 1.13 | 1.21 | 1.07 | **1.205** | |
| | BASF | **1.25** | **1.27** | **1.30** | **1.25** | 1.23 | 1.20 | 1.25 | 1.17 | 1.16 | 1.18 | 1.20 | 1.20 | 1.13 | 1.21 | 1.07 | **1.205** | |

**Notes:**
- All wind speed values in meters per second (m/s) unless otherwise indicated. 1m/s = 2.24 mph.
- Values in red boldface font are derived from the Central Ave met tower wind data.
- 80 meter wind speed data is estimated from 60 meter data and measured wind shear between 60 and 30 meters.
- ***Characteristic Turbulence Intensity values calculated on a

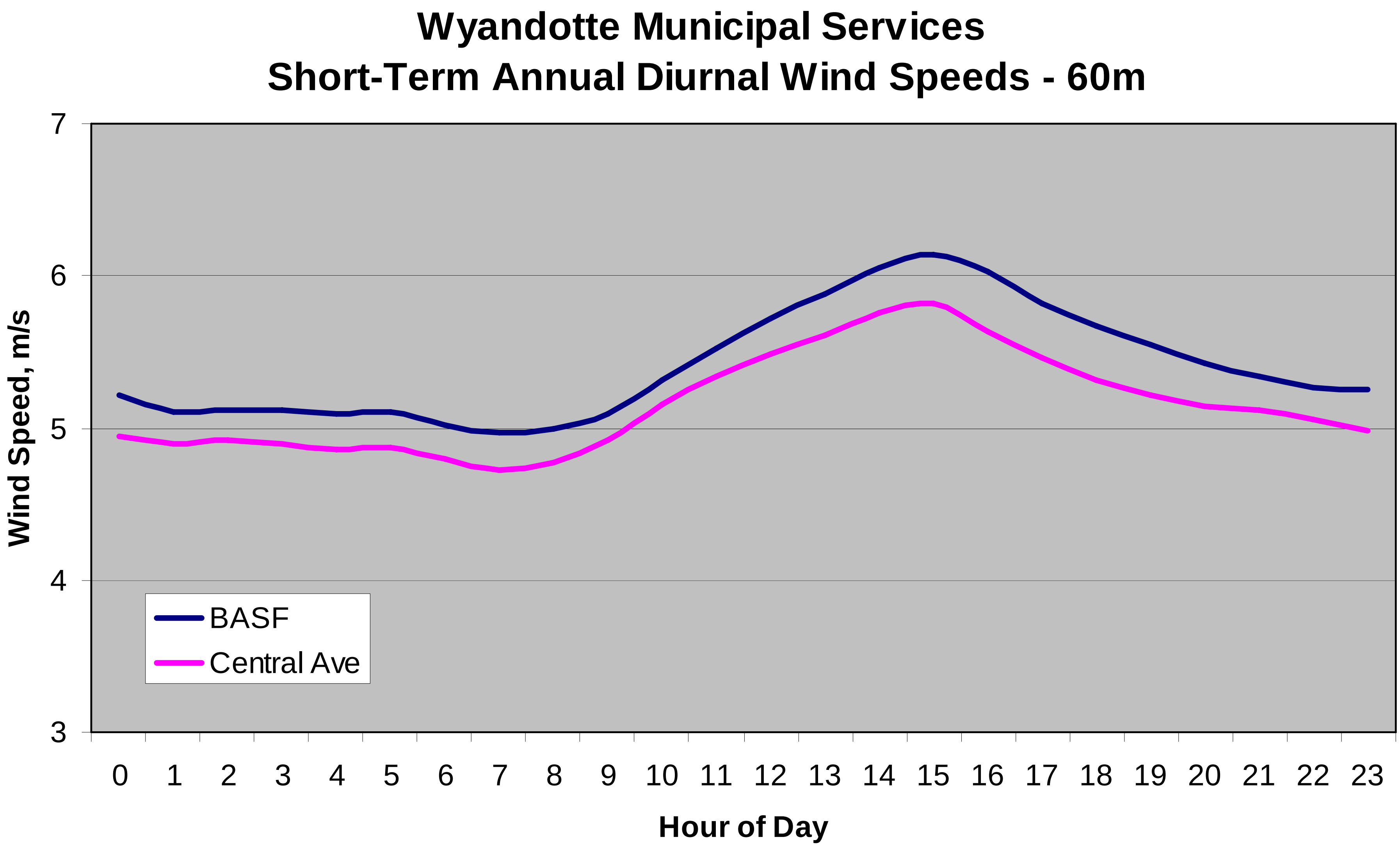


**Figure 2-2. Cumulative annual diurnal wind speeds.**

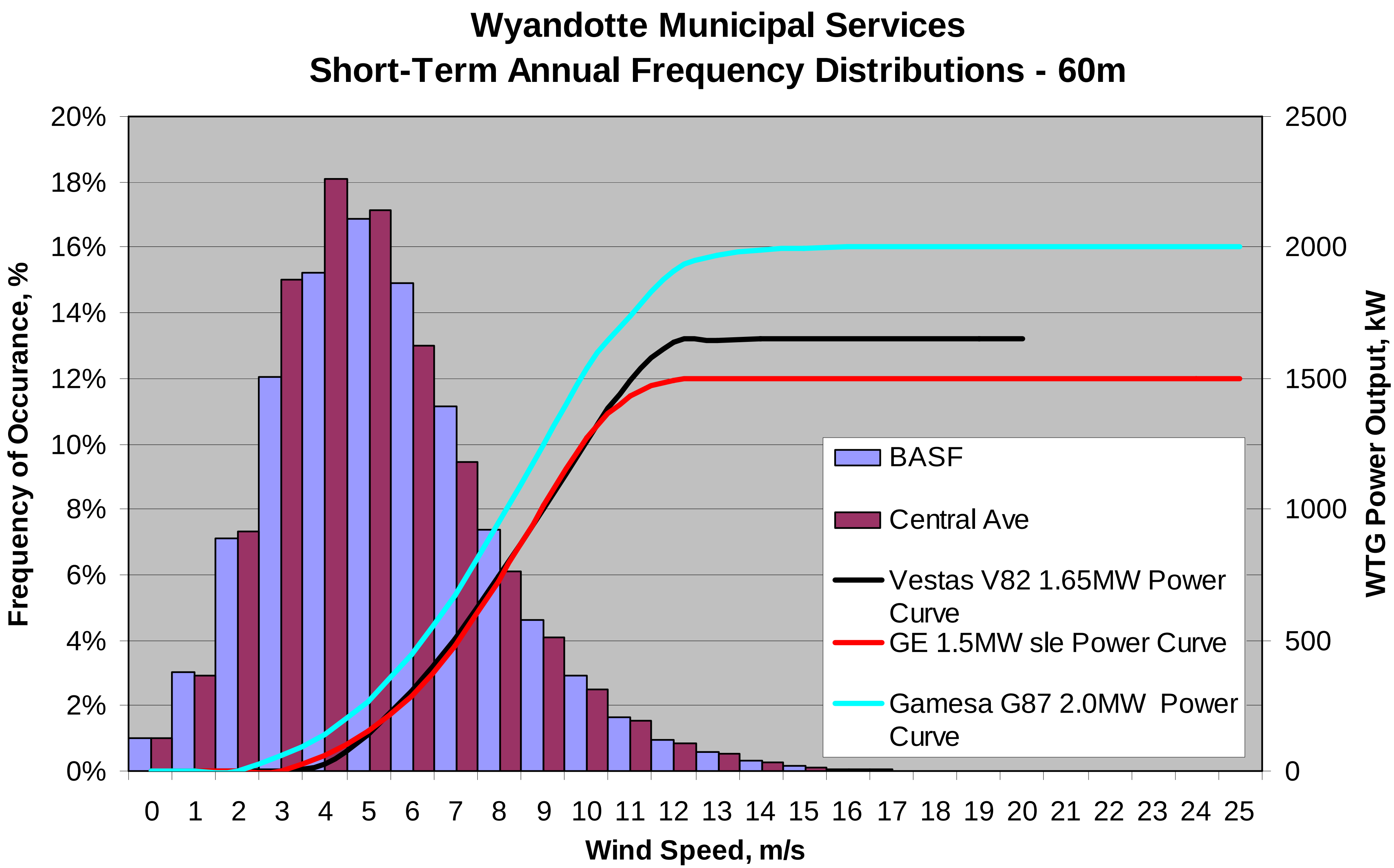


**Figure 2-3. Cumulative annual frequency distributions.**

As part of the International Electrotechnical Commission (IEC) 61400 series of standards governing the design of wind turbines, a series of designations are given to the wind resource of a site. These designations are used to match the appropriate turbine designs and models for a site's wind conditions. Based on the on-site wind data collected, the Wyandotte sites appear to have a Class III designation; however, the high characteristic turbulence intensity of the site appears to be beyond Category B and may warrant a Class A turbine to be used. Figure 2-4 and Figure 2-5 show the mean turbulence intensity graph of the 60 meter data calculated for all years, all months, for both towers; the calculations are based on the 3rd edition of the IEC standard 64100-1. This graph also includes the IEC turbulence categories for comparison. The energy production estimates discussed in Section 3 are based on wind turbine models of at least a Class IIIA designation. Ultimately, the designation of the site as it applies to the design of a specific wind turbine will be evaluated by the wind turbine manufacturer, to ensure the proper wind turbine model is provided.

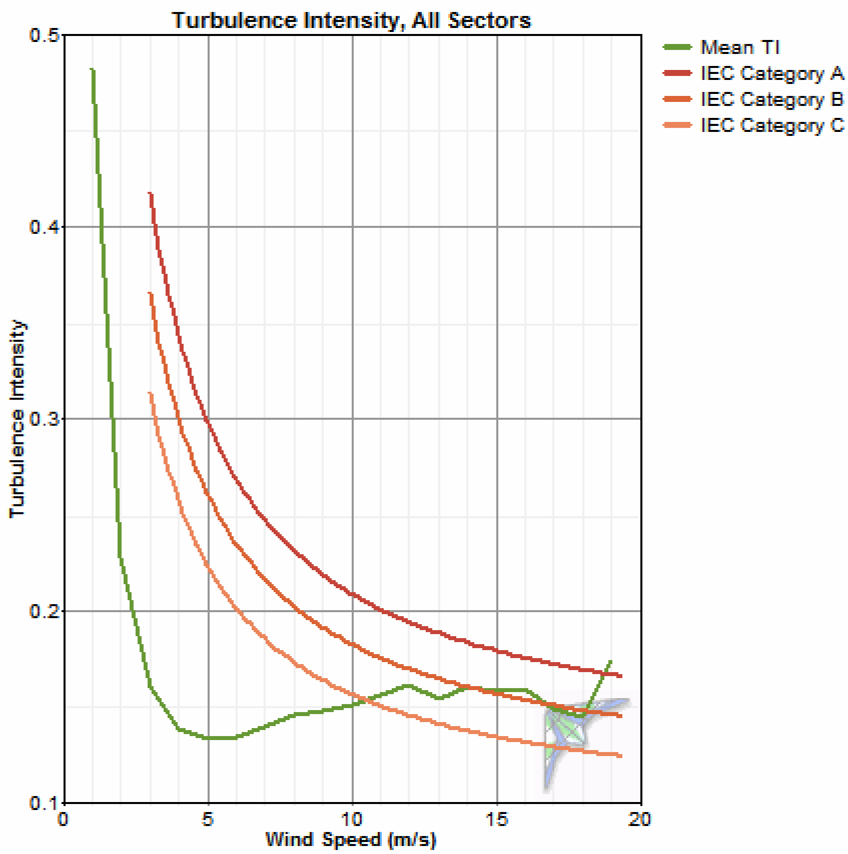


**Figure 2-4. BASF site turbulence intensity.**

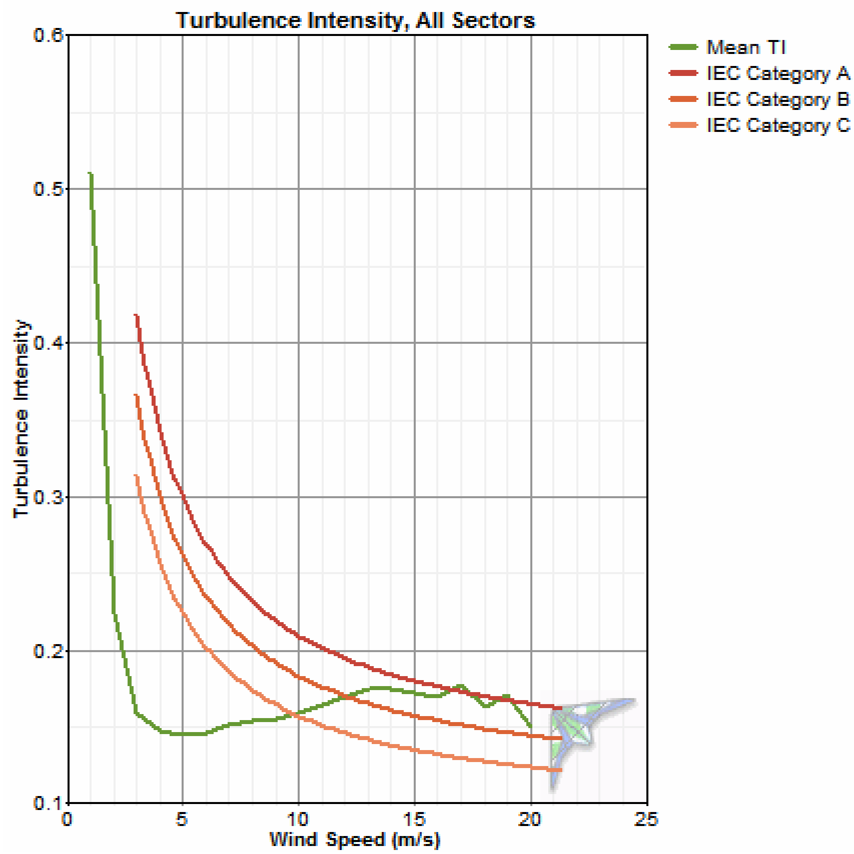


**Figure 2-5. Central Avenue site turbulence intensity.**

### *2.1.2 Met Tower Operational Status*

A recent preventative maintenance cycle was performed on both towers on October 17th, 2007. The following maintenance was performed:

- Tower Straightening/Inspection
- Guy Wire Tension Adjustment
- Anchor Inspection
- PV Panel Cleaning
- Logger operational inspection and maintenance
- Memory Card Data Download and Clearing

**Central Avenue Met tower:** The tower continues to operate well. Communications with this tower had resumed in early January for regular downloads and screening of the wind data. All sensors/booms appeared to be in good working order and passed operational tests.

**BASF Met tower:** The wind speed sensors on this tower appear to be functioning properly. During the October site visit, the field technician was able to confirm that both wind vanes on this tower were not functioning properly. Black & Veatch has determined that these sensors to have stopped functioning on the following dates:

- Wind Vane at 59 meters – Stopped functioning August 24, 2007.
- Wind Vane at 29 meters – Stopped functioning March 24, 2007.

As mentioned in the previous months' reports, the wind direction data from the Central Avenue Met tower had a high correlation to the BASF Met tower. Due to this relationship, the wind direction data collected from the Central Ave Met tower is used to fill in the "gap" in the wind direction data at the BASF site until a time when another sensor malfunction (such as the 60m anemometer) necessitates lowering the tower to replace the damaged instruments. This process is discussed in Section 2.2 .

While the recent preventative maintenance will help to ensure that the towers operate well through the winter season, Black & Veatch recommends that local personnel perform visual inspections after any major storms or icing events that may occur during the winter season to prevent or minimize any possibility of data loss. The visual inspections combined with weekly data screening will ensure dataset integrity.

### 2.1.3 Reference Station Data

While a year of data collection at or near a project site is usually deemed necessary for a wind energy project, a long-term data source is also needed to put the collected data into a historical perspective. Since the wind conditions at a site can change considerably between individual years, comparing the year over which data was collected to a long-term average is important in understanding a site's average long-term wind resource. Therefore Black & Veatch reviewed the wind data collected at two local weather stations as potential long-term data sources for WMS's wind resource estimates.

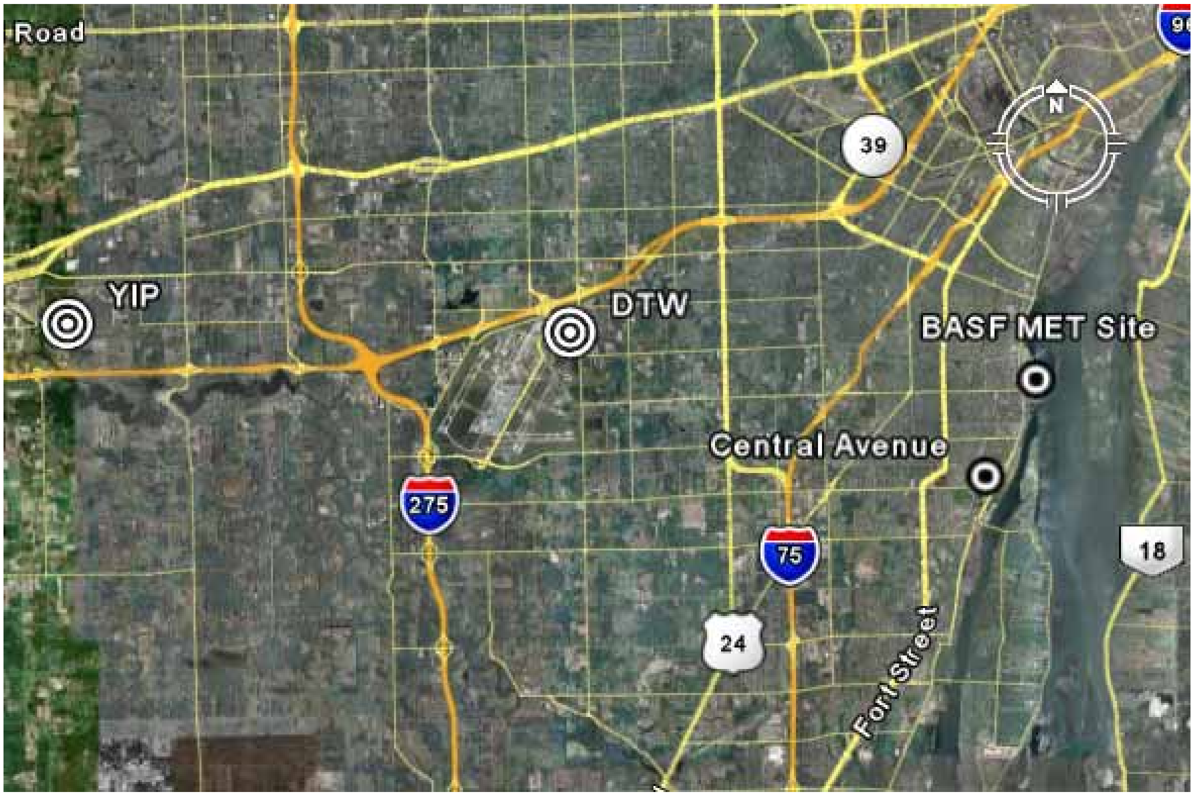


**Figure 2-6. Reference station locations.**

### *2.1.3.1 Detroit Metro Airport ASOS Data*

The Detroit Metro Airport weather station location is 42º 14' North, 83º 20' West (WGS84) with an elevation of 192 meters; a map showing this location in respect to the met towers is shown in Figure 2-6. This weather station is approximately 9 miles west of the met towers. The Detroit Metro Airport met tower is an Automated Surface Observation System (ASOS) station, identified by call sign "DTW." The ASOS specifications indicate that wind speed and direction are recorded at 10 meters (33 feet) above ground level.

Black & Veatch reviewed the data collected from January 1985 through February 2008; monthly averages from this period are presented in Table 2-3 and shown in Figure 2-7. The long-term average monthly wind speeds were calculated based only on months with data capture greater than 75 percent.

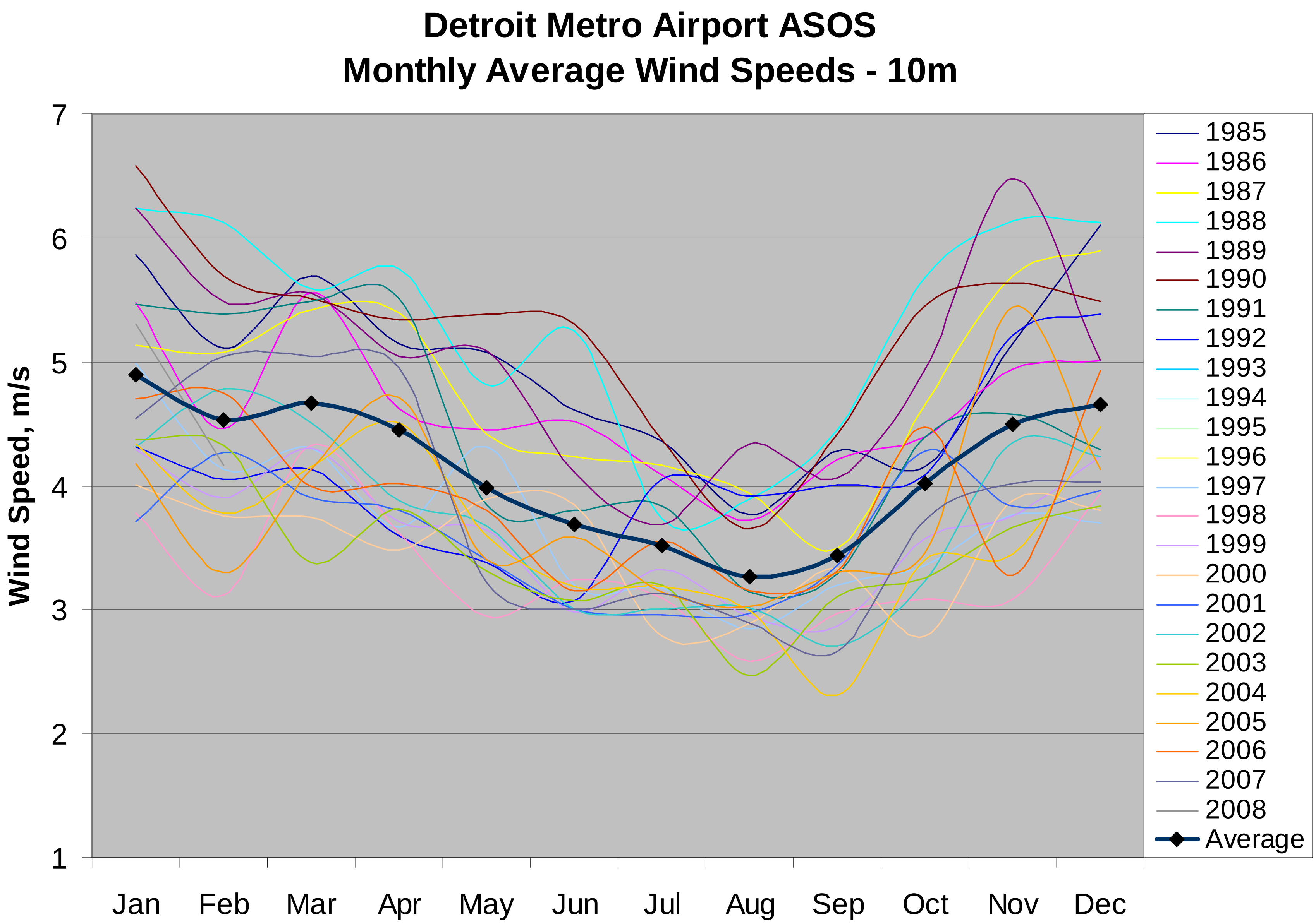


**Figure 2-7. Detroit Metro Airport wind speed averages.**

**Table 2-3. Detroit Metro Airport Monthly Average Wind Speeds – 10m.**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 5.86 | 5.11 | 5.69 | 5.14 | 5.07 | 4.61 | 4.35 | 3.77 | 4.28 | 4.15 | 5.14 | 6.10 |
| 1986 | 5.48 | 4.46 | 5.55 | 4.62 | 4.45 | 4.52 | 4.09 | 3.72 | 4.21 | 4.40 | 4.93 | 5.01 |
| 1987 | 5.13 | 5.08 | 5.42 | 5.39 | 4.42 | 4.23 | 4.16 | 3.94 | 3.50 | 4.66 | 5.69 | 5.89 |
| 1988 | 6.24 | 6.12 | 5.58 | 5.75 | 4.82 | 5.25 | 3.73 | 3.90 | 4.45 | 5.68 | 6.13 | 6.12 |
| 1989 | 6.23 | 5.49 | 5.55 | 5.04 | 5.09 | 4.11 | 3.68 | 4.33 | 4.06 | 4.93 | 6.48 | 5.01 |
| 1990 | 6.58 | 5.69 | 5.51 | 5.34 | 5.38 | 5.30 | 4.37 | 3.66 | 4.42 | 5.45 | 5.63 | 5.48 |
| 1991 | 5.47 | 5.38 | 5.48 | 5.50 | 3.85 | 3.80 | 3.83 | 3.14 | 3.28 | 4.39 | 4.57 | 4.29 |
| 1992 | 4.32 | 4.05 | 4.13 | 3.60 | 3.38 | 3.07 | 4.05 | 3.91 | 4.00 | 4.08 | 5.21 | 5.38 |
| 1993 | | | | | | | | | | | | |
| 1994 | | | | | | | | | | | | |
| 1995 | | | | | | | | | | | | |
| 1996 | | | | | | | | | | | 3.58 | |
| 1997 | 4.98 | 4.13 | 4.31 | 3.67 | 4.31 | 3.20 | 3.17 | 2.85 | 3.20 | 3.36 | 3.77 | 3.70 |
| 1998 | 3.78 | 3.11 | 4.33 | 3.62 | 2.95 | 3.24 | 3.09 | 2.58 | 2.97 | 3.08 | 3.08 | 3.94 |
| 1999 | 4.29 | 3.91 | 4.31 | 3.71 | 3.64 | 2.98 | 3.33 | 2.95 | 2.87 | 3.57 | 3.75 | 4.23 |
| 2000 | 4.01 | 3.75 | 3.74 | 3.48 | 3.89 | 3.85 | 2.78 | 2.89 | 3.34 | 2.79 | 3.88 | 3.80 |
| 2001 | 3.71 | 4.27 | 3.90 | 3.80 | 3.41 | 3.00 | 2.96 | 2.98 | 3.36 | 4.28 | 3.84 | 3.96 |
| 2002 | 4.32 | 4.78 | 4.50 | 3.89 | 3.68 | 3.00 | 3.01 | 3.01 | 2.71 | 3.23 | 4.34 | 4.23 |
| 2003 | 4.37 | 4.32 | 3.37 | 3.82 | 3.31 | 3.07 | 3.19 | 2.47 | 3.10 | 3.25 | 3.67 | 3.84 |
| 2004 | 4.34 | 3.77 | 4.16 | 4.51 | 3.60 | 3.18 | 3.19 | 3.00 | 2.31 | 3.41 | 3.45 | 4.47 |
| 2005 | 4.18 | 3.30 | 4.13 | 4.71 | 3.40 | 3.59 | 3.14 | 3.02 | 3.30 | 3.46 | 5.44 | 4.13 |
| 2006 | 4.70 | 4.75 | 3.99 | 4.02 | 3.80 | 3.16 | 3.55 | 3.15 | 3.32 | 4.48 | 3.28 | 4.92 |
| 2007 | 4.54 | 5.04 | 5.04 | 4.95 | 3.22 | 3.00 | 3.13 | 2.89 | 2.67 | 3.72 | 4.02 | 4.03 |
| 2008 | 5.30 | 4.17 | | | | | | | | | | |
| **Average** | **4.89** | **4.53** | **4.67** | **4.45** | **3.98** | **3.69** | **3.52** | **3.27** | **3.44** | **4.02** | **4.49** | **4.66** |

Notes: **All values in meters per second.**

### *2.1.3.2 Detroit Willow Run Airport ASOS Data*

The Detroit Willow Run Airport weather station location is 42º 14’ North, 83º 32’ West (WGS84) with an elevation of 218 meters; a map showing this location in respect to the met towers is shown in Figure 2-1. This weather station is approximately 20 miles west of the met towers. The Detroit Willow Run Airport met tower is an Automated Surface Observation System (ASOS) station, identified by call sign “YIP.” The ASOS specifications indicate that wind speed and direction are recorded at 10 meters (33 feet) above ground level.

Black & Veatch reviewed the data collected from January 1997 through February 2008; monthly averages from this period are presented in Figure 2-8 and shown in Table 2-4. The long-term average monthly wind speeds were calculated based only on months with data capture greater than 75 percent.

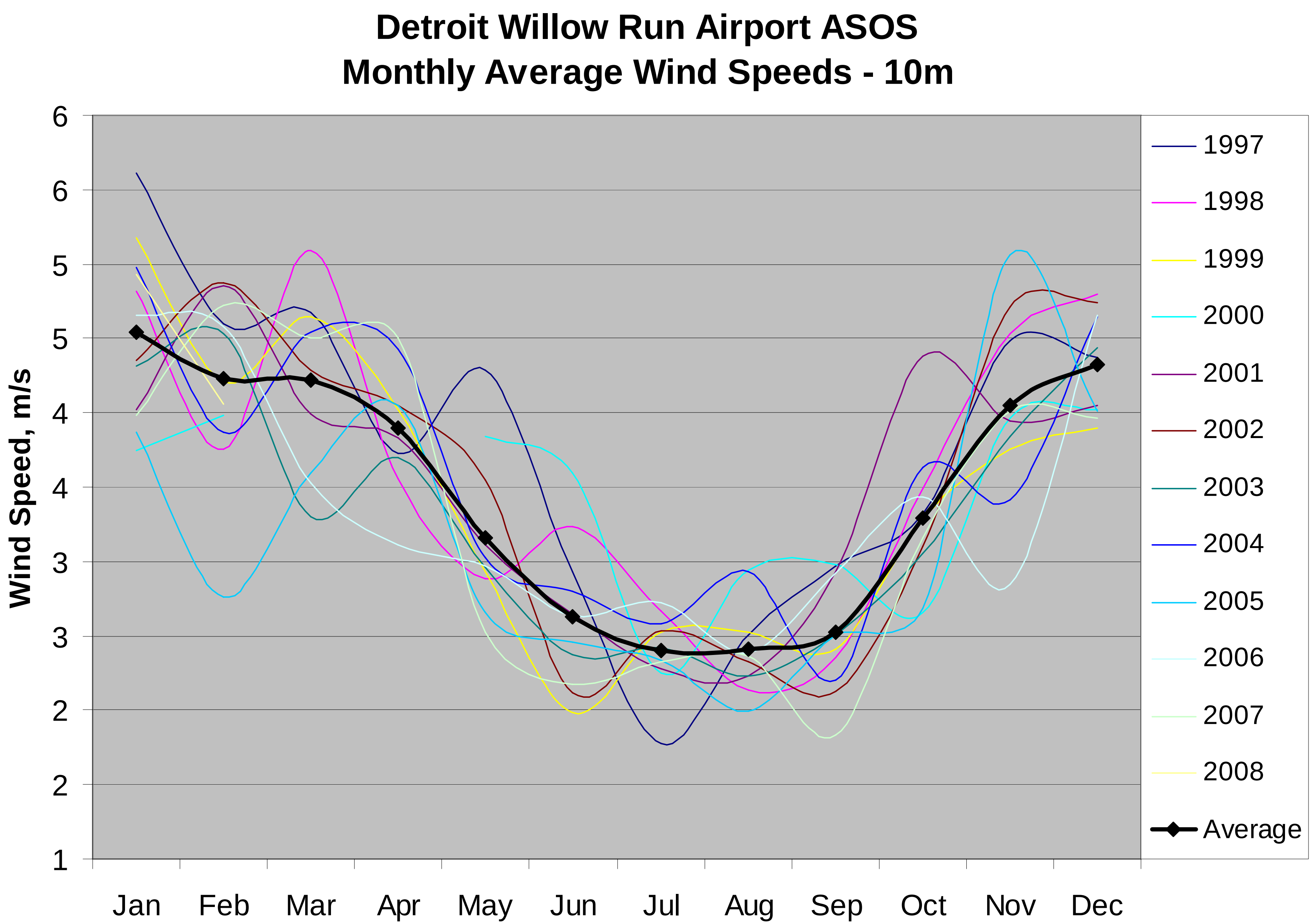


**Figure 2-8. Detroit Willow Run Airport wind speed averages.**

**Table 2-4.**
**Detroit Willow Run Airport Monthly Average Wind Speeds – 10m.**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 5.61 | 4.60 | 4.67 | 3.73 | 4.28 | 2.94 | 1.77 | 2.51 | 2.97 | 3.32 | 4.49 | 4.37 |
| 1998 | 4.82 | 3.75 | 5.09 | 3.56 | 2.88 | 3.23 | 2.67 | 2.13 | 2.35 | 3.49 | 4.53 | 4.80 |
| 1999 | 5.18 | 4.21 | 4.64 | 4.02 | 2.93 | 1.98 | 2.52 | 2.52 | 2.41 | 3.29 | 3.76 | 3.89 |
| 2000 | 3.75 | 3.98 | | | 3.84 | 3.60 | 2.25 | 2.94 | 2.98 | 2.65 | 3.96 | 4.02 |
| 2001 | 4.02 | 4.85 | 3.99 | 3.83 | 3.11 | 2.65 | 2.28 | 2.24 | 2.94 | 4.38 | 3.95 | 4.05 |
| 2002 | 4.36 | 4.87 | 4.28 | 4.05 | 3.55 | 2.12 | 2.54 | 2.32 | 2.13 | 3.10 | 4.71 | 4.74 |
| 2003 | 4.31 | 4.53 | 3.30 | 3.70 | 2.96 | 2.37 | 2.42 | 2.24 | 2.50 | 3.06 | 3.84 | 4.44 |
| 2004 | 4.98 | 3.87 | 4.54 | 4.43 | 3.03 | 2.80 | 2.58 | 2.93 | 2.21 | 3.63 | 3.41 | 4.64 |
| 2005 | 3.86 | 2.76 | 3.59 | 4.05 | 2.65 | 2.46 | 2.34 | 1.99 | 2.50 | 2.68 | 5.07 | 4.01 |
| 2006 | 4.66 | 4.58 | 3.53 | 3.11 | 2.97 | 2.64 | 2.73 | 2.38 | 2.92 | 3.43 | 2.85 | 4.66 |
| 2007 | 3.98 | 4.73 | 4.50 | 4.50 | 2.52 | 2.18 | 2.32 | 2.36 | 1.83 | 3.16 | 4.01 | 3.97 |
| 2008 | 4.93 | 4.05 | | | | | | | | | | |
| **Average** | **5.61** | **4.60** | **4.67** | **3.73** | **4.28** | **2.94** | **1.77** | **2.51** | **2.97** | **3.32** | **4.49** | **4.37** |
| Notes: **All values in meters per second.** | | | | | | | | | | | | |

Wind data collected from ASOS stations is not intended for wind energy resource assessment since it is commonly collected with instruments fairly low to the ground. At both the Detroit airports, the data was collected at 10 meters (33 feet) above ground level, far lower than the 80 meter hub height of interest in this report. Since scaling this low-level data upward to the proposed turbine hub heights is not preferable when a better data source is available, Black & Veatch did not attempt to use this data directly for wind resource estimation. Instead, Black & Veatch used the reference stations to review how data collected at the Wyandotte met towers compares with the long-term data from the Detroit airport ASOS stations. This comparison and the subsequent impact to the wind resource estimates are presented in Section 2.2 .

To verify the datasets, Black & Veatch performed correlations between the onsite met towers and the reference station data sources on a daily basis. Table 2-5 shows the daily correlation estimates of the Detroit Airport datasets to the Wyandotte met towers.

The correlations between the met tower data and the reference station data are strong enough to indicate that these towers were experiencing similar wind condition changes on a daily basis. Black & Veatch hypothesizes the reason the correlations between the reference stations and the onsite met towers are not stronger may be due to nearby obstructions impacting the flow of the wind as distance from the met towers increases.

**Table 2-5.**
**Daily Met Data Correlations to other Local Datasets.**

| | BASF Met Tower | | | Central Ave Met Tower | | |
|---|---|---|---|---|---|---|
| | 60m | 30m | 10m | 60m | 30m | 10m |
| Detroit Metro Airport (DTW) | 0.931 | 0.932 | 0.921 | 0.944 | 0.960 | 0.949 |
| Detroit Willow Run Airport (YIP) | 0.705 | 0.716 | 0.713 | 0.729 | 0.762 | 0.770 |

After review of the quality checked datasets, Black & Veatch determined the DTW ASOS data provided the longest period of record available and the best correlation to the met tower wind data. Black & Veatch used the measurements from this location as the project site reference dataset for the MCP calculations.

## 2.2 Wind Resource Estimate

At the time of this report, the BASF met tower had not collected a complete year of data as it was installed several months after the Central Ave met tower was commissioned. Given that the Central Avenue and BASF met towers have similar tower configurations, concurrent time series data with strong correlations and the Central Avenue met tower dataset extends over a full year, Black & Veatch used the overlapping time series data from these met towers to extend the BASF dataset from January 2007 thru March 2007. The data was synthesized by establishing directional wind speed adjustment ratios with the concurrent data from the Central Avenue and BASF met towers. These directional ratios where then used to adjust the Central Avenue met data to extend the BASF met tower dataset. By these methods, the BASF met tower dataset was extended to encompass 14 full months of data capture.

With over a year of on-site data from both met towers, and a long-term data source, Black & Veatch estimated the long-term wind resource on the reservation using the Measure-Correlate-Predict (MCP) method.

The first step in the MCP process was to put the wind speeds measured at the each of the met locations into historical perspective. Black & Veatch compared the monthly average wind speeds of the data collected at the long-term reference station over the time period data was collected at each met location with the monthly average wind speeds of every complete month on record. For each month, the ratio of the monthly average wind speeds to the long-term monthly average wind speeds at the Detroit Metro Airport ASOS station was determined. These ratios were then applied to the met tower data sets to adjust the recorded wind speeds and create an estimate of the long-term wind speeds at this met location. These wind speeds are shown in Table 2-6.

Finally, Black & Veatch adjusted the 60 meter long-term wind speed data from each of the met towers to estimate the long-term averages at the wind turbine hub height of interest, 80 meters. To make this height adjustment, Black & Veatch utilized the wind shear power law approximation, which defines the relationship between wind speed and height above ground as:

$$V(Z) = V(z_r) \cdot \left( \frac{z}{z_r} \right)^{\alpha}$$

where:

| | |
|---|---|
| $V(z)$ | = wind speed at height of interest |
| $V(z_r)$ | = wind speed at reference height |
| $z$ | = height of interest |
| $z_r$ | = reference height |
| $\alpha$ | = wind shear component |

Black & Veatch utilized the data collected at 30 and 60 meters to estimate the wind shear component, alpha ($\alpha$), for each met tower. The power law approximation was then applied to calculate the estimated long-term wind speeds at 80 meters. The resulting long-term average wind speeds at various heights above ground for each met tower are described below.

### *2.2.1 BASF Met Location*

At the BASF met tower site, the long-term average wind speed at 60 meters above ground level is estimated to be approximately 5.8 meters per second (13.0 mph), which places the site in the Class 1 wind power category as defined by the NREL Wind Resource Atlas of the United States. The average annual wind shear, $\alpha$, at this site is estimated to be about 0.196. The wind speed breakdown is provided in Table 2-6 and shown graphically in Figure 2-9.

**Table 2-6. Estimated Long-Term Monthly Average Wind Speeds – BASF.**

| Month | Measured | | Predictions | | |
|---|---|---|---|---|---|
| | 60 meters | Historical Correlation | 60 meters | Wind Shear | 80 meters |
| January-07 | 5.69 | 1.08 | 6.14 | 0.201 | 6.50 |
| February-07 | 6.20 | 0.90 | 5.58 | 0.175 | 5.86 |
| March-07 | 6.53 | 0.93 | 6.05 | 0.208 | 6.42 |
| April-07 | 6.38 | 0.90 | 5.73 | 0.171 | 6.02 |
| May-07 | 4.98 | 1.24 | 6.16 | 0.191 | 6.50 |
| June-07 | 4.45 | 1.23 | 5.47 | 0.203 | 5.80 |
| July-07 | 4.55 | 1.12 | 5.12 | 0.172 | 5.38 |
| August-07 | 4.24 | 1.13 | 4.79 | 0.158 | 5.01 |
| September-07 | 4.47 | 1.29 | 5.77 | 0.238 | 6.18 |
| October-07 | 5.70 | 1.08 | 6.17 | 0.227 | 6.59 |
| November-07 | 5.72 | 1.12 | 6.40 | 0.205 | 6.79 |
| December-07 | 5.50 | 1.16 | 6.37 | 0.209 | 6.77 |
| January-08 | 6.52 | 0.92 | 6.01 | 0.195 | 6.37 |
| February-08 | 5.42 | 1.09 | 5.90 | 0.170 | 6.20 |
| **Annual Average** | **5.37** | **1.08** | **5.82** | **0.196** | **6.16** |

**Notes:**
• All wind speed values in meters per second (m/s) unless otherwise indicated. 1 m/s = 2.24 mph.

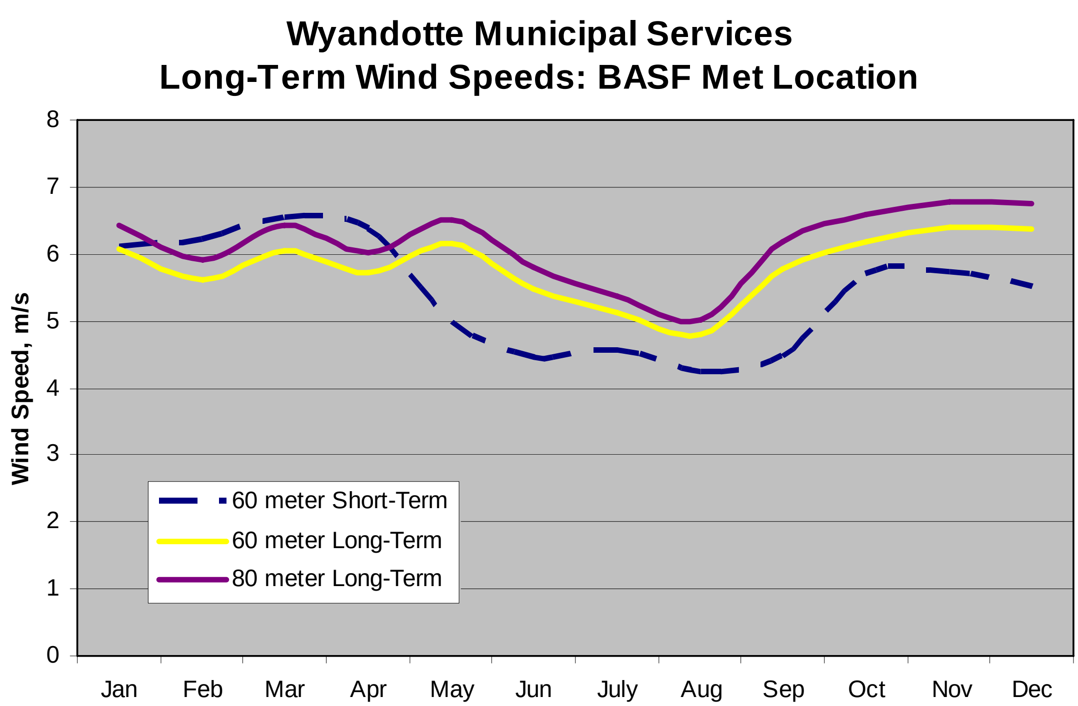


**Figure 2-9 Long term monthly average wind speeds – BASF.**

The 60 meter wind rose for the BASF met tower is shown in Figure 2-10. A wind rose is a plot of the amount of the total wind energy potential by wind direction. Each "slice" represents all winds coming from a 30 degree arc (for instance, the top slice represents all winds coming from a wind direction between 345 degrees and 15 degrees, while the next slice clockwise represents all winds coming from a wind direction between 15 degrees and 45 degrees). The length of the slice indicates the percentage of the total annual wind energy potential that comes from the corresponding wind direction (for instance, the top slice has a value of about 5 percent, meaning 5 percent of the total annual energy potential at this location comes from the 345 degrees to 15 degrees wind direction arc). Since the largest slices come from the south & southwest directions, this means highest energy winds will come from the south and southwest. However, a significant amount of wind energy also comes from several other sectors from 75 degrees to 315 degrees. This non-unidirectional distribution of the winds indicate that wide spacing of neighboring turbines will be needed to maintain good exposure to these critical wind directions. Monthly wind roses are provided at 3.4 Appendix B.

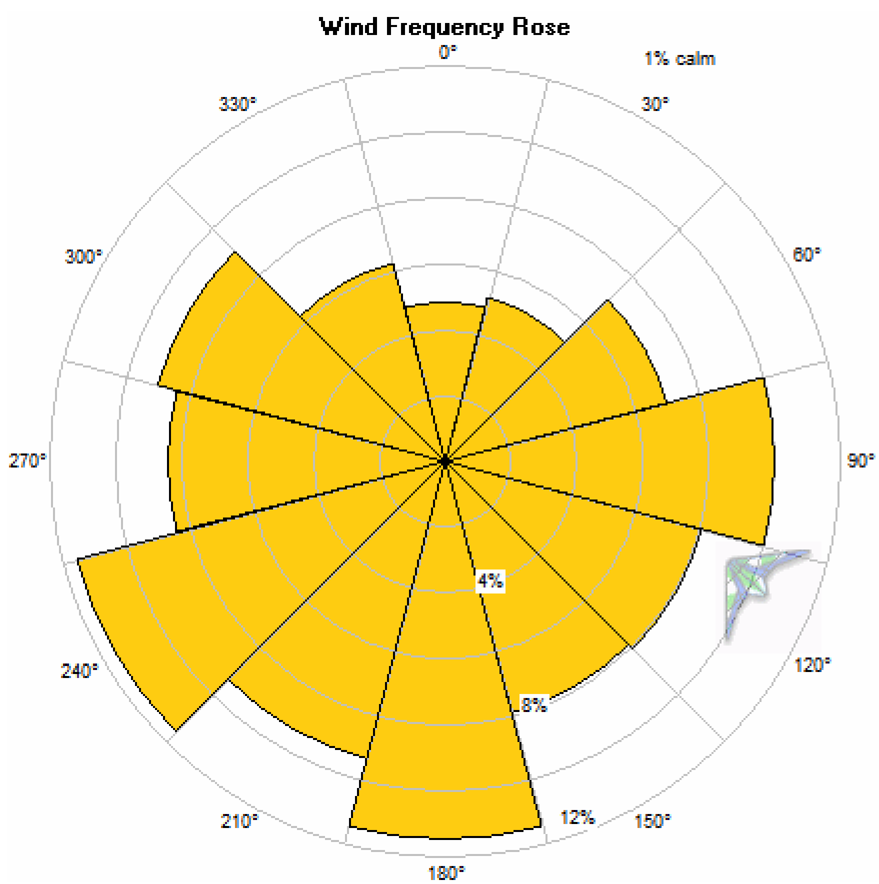


**Figure 2-10 Annual 60m wind rose – BASF.**

### *2.2.2 Central Avenue Met Location*

At the Central Avenue met tower site, the long-term average wind speed at 60 meters above ground level is estimated to be approximately 5.5 meters per second (12.3 mph), which places the site in the Class 1 wind power category. The average wind shear, α, at this site is estimated to be about 0.205. The wind speed breakdown is provided in Table 2-7 and shown graphically in Figure 2-11.

**Table 2-7. Estimated Long-Term Monthly Average Wind Speeds – Central Ave.**

| Month | Measured | | Predictions | | |
|---|---|---|---|---|---|
| | 60 meters | Historical Correlation | 60 meters | Wind Shear | 80 meters |
| January-07 | 5.52 | 1.08 | 5.95 | 0.214 | 6.33 |
| February-07 | 6.05 | 0.90 | 5.47 | 0.186 | 5.77 |
| March-07 | 6.27 | 0.93 | 5.81 | 0.228 | 6.21 |
| April-07 | 6.21 | 0.90 | 5.58 | 0.204 | 5.92 |
| May-07 | 4.60 | 1.24 | 5.68 | 0.220 | 6.05 |
| June-07 | 4.18 | 1.23 | 5.14 | 0.196 | 5.44 |
| July-07 | 4.23 | 1.12 | 4.76 | 0.157 | 4.98 |
| August-07 | 3.94 | 1.13 | 4.46 | 0.155 | 4.66 |
| September-07 | 4.11 | 1.29 | 5.30 | 0.239 | 5.68 |
| October-07 | 5.31 | 1.08 | 5.75 | 0.232 | 6.15 |
| November-07 | 5.35 | 1.12 | 5.99 | 0.212 | 6.36 |
| December-07 | 5.18 | 1.16 | 5.99 | 0.209 | 6.36 |
| January-08 | 6.22 | 0.92 | 5.74 | 0.206 | 6.09 |
| February-08 | 5.25 | 1.09 | 5.71 | 0.197 | 6.02 |
| **Annual Average** | **5.08** | **1.09** | **5.49** | **0.205** | **5.83** |

**Notes:**
• All wind speed values in meters per second (m/s) unless otherwise indicated. 1 m/s = 2.24 mph.

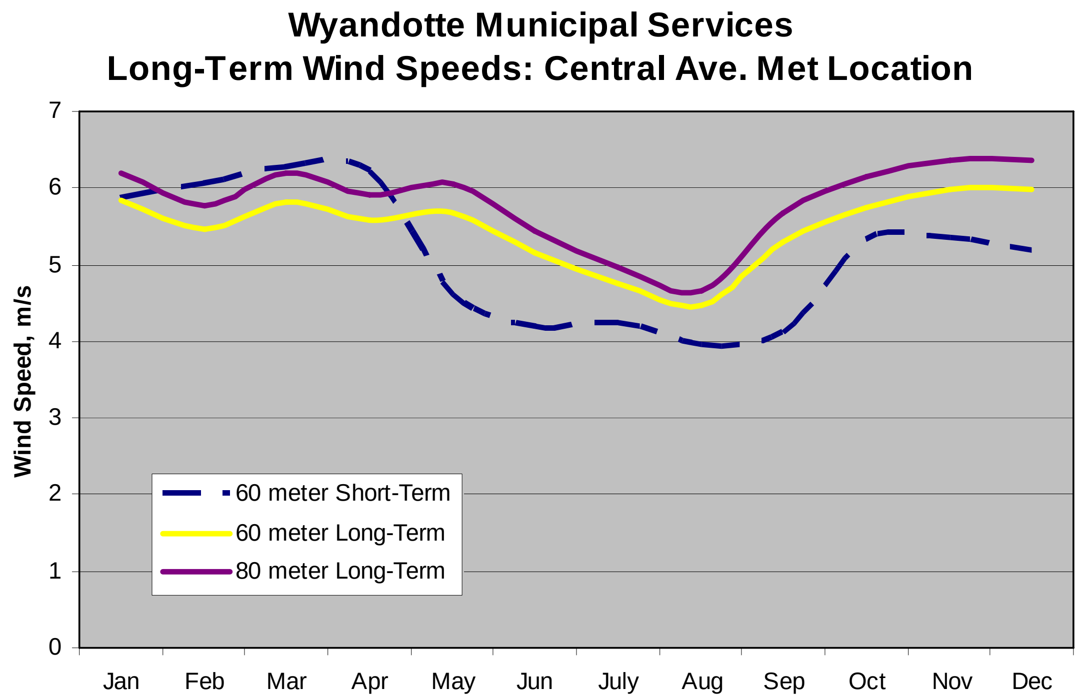


**Figure 2-11 Long-term monthly average wind speeds – Central Avenue.**

Figure 2-12 is the 60 meter wind rose for the Central Avenue met location. Like the BASF met tower site, the majority of the energy at this site comes from several directions, with the strongest portion coming from the south and southwest.

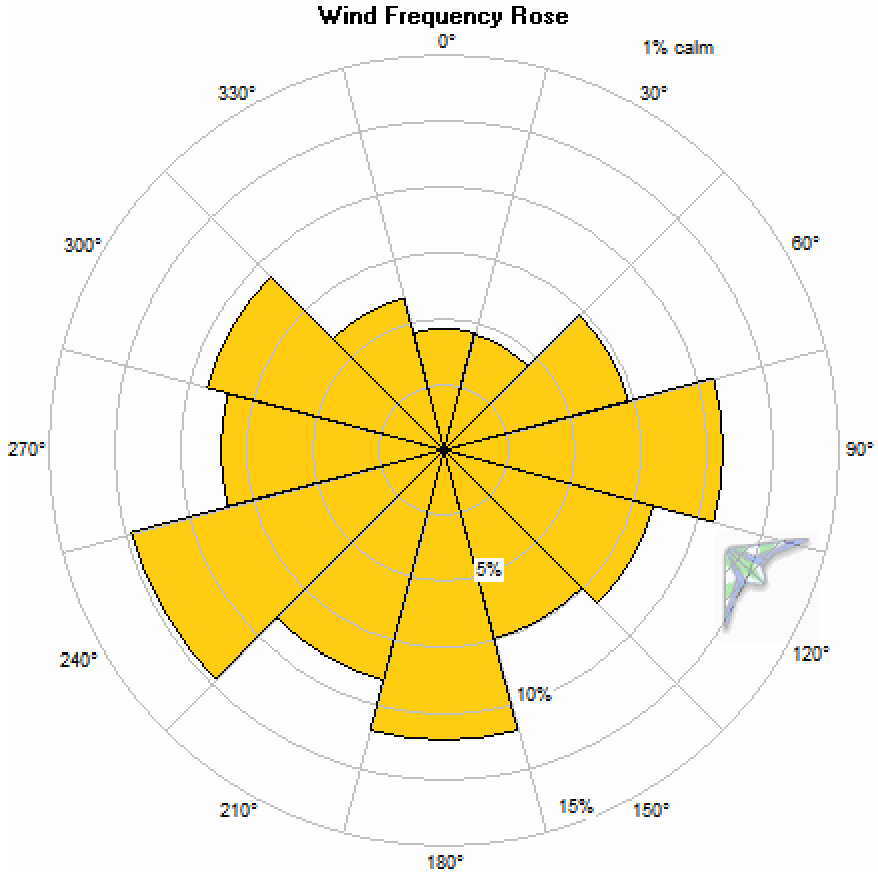


**Figure 2-12 Annual 60m wind rose – Central Avenue.**

# 3.0 Energy Production Estimates

The wind energy production estimates in this section display the likely performance for several turbine models that have operational characteristics conducive for the wind resource observed at this project area. These production estimates incorporate an assumed 8 percent project loss and are based on power curves matching the observed average air densities at each met tower site.

## 3.1 Wind Turbine Power Curves

Each wind turbine design has a unique characteristic of output power versus input wind speed. This characteristic is referred to as the turbine's "power curve". In Table 3-1, Black & Veatch compares the power curves for each turbine evaluated in this study. These curves are also shown in Figure 2-3. As power curves are dependent upon air density, Black & Veatch chose the published power curve closest to the average air density based on the pressure readings taken by the Central Avenue met tower (1.20 $kg/m^3$).

**Table 3-1. Comparison of Wind Turbine Power Curves.**

| Wind Speed | GE 1.5 xle | Vestas V82 | Gamesa G87 |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 |
| 3 | 2 | 0 | 60 |
| 4 | 58 | 27 | 142 |
| 5 | 154 | 142 | 268 |
| 6 | 287 | 305 | 444 |
| 7 | 475 | 504 | 673 |
| 8 | 724 | 746 | 949 |
| 9 | 1,014 | 999 | 1,249 |
| 10 | 1,274 | 1,260 | 1,541 |
| 11 | 1,434 | 1,489 | 1,737 |
| 12 | 1,491 | 1,636 | 1,910 |
| 13 | 1,500 | 1,647 | 1,970 |
| 14 | 1,500 | 1,648 | 1,991 |
| 15 | 1,500 | 1,650 | 1,998 |
| 16 | 1,500 | 1,650 | 2,000 |
| 17 | 1,500 | 1,650 | 2,000 |
| 18 | 1,500 | 1,650 | 2,000 |
| 19 | 1,500 | 1,650 | 2,000 |
| 20 | 1,500 | 1,650 | 2,000 |
| 21 | 1,500 | 0 | 2,000 |
| 22 | 1,500 | 0 | 2,000 |
| 23 | 1,500 | 0 | 2,000 |
| 24 | 1,500 | 0 | 2,000 |
| 25 | 1,500 | 0 | 2,000 |

Notes: Wind speed values in m/s, power values in kW.
[a] Manufacturer supplied power curve for 1.20 $kg/m^3$

## 3.2 Production Losses

Black & Veatch has estimated the potential production losses that might impact wind turbines at the potential project sites. The losses are summarized in Table 3-2.

**Table 3-2. Project Production Loss Factors.**

| Loss Factor | Loss Percent |
|---|---|
| Topographic Effect | 0.0% |
| Wake Effect | 0.0% |
| Turbine Availability | 3.0% |
| Turbine Power Curve | 0.0% |
| Grid Availability | 0.2% |
| Electrical Losses | 2.0% |
| Columnar Losses | 0.0% |
| Blade Contamination | 0.5% |
| Icing | 0.5% |
| Model Estimate | 2.0% |
| High Wind Hysteresis | 0.0% |
| **Product of Loss Factors** | **8.0%** |

- **Topographic Effect:** This is the loss (or gain) due to wind speed reductions (or increases) between the met tower and turbine caused by the site's topography. This value varies somewhat by turbine height and rotor diameter.
- **Wake Effect:** This is the energy loss due to the effect one turbine will have on another, or the wake caused by any structure on the wind turbines. This effect varies by rotor diameter and speed.
- **Turbine Availability:** Wind turbine manufacturers will specify an availability level to be covered in a warranty. This value assumes the turbine's availability is only at the warranted value.
- **Turbine Power Curve:** The wind turbine manufacturer will warranty a performance level from the turbine at a percentage of the power curve values. Typical warranty levels are 95 to 97 percent of published power curve. However, typical industry practice does not consider this as a potential loss, given that most wind turbines operate at or slightly above

their published power curves. For this study, Black & Veatch left the value as 0 percent loss.

- **Grid Availability:** An estimate is made as to the amount of time that the utility will be available to receive power from the project. All grid systems are offline periodically for maintenance, and projects in more remote locations are generally connected to weaker grid systems that are more prone to failure. Losses for grid availability vary between 0.1 percent for very strong grid systems to as high as 5 percent for weak systems. Outside of the United States losses may be even higher.
- **Electrical Losses:** Losses in the lines and electrical equipment prior to the plant's revenue meters are covered by this factor. Points of significant electrical losses in a wind energy project usually include the underground and overhead distribution lines connecting the turbines to a substation, and the substation's primary transformer. Typical electrical loss values range from as low as 1 percent up to 10 percent or more, depending on the project layout and equipment used.
- **Columnar Losses:** If a project of many wind turbines is arranged in rows, turbine manufacturers may require the shutdown of some turbines when the winds are coming from directions parallel to the rows. These losses will not apply to the options defined in this report.
- **Blade Contamination:** Wind turbine performance is sensitive to the cleanliness of the turbine's blades. In areas of high dust or insects, contamination can build up on the turbine blades that will limit the turbine's performance (causing losses of up to 5 percent or more). Often the blades are cleaned by occasional rainfall, but in some areas periodic blade washing is required. An annual loss of 0.5 percent was assumed for blade contamination.
- **Icing:** During winter storms, snow and ice will build on the wind turbine blades causing the same degradation as caused by dust and insects. While this contamination will build much faster than summer contamination, it is often cleared after a few hours of direct sunlight (even at continued sub-zero temperatures). Based on the climate in the project area, a loss of 0.5 percent was assumed for the lost energy due to icing.
- **Model Estimate:** Black & Veatch estimated the performance of the wind turbines using a standard spreadsheet modeling approach. Due to uncertainties in input data, a 2 percent loss was assumed to account for model uncertainty.

- **High Wind Hysteresis:** When wind speeds exceed the operational range of a wind turbine, the turbine shuts down to protect itself. Such shutdowns normally require the turbine to remain offline for several minutes, even if the wind speed returns to the operational range in a shorter time. Sites with a significant number of these high wind events suffer lost energy due to this hysteresis effect, which is in addition to the amount of time the average wind speed remains above the cut-out wind speed. Because the project site does not have a significant number of high wind events on record, no losses due to hysteresis were applied.

## 3.3 Production Estimates and Comparisons

Based on the wind analysis discussed in Section 2, Black & Veatch estimated the production for the Gamesa G87, Vestas V82 and GE 1.5MW. The long-term wind data from each met tower was used with simple spreadsheet lookup function to determine energy production on a 10 minute basis and summed to determine the total annual gross production from the turbine. Each wind turbine installation is subject to losses discussed in Section 3.2 . These losses were applied to the gross energy estimate to determine the project's net energy estimate. Finally, a capacity factor was calculated which represents the net annual generation compared to maximum possible generation from the wind turbine (a value of 100% would mean the turbine would operate at rated power every hour of the year; a typical capacity factor for a project in the Northeast U.S. is about 30 percent).

The resulting energy and capacity factor estimates for a single turbine installation at each of the met tower locations are shown in detail below in Table 3-3 and Table 3-4. Figure 3-1 and Figure 3-3 compare the monthly generation levels of each wind turbine option for each met location.

### *3.3.1 BASF Project Area*

Figure 3-1 shows the estimated monthly generation for a single turbine on the BASF site. The estimated generation and capacity factor are also shown in Table 3-3.

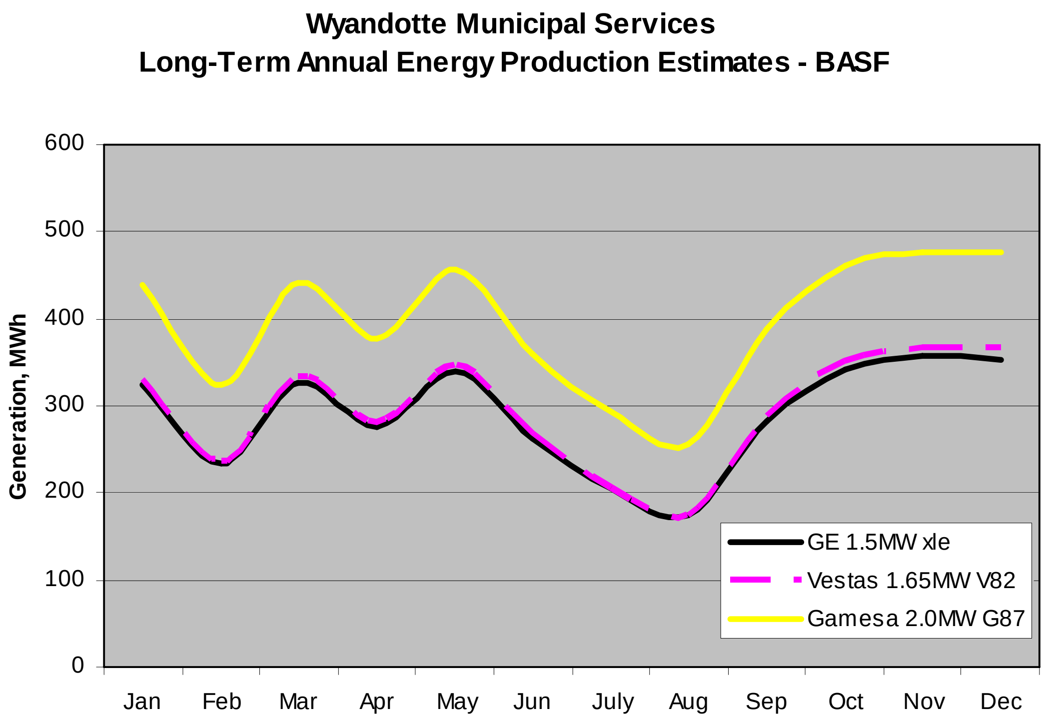


**Figure 3-1  BASF monthly wind generation estimates.**

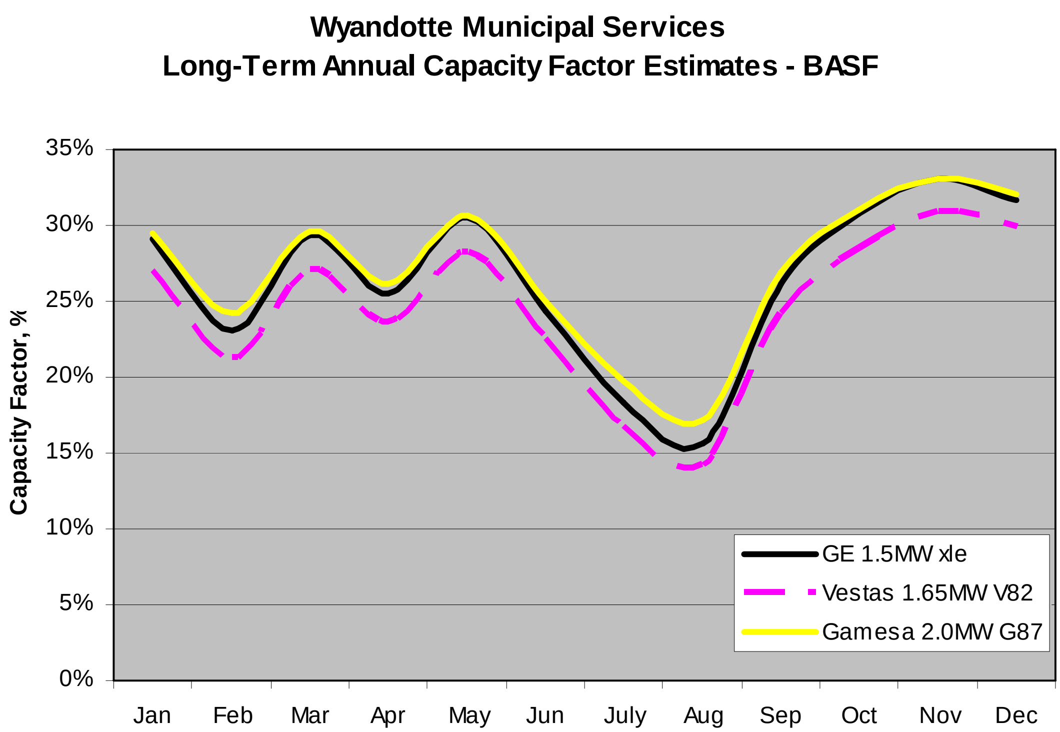


**Figure 3-2  BASF monthly capacity factor estimates.**

**Table 3-3. BASF Project Area Production Estimates.**

| Month | GE 1.5MW xle | | Vestas V82 | | Gamesa G87 | |
|---|---|---|---|---|---|---|
| | MWh | C.F. | MWh | C.F. | MWh | C.F. |
| January | 325 | 29.1% | 332 | 27.0% | 439 | 29.5% |
| February | 233 | 23.1% | 236 | 21.3% | 325 | 24.2% |
| March | 327 | 29.3% | 333 | 27.1% | 441 | 29.6% |
| April | 276 | 25.6% | 281 | 23.6% | 377 | 26.2% |
| May | 340 | 30.5% | 346 | 28.2% | 456 | 30.6% |
| June | 263 | 24.4% | 268 | 22.6% | 361 | 25.0% |
| July | 204 | 18.3% | 206 | 16.8% | 294 | 19.8% |
| August | 175 | 15.7% | 175 | 14.2% | 256 | 17.2% |
| September | 283 | 26.2% | 288 | 24.3% | 388 | 27.0% |
| October | 343 | 30.7% | 350 | 28.5% | 461 | 31.0% |
| November | 357 | 33.0% | 367 | 30.9% | 476 | 33.1% |
| December | 354 | 31.7% | 366 | 29.8% | 477 | 32.1% |
| **Annual (P50)** | **3,480** | **26.5%** | **3,548** | **24.5%** | **4,752** | **27.1%** |
| P90 Average | 2,576.3 | 19.6% | 2,599.0 | 18.0% | 3,654.3 | 20.9% |
| P95 Average | 2,320.0 | 17.7% | 2,329.8 | 16.1% | 3,343.1 | 19.1% |

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedance, as discussed in Section 3.4.

### *3.3.2 Central Avenue Project Area*

Figure 3-3 shows the estimated monthly generation for a single turbine on the Central Avenue site. The estimated generation and capacity factor are also shown in Table 3-4.

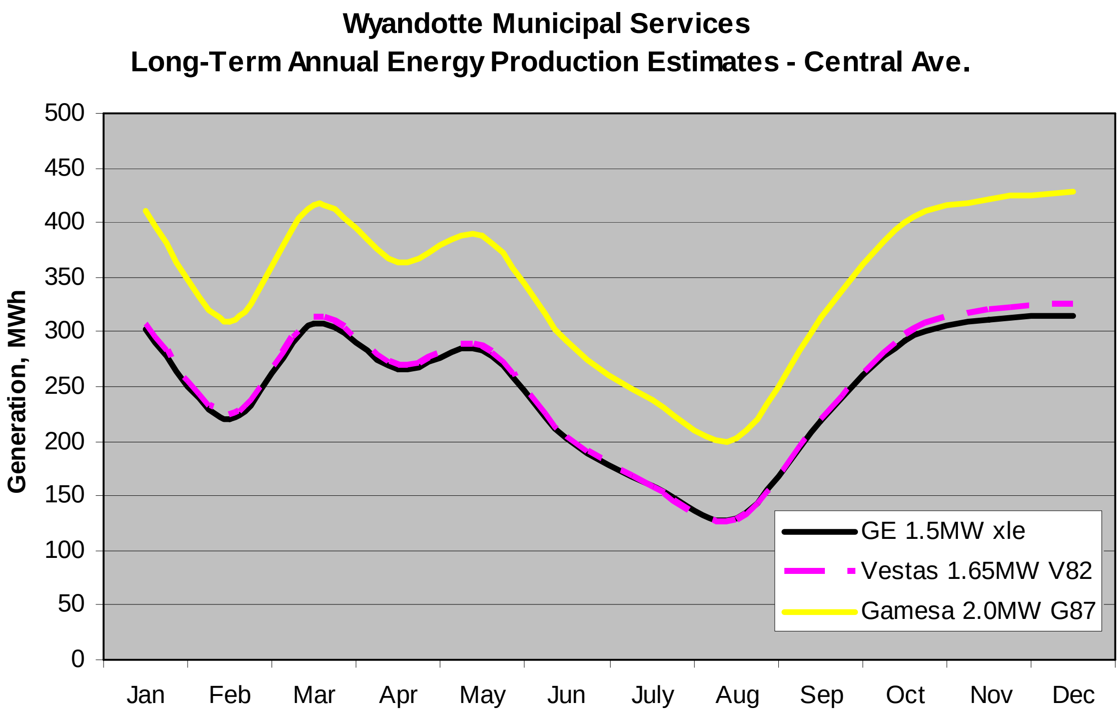


**Figure 3-3 Central Avenue monthly wind generation estimates.**

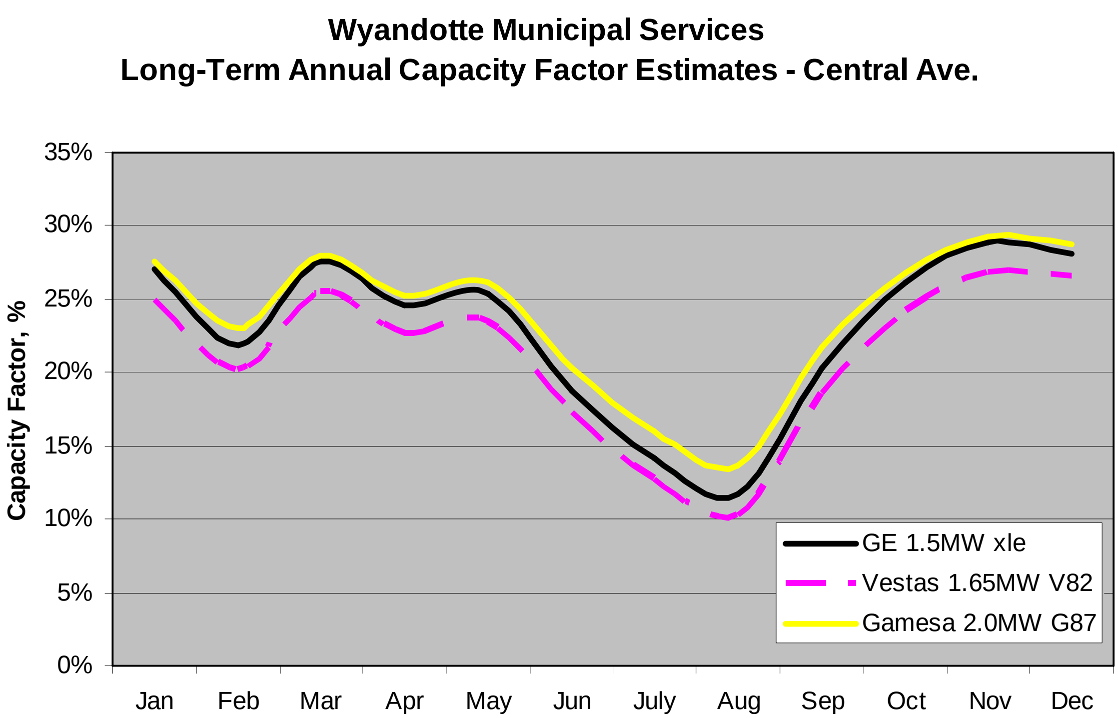


**Figure 3-4 Central Avenue monthly capacity factor estimates.**

**Table 3-4. Central Avenue Project Area Production Estimates.**

| Month | GE 1.5MW xle | | Vestas V82 | | Gamesa G87 | |
|---|---|---|---|---|---|---|
| | **MWh** | **C.F.** | **MWh** | **C.F.** | **MWh** | **C.F.** |
| January | 302 | 27.0% | 307 | 25.0% | 411 | 27.6% |
| February | 221 | 21.9% | 223 | 20.1% | 310 | 23.1% |
| March | 308 | 27.6% | 313 | 25.5% | 417 | 28.0% |
| April | 265 | 24.6% | 269 | 22.6% | 364 | 25.3% |
| May | 283 | 25.4% | 287 | 23.4% | 389 | 26.1% |
| June | 203 | 18.8% | 205 | 17.3% | 292 | 20.3% |
| July | 158 | 14.2% | 157 | 12.8% | 239 | 16.0% |
| August | 130 | 11.6% | 127 | 10.3% | 203 | 13.6% |
| September | 219 | 20.2% | 221 | 18.6% | 312 | 21.7% |
| October | 292 | 26.2% | 296 | 24.1% | 400 | 26.9% |
| November | 312 | 28.9% | 319 | 26.9% | 422 | 29.3% |
| December | 314 | 28.2% | 326 | 26.5% | 429 | 28.8% |
| **Annual (P50)** | **3,007** | **22.9%** | **3,051** | **21.1%** | **4,186** | **23.9%** |
| P90 Average | 2,187 | 16.6% | 2,190 | 15.2% | 3,180 | 18.2% |
| P95 Average | 1,955 | 14.9% | 1,946 | 13.5% | 2,895 | 16.5% |

Notes: C.F. is Capacity Factor
P50, P90, and P95 refer to the probability of exceedence, as discussed in Section 3.4.

Figure 3-5 compares the monthly production of each project option for a common wind turbine type (Gamesa G87), and Figure 3-6 compares the capacity factors.

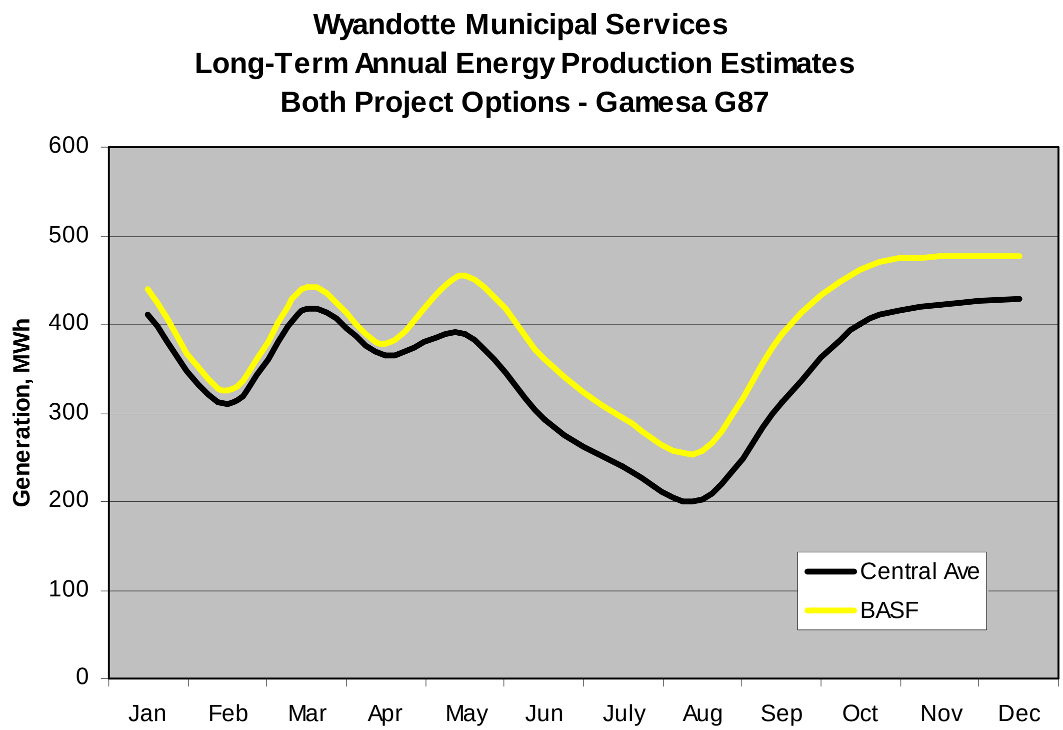


**Figure 3-5 Monthly wind generation estimate – All Projects**

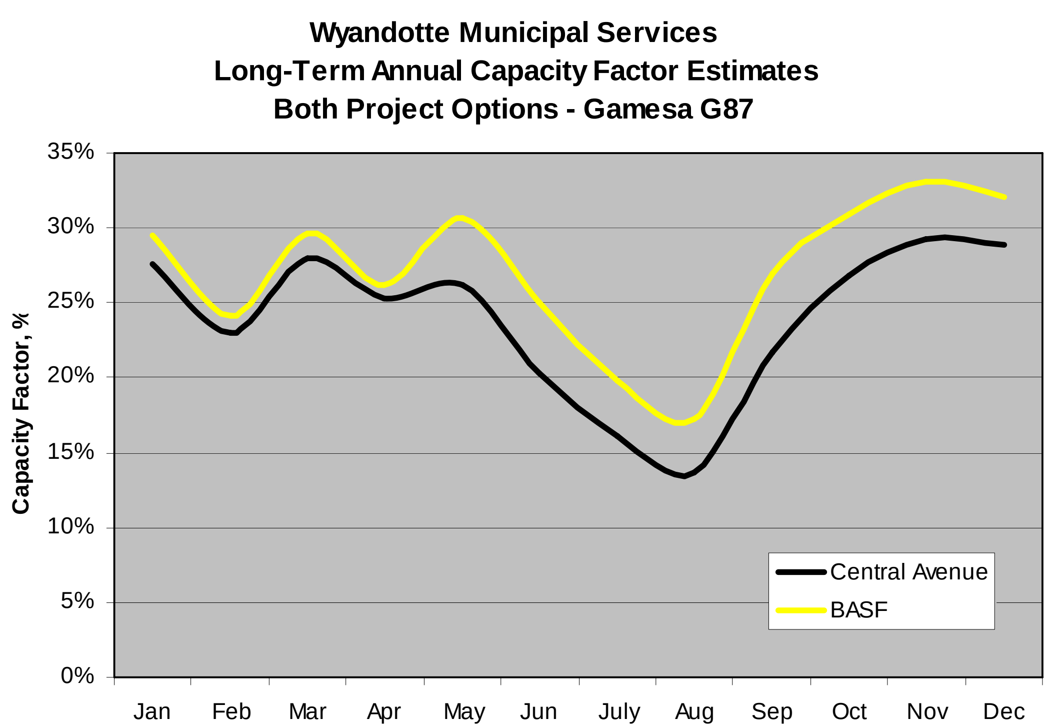


**Figure 3-6 Monthly capacity factor estimates – All Projects**

## 3.4 Uncertainty Analysis

Based on the analysis detailed above, Black & Veatch has estimated the long-term average wind speeds seen at all turbine locations in each project to be:

- 6.15 m/s at 80 meters above ground level for the BASF Site
- 5.82 m/s at 80 meters above ground level for the Central Avenue Site

The corresponding long-term average production for the various turbine types were presented as the Annual Average (P50) in Section 3.3 . These values correspond to the 50 percent confidence value estimates, meaning that there is a 50 percent chance that the true long-term average wind speed is higher, and a 50 percent chance it is lower. To determine the sensitivity of the production to variations in wind speed, and to estimate the magnitude of variations possible, an analysis combining the following uncertainty factors was performed.

- **Long-term wind speed variability:** this is a measure of how well understood the long-term wind resource is, and is determined by the length of the long-term data set analyzed.
- **Correlation standard error:** this value is a measure of how well the on-site data correlated to the long-term data source.
- **Anemometer calibration:** this is the stated calibration of the primary anemometer used to measure the on-site wind resource. For uncalibrated instruments, the standard accuracy of the anemometer published by its manufacturer is used. For instruments left installed past their calibration period, or for longer than one year for uncalibrated sensors, an increase in the calibration uncertainty may be applied for expected sensor degradation.
- **Topographic and wake modeling:** the models used to estimate the energy production have uncertainty associated with them.
- **Wind variability:** this is a single-year estimate of the long-term variability, signifying the uncertainty of estimating the "next year's" power production.

Table 3-5 and Table 3-6 show the breakdown of uncertainty components for each turbine and project option. The resulting Combined Standard Error values are used to calculate the P90 and P95 annual energy estimates in the previous section. For each option, the true long-term annual average energy has a 90 percent chance of being greater than the P90 estimate, and a 95 percent chance of being greater than the P95 estimate. These values can be used for sensitivity evaluations in a project pro forma or payback analysis.

**Table 3-5. BASF Project Site Production Estimate Uncertainty.**

| **Turbine** | | | GE 1.5 MW xle | Vestas V82 | Gamesa G87 |
|---|---|---|---|---|---|
| Project Rating | MW | | 1.5 | 1.65 | 2 |
| P50 Est. Generation | MWh/yr | | 3,480 | 3,548 | 4,752 |
| P50 Wind Speed | m/s | | 6.15 | 6.15 | 6.15 |
| Energy Sensitivity | MWh/yr/(m/s) | | 1,305 | 1,371 | 1,585 |
| **Factor** | **Uncertainty** | | | | |
| | **percent** | **m/s** | **MWh/yr** | **MWh/yr** | **MWh/yr** |
| Long-Term Wind Variability[1] | 1.4% | 0.08 | 110 | 115 | 133 |
| Correlation[2] | | 0.34 | 450 | 472 | 546 |
| Anem. Calibration | 2.0% | 0.12 | 160 | 169 | 195 |
| Model Error | 2.0% | 0.12 | 160 | 169 | 195 |
| Wind Variability | 6.0% | 0.35 | 481 | 506 | 585 |
| **Combined Standard Error** | **89.0%** | | **705** | **741** | **856** |

Notes: [1]Long-Term variability based on Detroit Metro Airport data
[2]Correlation done on a monthly average basis

**Table 3-6. Central Avenue Project Site Production Estimate Uncertainty.**

| **Turbine** | | | GE 1.5 MW xle | Vestas V82 | Gamesa G87 |
|---|---|---|---|---|---|
| Project Rating | MW | | 1.5 | 1.65 | 2 |
| P50 Est. Generation | MWh/yr | | 3,480 | 3,548 | 4,752 |
| P50 Wind Speed | m/s | | 6.15 | 6.15 | 6.15 |
| Energy Sensitivity | MWh/yr/(m/s) | | 1,305 | 1,371 | 1,585 |
| **Factor** | **Uncertainty** | | | | |
| | **percent** | **m/s** | **MWh/yr** | **MWh/yr** | **MWh/yr** |
| Long-Term Wind Variability[1] | 1.4% | 0.08 | 110 | 115 | 133 |
| Correlation[2] | | 0.34 | 450 | 472 | 546 |
| Anem. Calibration | 2.0% | 0.12 | 160 | 169 | 195 |
| Model Error | 2.0% | 0.12 | 160 | 169 | 195 |
| Wind Variability | 6.0% | 0.35 | 481 | 506 | 585 |
| **Combined Standard Error** | **89.0%** | | **705** | **741** | **856** |

Notes: [1]Long-Term variability based on Detroit Metro Airport data
[2]Correlation done on a monthly average basis

# Appendix A. Met Tower Records

**Nomad2 Data Sheet**

**Central Ave MET 2539**

Cellular Account Information:

| **PARAMETER** | **ORIGIN** | |
|---|---|---|
| Nomad2 Serial Number | Found on inside front cover of Symphonie | **2539** |
| Cellular Service Provider | Name of company providing cellular service | **VerizonWireless** |
| ESN | Provide by user, found on AMPS iPack label | |
| MIN | Supplied by cellular service provider | 734-626-7725 |
| MDN | | |
| SID | Supplied by cellular service provider | |
| System Preference | Supplied by cellular service provider | |

Internet Account Information:

| **PARAMETER** | **ORIGIN** | |
|---|---|---|
| Internet Service Provider (ISP) | Name of company providing internet service | **Verizonwireless.com** |
| Primary ISP Phone Number | Provided by ISP | **#777** |
| Secondary ISP Phone Number | Provided by ISP | |
| Primary Domain Name Service (DNS) Number | Provided by ISP, found on ISP's web site | |
| Secondary Domain Name Service (DNS) Number | Provided by ISP, found on ISP's web site | |
| ation Method (PAP/CHAP) | Provided by ISP | **CHAP** |
| User Name | Provided/approved by ISP | **Mobile#@vzw3g.com** |
| User Password | Provided/approved by ISP | **vzw** |
| SMTP Server Name | Provided/approved by ISP | **smtp.vzmail.net** |
| SMTP Login (if required) | | **Mobile#@vzwmail.net** |
| SMTP Password (if required) | | verizon |
| Recipient's E-mail Address | Provided by user | **WindData@BV.com** |
| Recipient's Name | Provided by user | **Black & Veatch** |
| Recipient's E-mail Address | Provided by user | |
| Recipient's Name | Provided by user | |
| Recipient's E-mail Address | Provided by user | |
| Recipient's Name | Provided by user | |
| Sender's E-mail Address | Provided/approved by ISP | |
| E-mail Subject Line | Provided by user | |
| Next Call Time | Provided by user | |
| Call Interval | Provided by user | |
| | | |
| | | |
| | | |

# Site Data

| | | | |
|---|---|---|---|
| Site Number | 2539 | Project Number | 144374 |
| Site Name | Central Avenue | Project Name | Wyandotte |
| Latitude (WGS 84) | 42º 11' 20.41" N | Time Zone | CST ( -5 ) |
| Longitude | 83º 9' 46.94" W | Magnetic Declination | |
| Elevation | 175m | Prevailing Winds | W/SW |
| GPS Used | Garmin eTrex | GPS Horizontal Accuracy (ft) | |
| Installation Crew | Anemometry Specialists/City of Wyandotte | Phone Numbers: | |
| Site Description | Urban Area, 1-3 story buildings within several thousand feet of tower. | | |
| Terrain Features | Flat, thin patches of tall grass. | | |
| Soil Type | Mostly compressed gravel and backfill, class 3-4 soil | | |
| Site Photos | Up tower facing north: | Yes | |
| | One of each 8 sectors: | Yes | |
| | Several general site photos: | Yes | |
| Installation Date | 12/21/06 | | |
| Removal Date | | | |

## Field Contact Information

| | |
|---|---|
| Company | Black & Veatch |
| Contact Person | Sean Tilley |
| Address | 11401 Lamar Avenue<br>Overland Park, KS 66211 |
| Phone Number | (913) 208-4212<br>(913 458-2196 Office |
| Fax Number | (913) 458-2122 |
| e-mail Address | TilleyS@BV.com |

## Notes

# Sensor Information

## Digital Channels

| | Anemometer 1 | Anemometer 2 | Anemometer 3 | Anemometer 4 | Open Channel | Open Channel |
|---|---|---|---|---|---|---|
| Monitoring Height | 60m | 30m | 30m | 60m | | |
| Primary or Redundant | Primary | Redundant | Primary | Primary | | |
| Mount Orientation (degrees magnetic) | 135 deg; SE | 135 deg; SE | 135 deg; SE | 315 deg; NW | | |
| Boom Length (beyond tower leg) | 60.5” | 60.5” | 60.5” | 60.5” | | |
| Units | M/sec | M/sec | M/sec | M/sec | | |
| Scale | 0.765 | 0.765 | 0.765 | 0.765 | | |
| Offset | 0.350 | 0.350 | 0.350 | 0.350 | | |
| Logger Channel No. | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** |

| | Barometric Sensor | Open Channel | Open Channel | Open Channel |
|---|---|---|---|---|
| Monitoring Height | In Logger | | | |
| Primary or Redundant | | | | |
| Full Range: | 0 to 5.0 V | | | |
| Boom Length (beyond tower leg) | | | | |
| Units | kPa | | | |
| Slope | 10.000 kPa/V | | | |
| Offset | 59.000 | | | |
| Logger Channel No. | **C7** | **C8** | **C9** | **C10** |

## Analog Channels

| | Wind Vane 1 | Wind Vane 2 | Thermistor: SWI 10K Probe | Open Channel | Open Channel | Open Channel |
|---|---|---|---|---|---|---|
| Monitoring Height | 59m | 29m | 3m | | | |
| Mount Orientation (degrees magnetic) | 225 deg; SW | 225 deg; SW | S | | | |
| Boom Length (beyond tower leg) | 60.5” | 60.5” | | | | |
| Deadband Orientation (Degrees Magnetic) | | | | | | |
| Units | M/sec | M/sec | $^{o}$C | | | |
| Scale | 0.765 | 0.765 | .138 | | | |
| Offset | 0.350 | 0.350 | -86.383 | | | |
| Offset in Logger | | | | | | |
| Logger Channel No. | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** |

## Tower

| | |
|---|---|
| **Tower Type** | Ohmega |
| **Height** | 60m |
| **Diameter** | 8 inches |
| **Lay down Direction** | East |
| **Number & Type of Lifting Anchors** | 2 10” Helix screw-ins; protruding 2-3 ft. above ground. Will need Ohmega gin pole or NRG adapter with a 60m gin pole to perform maintenance. |

**Nomad2 Data Sheet**

**BASF MET 2540**

Cellular Account Information:

| PARAMETER | ORIGIN | |
|---|---|---|
| Nomad2 Serial Number | Found on inside front cover of Symphonie | **2539** |
| Cellular Service Provider | Name of company providing cellular service | **VerizonWireless** |
| ESN | Provide by user, found on AMPS iPack label | |
| MIN | Supplied by cellular service provider | 734-626-7725 |
| MDN | | |
| SID | Supplied by cellular service provider | |
| System Preference | Supplied by cellular service provider | |

Internet Account Information:

| PARAMETER | ORIGIN | |
|---|---|---|
| Internet Service Provider (ISP) | Name of company providing internet service | **Verizonwireless.com** |
| Primary ISP Phone Number | Provided by ISP | **#777** |
| Secondary ISP Phone Number | Provided by ISP | |
| Primary Domain Name Service (DNS) Number | Provided by ISP, found on ISP's web site | |
| Secondary Domain Name Service (DNS) Number | Provided by ISP, found on ISP's web site | |
| ation Method (PAP/CHAP) | Provided by ISP | **CHAP** |
| User Name | Provided/approved by ISP | **Mobile#@vzw3g.com** |
| User Password | Provided/approved by ISP | **vzw** |
| SMTP Server Name | Provided/approved by ISP | **smtp.vzmail.net** |
| SMTP Login (if required) | | **Mobile#@vzwmail.net** |
| SMTP Password (if required) | | verizon |
| Recipient's E-mail Address | Provided by user | **WindData@BV.com** |
| Recipient's Name | Provided by user | **Black & Veatch** |
| Recipient's E-mail Address | Provided by user | |
| Recipient's Name | Provided by user | |
| Recipient's E-mail Address | Provided by user | |
| Recipient's Name | Provided by user | |
| Sender's E-mail Address | Provided/approved by ISP | |
| E-mail Subject Line | Provided by user | |
| Next Call Time | Provided by user | |
| Call Interval | Provided by user | |
| | | |
| | | |
| | | |

# Site Data

| | | | |
|---|---|---|---|
| Site Number | 2540 | Project Number | 144374 |
| Site Name | BASF | Project Name | Wyandotte |
| Latitude (WGS 84) | 42º 13' 6.24" N | Time Zone | CST ( -5 ) |
| Longitude | 83º 8' 33.34" W | Magnetic Declination | |
| Elevation | 177m | Prevailing Winds | W/SW |
| GPS Used | Garmin eTrex | GPS Horizontal Accuracy (ft) | |
| Installation Crew | Anemometry Specialists/City of Wyandotte | Phone Numbers: | |

| | | |
|---|---|---|
| Site Description | Urban/Industrial Area, 1-3 story buildings within several thousand feet of tower. | |
| Terrain Features | Flat, thin patches of tall grass. | |
| Soil Type | Brownfield, mostly compressed gravel and backfill, class 3-4 soil | |
| Site Photos | Up tower facing north: | Yes |
| | One of each 8 sectors: | Yes |
| | Several general site photos: | Yes |
| Installation Date | 12/21/06 | |
| Removal Date | | |

## Field Contact Information

| | |
|---|---|
| Company | Black & Veatch |
| Contact Person | Sean Tilley |
| Address | 11401 Lamar Avenue<br>Overland Park, KS 66211 |
| Phone Number | (913) 208-4212<br>(913 458-2196 Office |
| Fax Number | (913) 458-2122 |
| e-mail Address | TilleyS@BV.com |

## Notes

# Sensor Information

## Digital Channels

| | Anemometer 1 | Anemometer 2 | Anemometer 3 | Anemometer 4 | Open Channel | Open Channel |
|---|---|---|---|---|---|---|
| Monitoring Height | 60m | 60m | 30m | 10m | | |
| Primary or Redundant | Primary | Primary | Primary | Redundant | | |
| Mount Orientation (degrees magnetic) | 135 deg; SE | 315 deg; NW | 135 deg; SE | 135 deg; SE | | |
| Boom Length (beyond tower leg) | 60.5” | 60.5” | 60.5” | 60.5” | | |
| Units | M/sec | M/sec | M/sec | M/sec | | |
| Scale | 0.765 | 0.765 | 0.765 | 0.765 | | |
| Offset | 0.350 | 0.350 | 0.350 | 0.350 | | |
| Logger Channel No. | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** |

| | Open Channel | Open Channel | Open Channel | Open Channel |
|---|---|---|---|---|
| Monitoring Height | | | | |
| Primary or Redundant | | | | |
| Full Range: | | | | |
| Boom Length (beyond tower leg) | | | | |
| Units | | | | |
| Slope | | | | |
| Offset | | | | |
| Logger Channel No. | **C7** | **C8** | **C9** | **C10** |

## Analog Channels

| | Wind Vane 1 | Wind Vane 2 | Thermistor: SWI 10K Probe | Open Channel | Open Channel | Open Channel |
|---|---|---|---|---|---|---|
| Monitoring Height | 49m | 29m | 3m | | | |
| Mount Orientation (degrees magnetic) | 217 deg; SW | 217 deg; SW | S | | | |
| Boom Length (beyond tower leg) | 60.5” | 60.5” | | | | |
| Deadband Orientation (Degrees Magnetic) | | | | | | |
| Units | M/sec | M/sec | $^{o}$C | | | |
| Scale | 0.765 | 0.765 | .138 | | | |
| Offset | 0.350 | 0.350 | -86.383 | | | |
| Offset in Logger | **217** | **217** | | | | |
| Logger Channel No. | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** |

## Tower

| | |
|---|---|
| **Tower Type** | Ohmega |
| **Height** | 60m |
| **Diameter** | 8 inches |
| **Lay down Direction** | East |
| **Number & Type of Lifting Anchors** | 2 10” Helix screw-ins; protruding 2-3 ft. above ground. Will need Ohmega gin pole or NRG adapter with a 60m gin pole to perform maintenance. |

# Appendix B. Wind Resource Plots

Black & Veatch prepared summary plots of the short-term wind data from each of the met towers reviewed in this study.

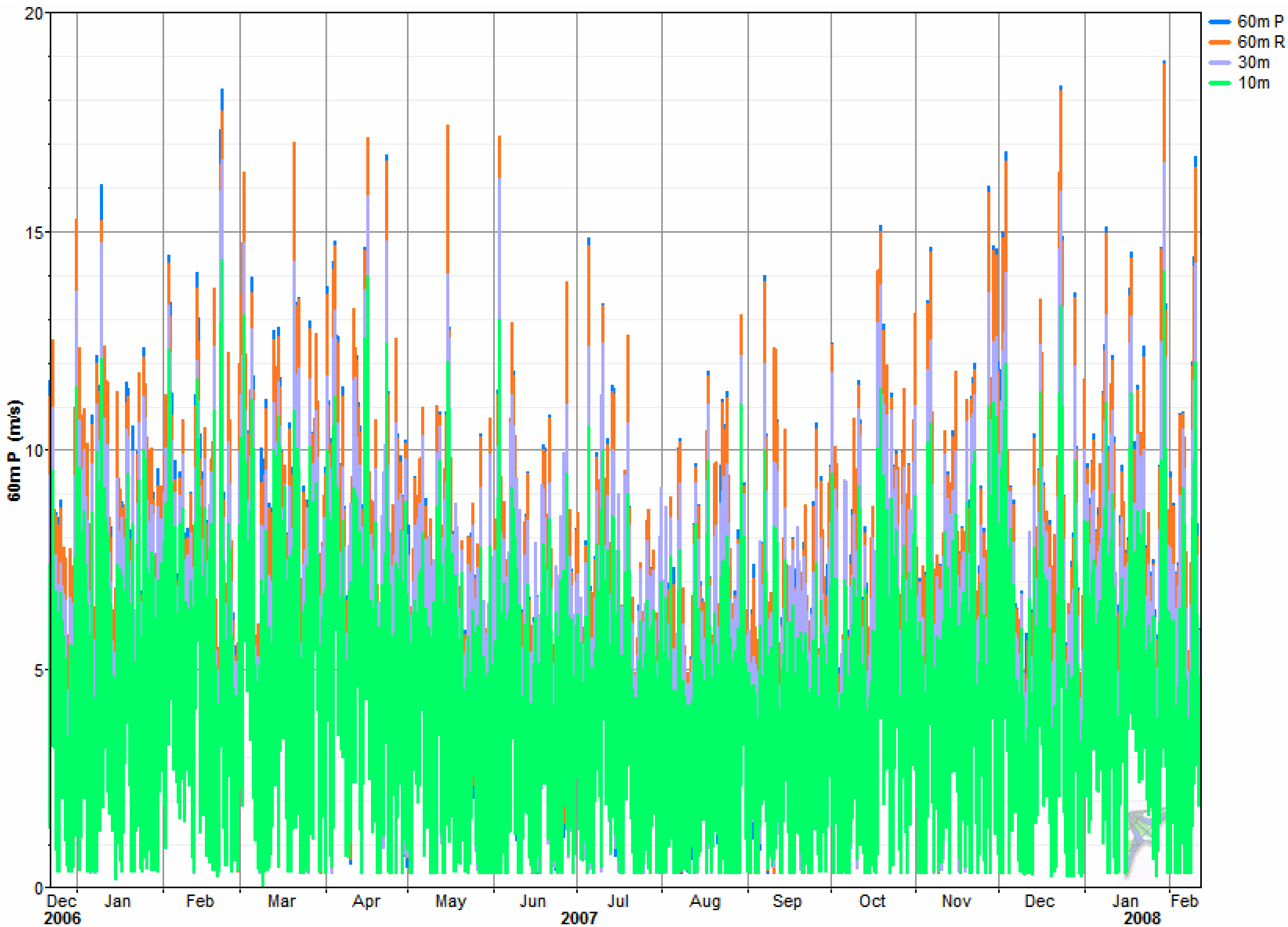


**Figure B-7. BASF 10-min short-term annual average wind speeds.**

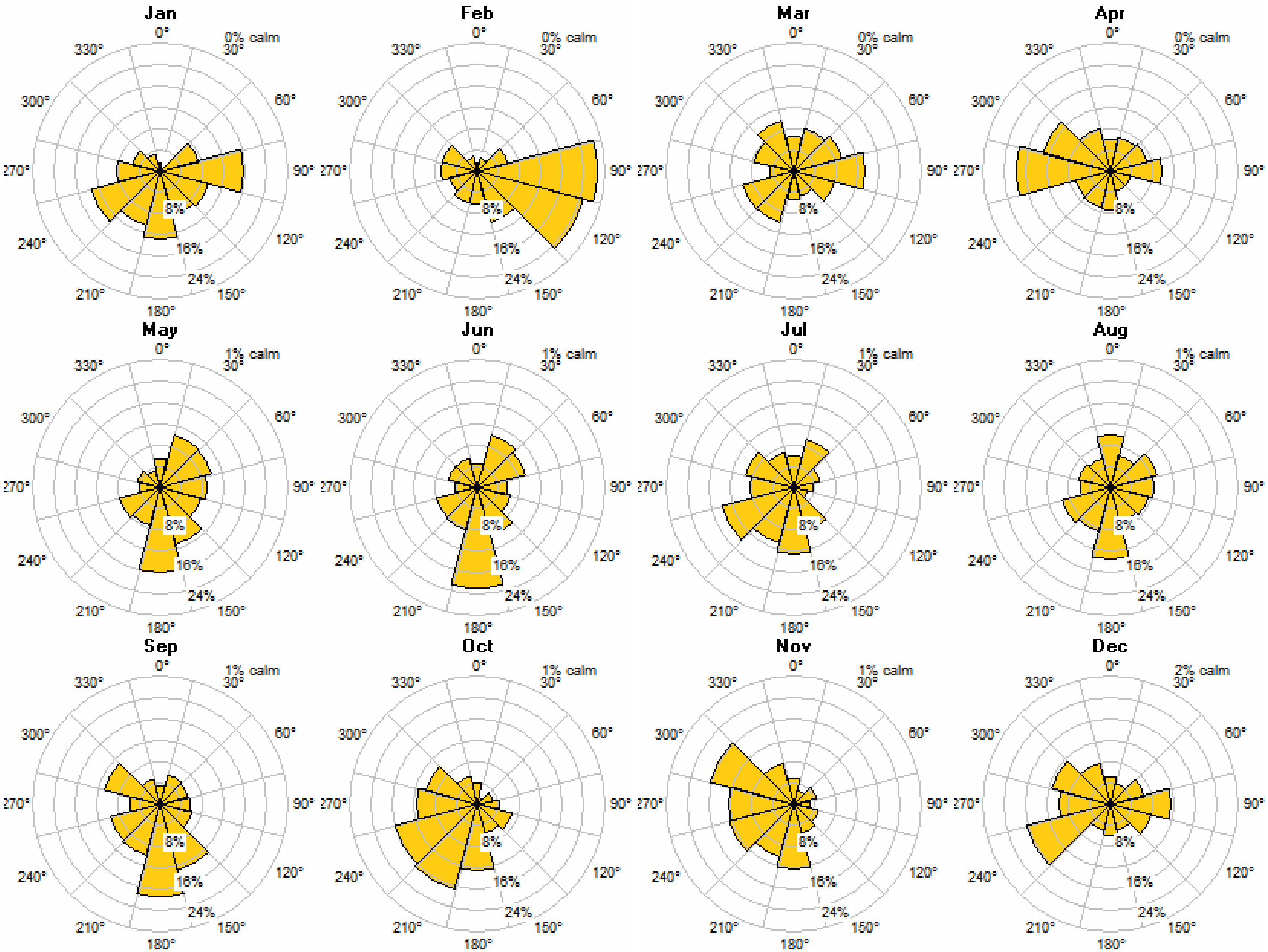


**Figure B-8. BASF short-term 60m monthly wind roses.**

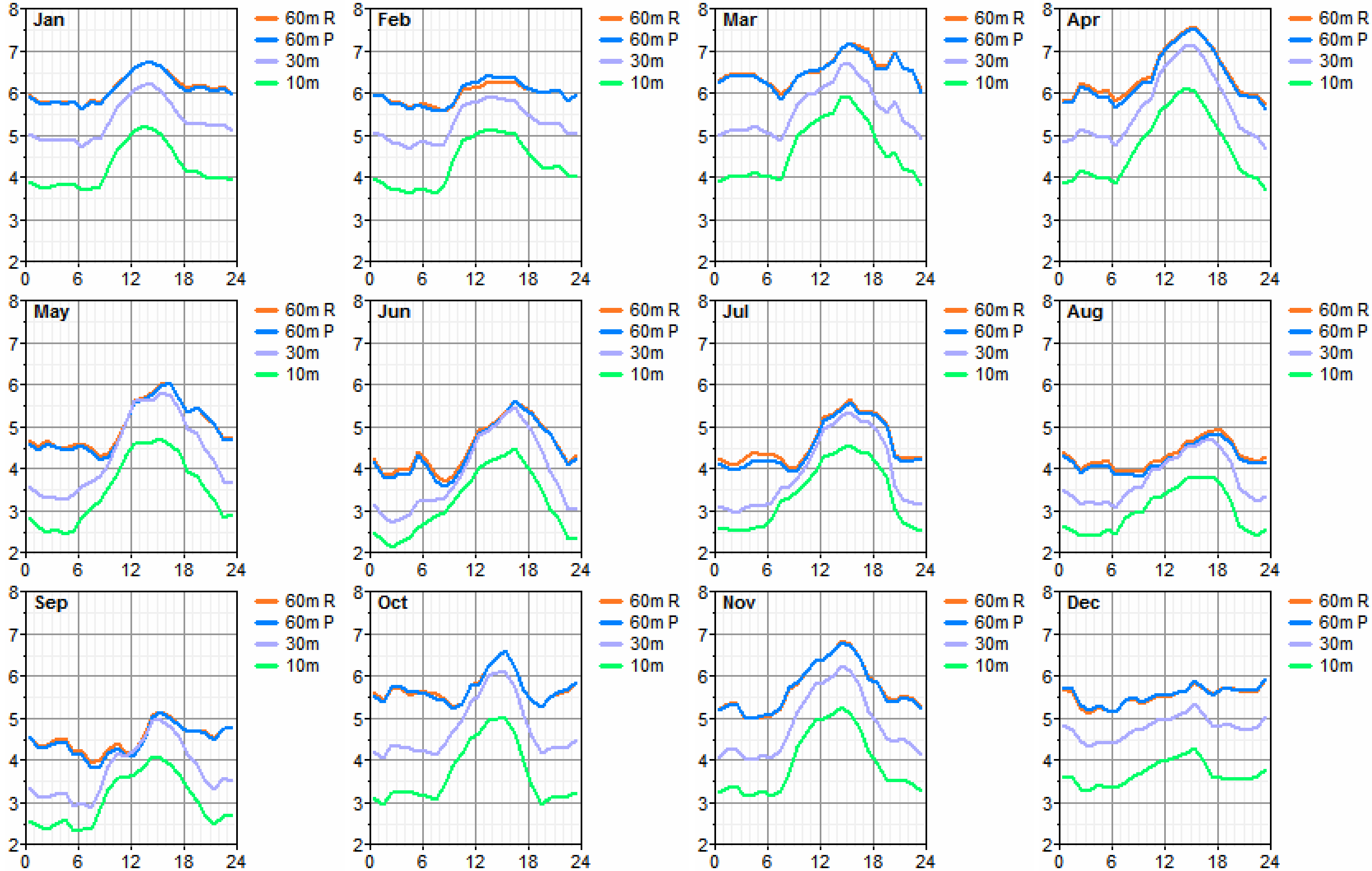


**Figure B-9. BASF monthly short-term diurnal wind speeds.**

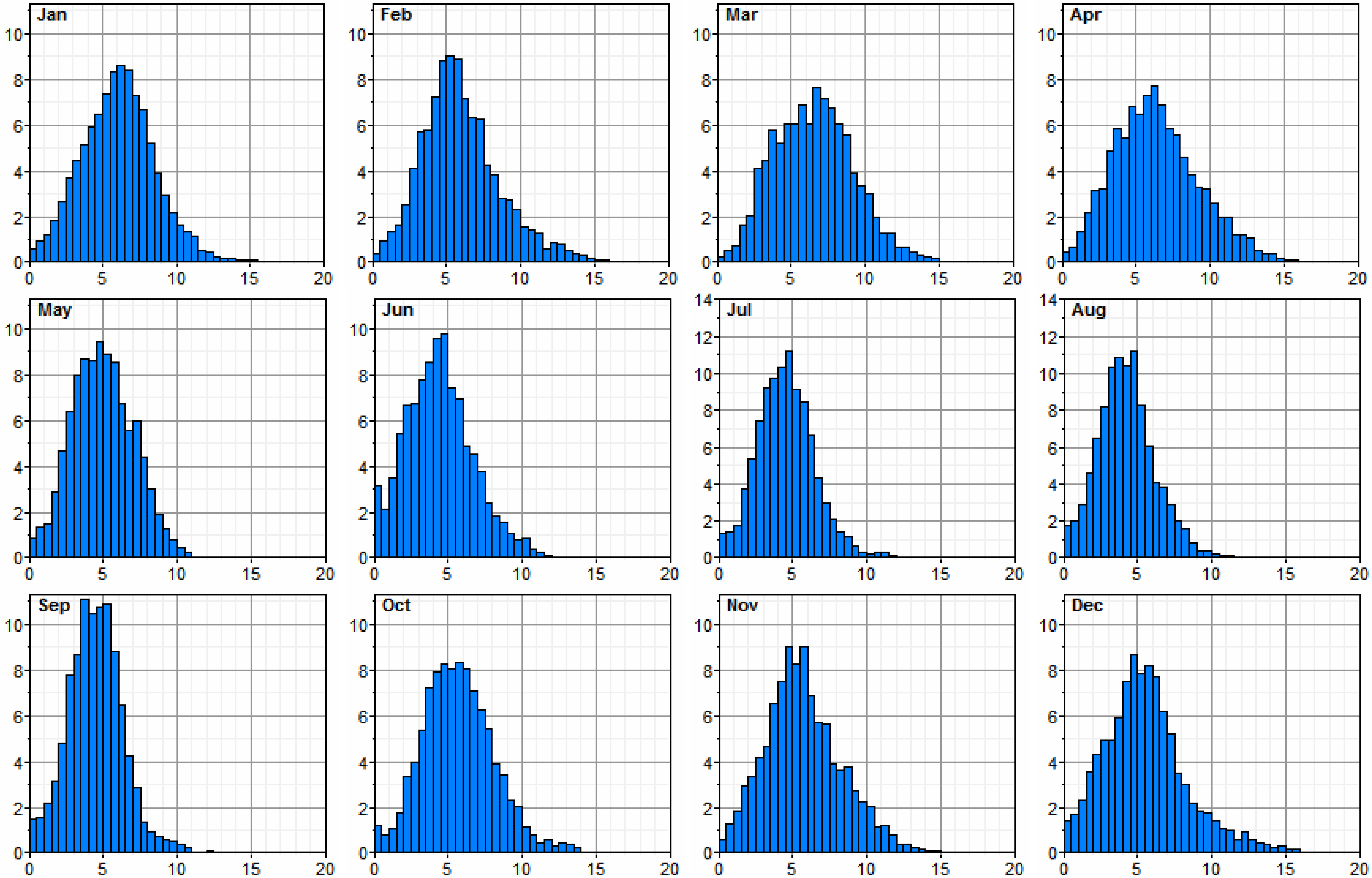


**Figure B-10. BASF monthly 60m wind speed frequency distributions.**

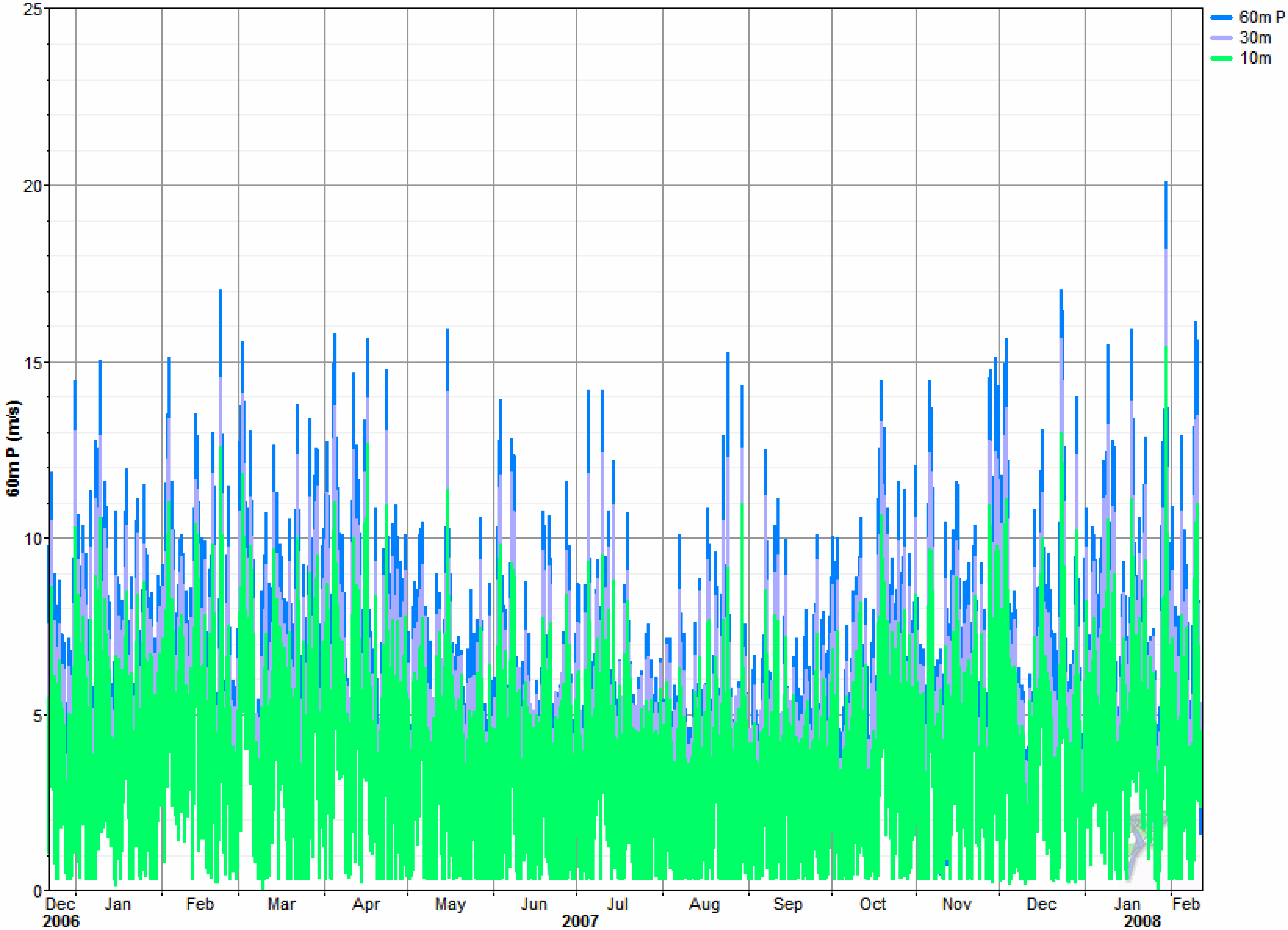


**Figure B-11. Central Avenue 10-min short-term average wind speeds.**

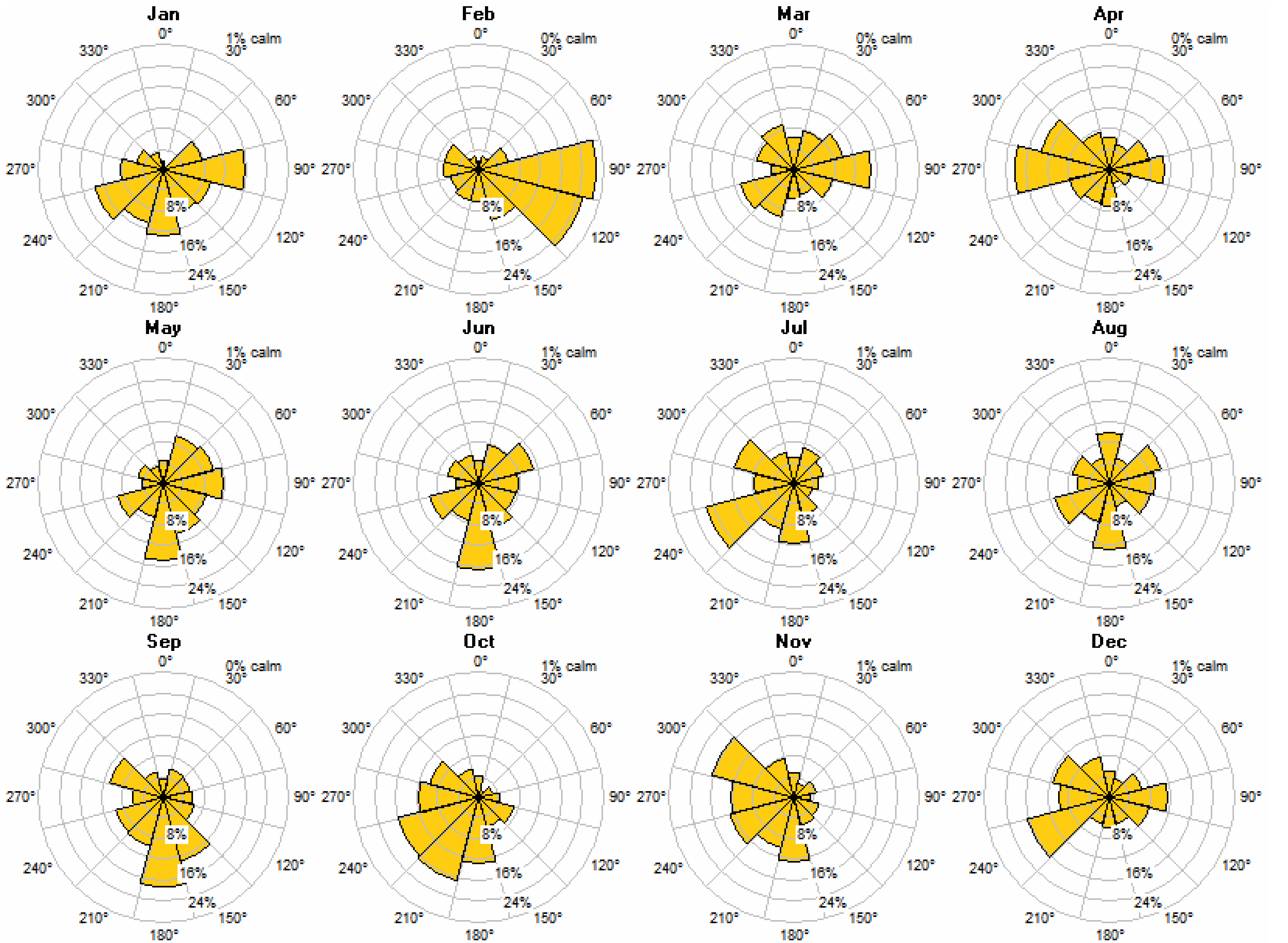


**Figure B-12. Central Avenue short-term 60m monthly wind roses.**

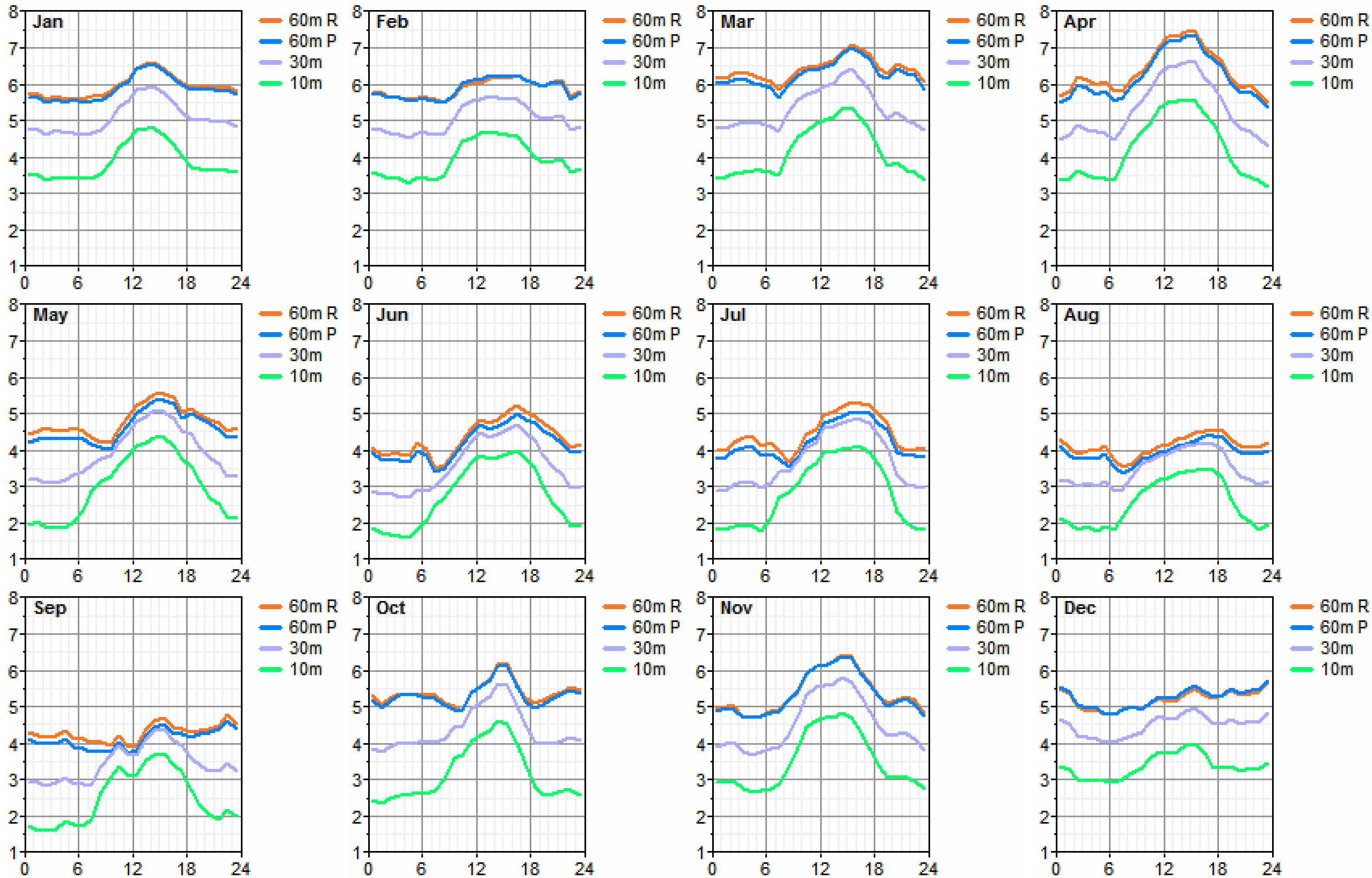


**Figure B-13. Central Avenue monthly short-term diurnal wind speeds.**

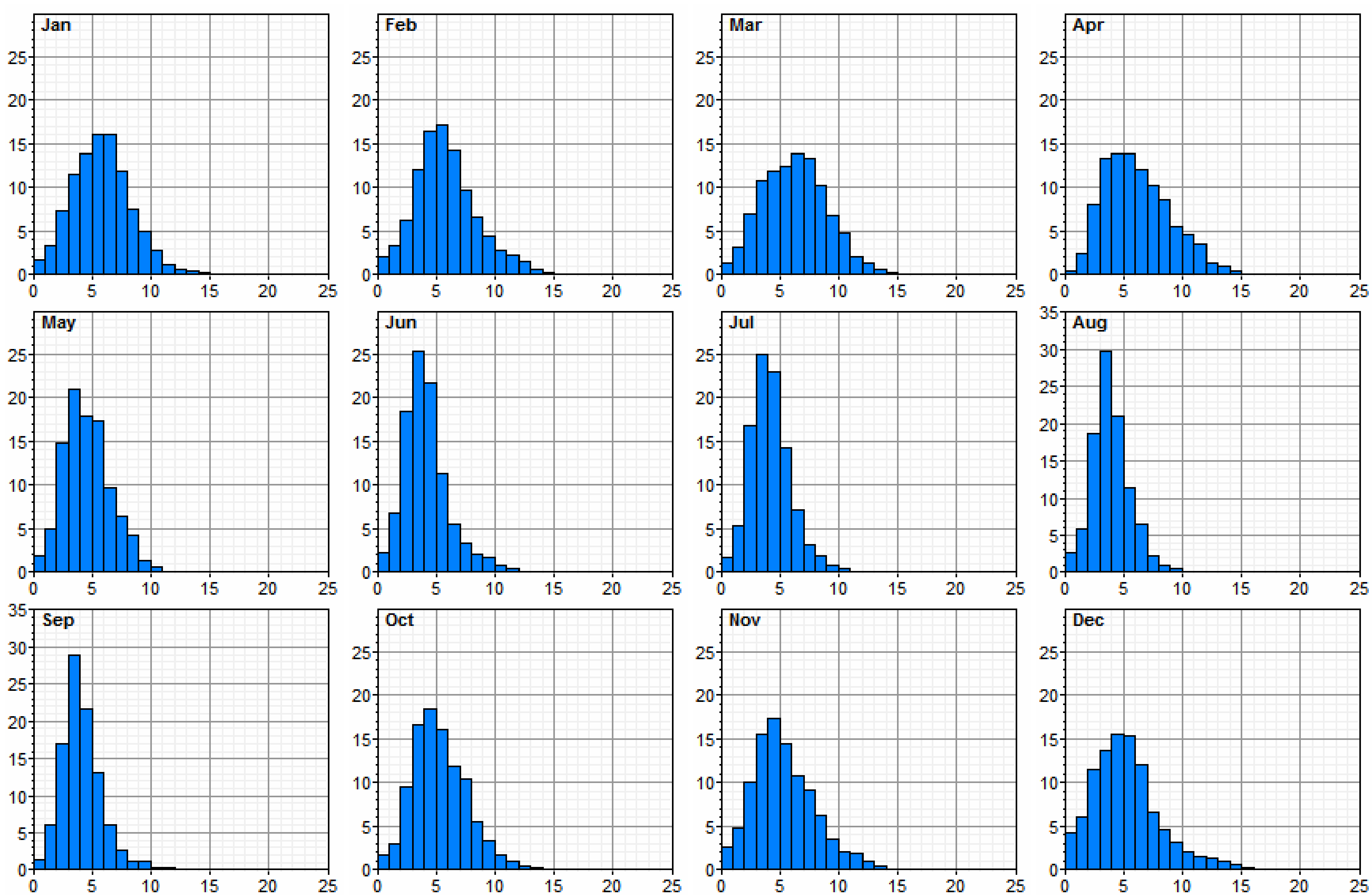


**Figure B-14. Central Avenue monthly short-term 60m frequency distributions.**