TALL TOWERS WIND ENERGY MONITORING & COMMUNITY WIND PROJECTS

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Presented: Michigan Wind Working Group

Lansing, 28 January 2010

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FCOUS OF PRESENTATION

- **Background of the tall towers wind monitoring project**
  - Project team
  - Project objectives
- **Site locations and equipment installed**
- **Data collected and reports generated**
- **Status of on going community wind projects**

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WIND MONITORING PROJECT TEAM

- **Project is funded by the American Recovery and Reinvestment Act of 2009**
  - Competitive grant process
- **Project cooperators**
  - Energy Office of the Michigan Department of Energy, Labor and Economic Growth
  - Michigan State University
  - Michigan Public Safety Communications System (MPSCS)

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PROJECT OBJECTIVES

- The specific objectives of this project are as follows:
  1. Expand the publicly available information regarding wind energy in Michigan at the higher tower heights
  2. Compare wind energy data collected as part of this project to other wind energy sources

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(Project Objectives Continued)

3. Use the collected project data to encourage the development of wind energy in Michigan which will also be a stimulus for job creation, reduce reliance on imported energy and provide for an alternative energy source.

4. Prepare educational materials and hold informational meetings to report results from the project

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INSTALLATION SITES

- **Selection criteria**
  - Identified good wind area
  - A tower was available to install wind monitoring equipment
    - **Adequate height**
    - **Part of system controlled by state**
    - **Approval of MPSCS**

- **Phase 1 – Prototype System**
  - Berrien County (tower 5404)
  - Funded as part of Wisconsin project
  - Have been collecting wind data since April 15, 2009.

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(Installation Sites Continued)

- **Phase 2 – Current grant selected sites**
  - All these sites had equipment installed by mid-May, ‘10
  - Project defined sites
    - **Gratiot County (tower 1402)**
    - **Delta County (tower 8407)**
    - **Antrim County (tower 7901)**
    - **Mason County (tower 6604)**
    - **Hillsdale County (tower 1902)**
  - SWOT Team selected sites
    - **Allegan County (tower 5502)**
    - **Alpena County (tower 7207)**
    - **Chippewa County (tower 9302)**
  - Possible additional tower at Marquette

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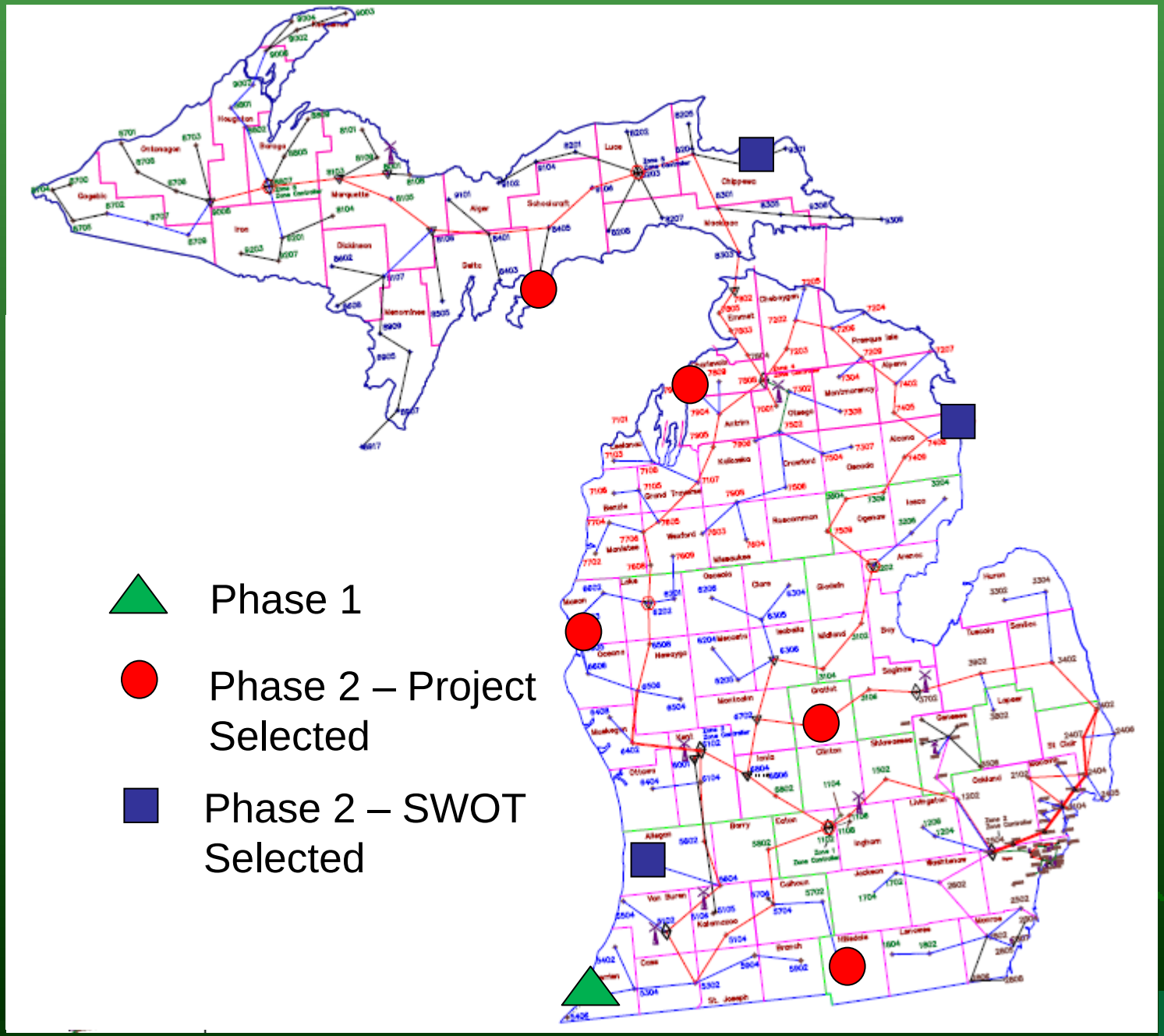

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EQUIPMENT INSTALLED

Equipment (Sensors)	100-M	80-M	60-M	10-M
Calib. Anemometers	2	2	2	
Wind Direction Vane	1	1		
Temperature Sensor				1
Barometric Pres. Sensor				1

Data logger installed at base of tower

-- Has cellular telephone data transfer capability

-- Solar cell and battery power source

For three of these towers the project is also collecting wind data at the 120 meter level

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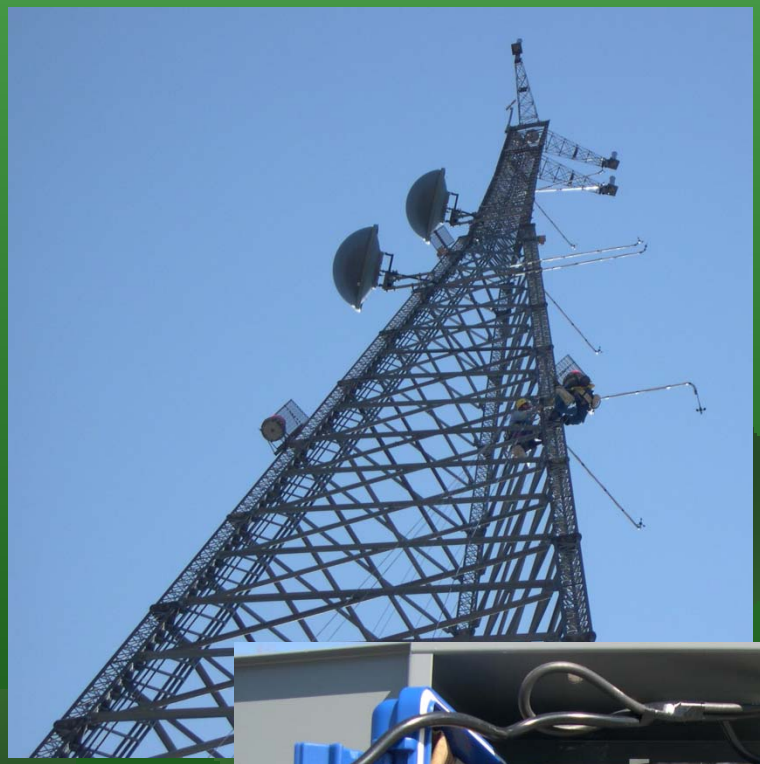

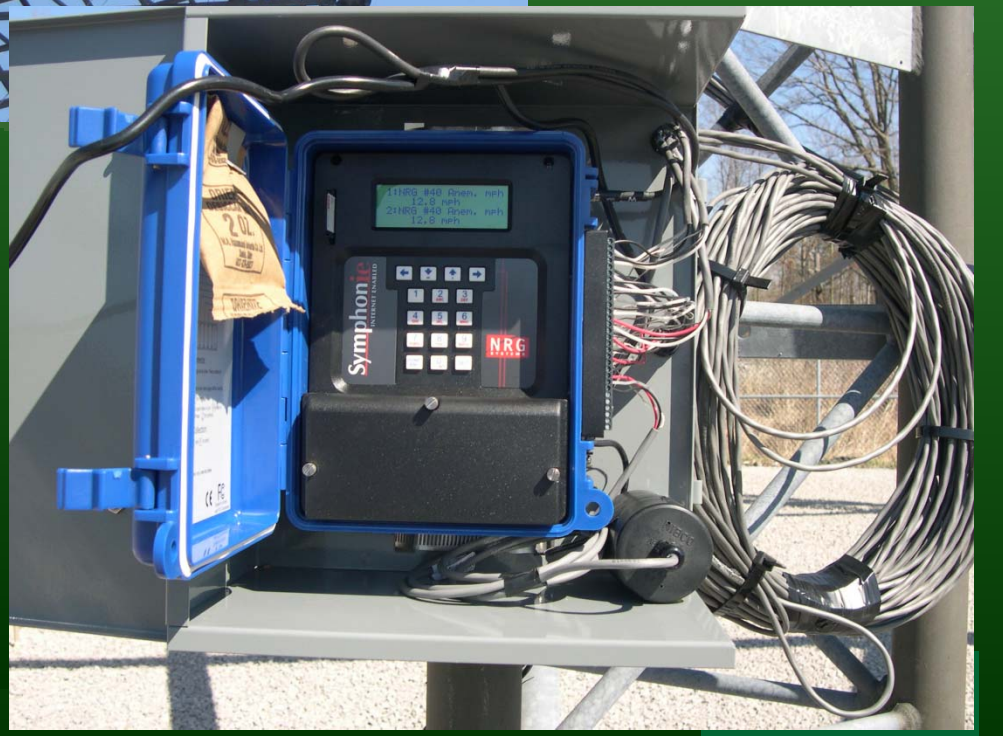

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DATA MEASURED

- **Data collection period is from equipment installation until June 30, 2011**
- **Data sampling process**
  - Each instrument is sampled every 2 seconds
  - 10 minutes record is created from the 2-second measurements (mean, max, min & std dev)
    - **Recorded in non-volatile memory**
  - Twice a week data is transmitted by cellular phone/internet to 3 separate computers

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REPORTS GENERATED

- **Standard reports generated by system supplied software from NRG**
  - Wind frequency distribution by time period
  - Wind rose chart by time period
  - Monthly wind average table
  - Monthly wind speed graph
  - Monthly temperature graph
  - Monthly barometric pressure chart
- **Raw data once cleaned and verified will be placed on-line as comma delimited files**

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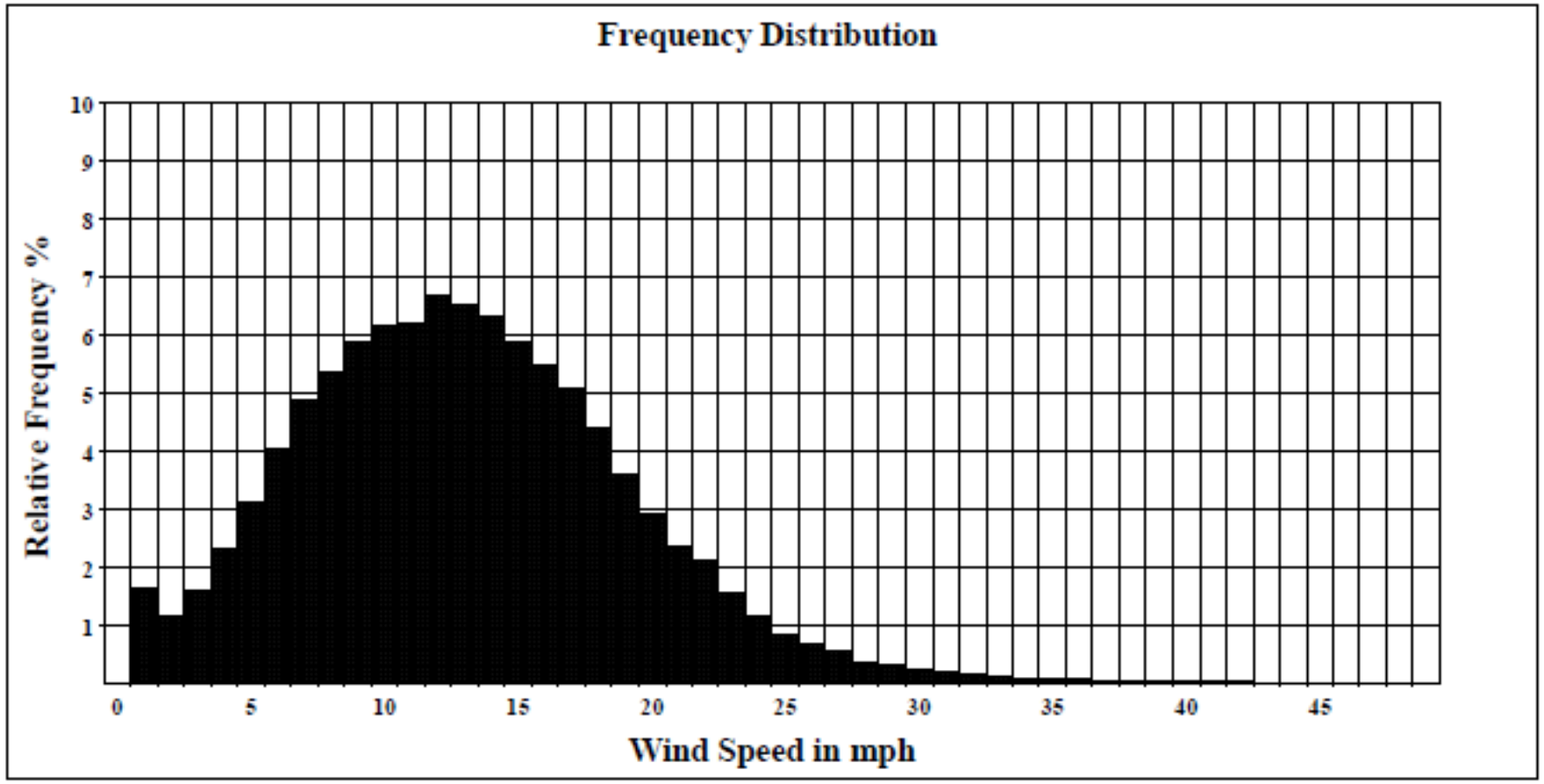
Site Information:
Project: MSU Tall Towers
Location: Sawyer
Elevation: 670

Sensor on channel 1:
NRG #40 Anem. mph
Height: 328 ft
Serial #: SN:

4/18/2009 to 4/17/2010
Frequency Distribution Ch 1
SITE 1620
Sawyer



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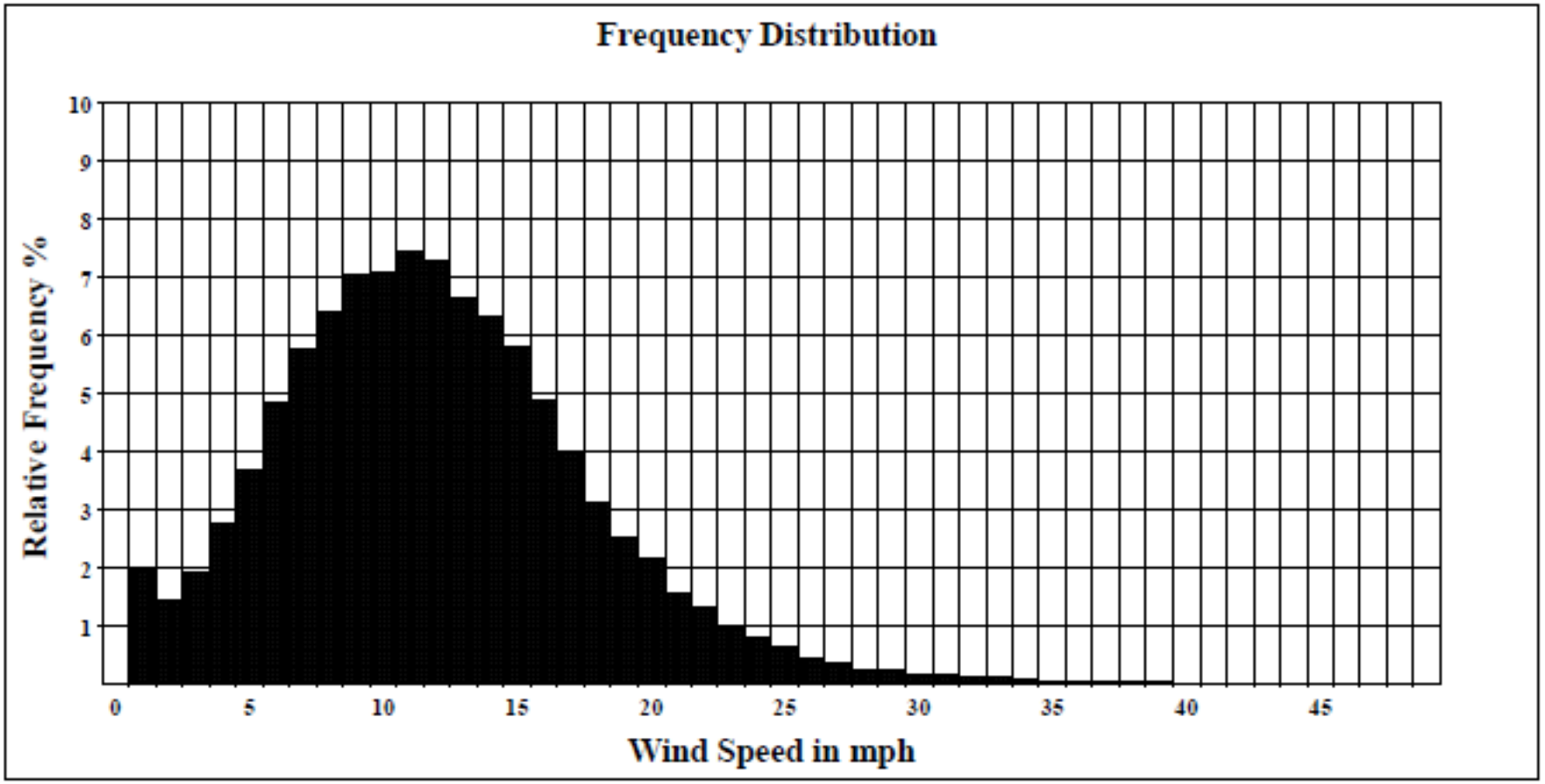
Site Information:
Project: MSU Tall Towers
Location: Sawyer
Elevation: 670

Sensor on channel 3:
NRG #40 Anem. mph
Height: 265 ft
Serial #: SN:

4/18/2009 to 4/17/2010
Frequency Distribution Ch 3
SITE 1620
Sawyer



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Site Information:

Project: MSU Tall Towers

Location: Sawyer

Elevation: 670

Sensor on channel 5:

NRG #40 Anem. mph

Height: 200 ft

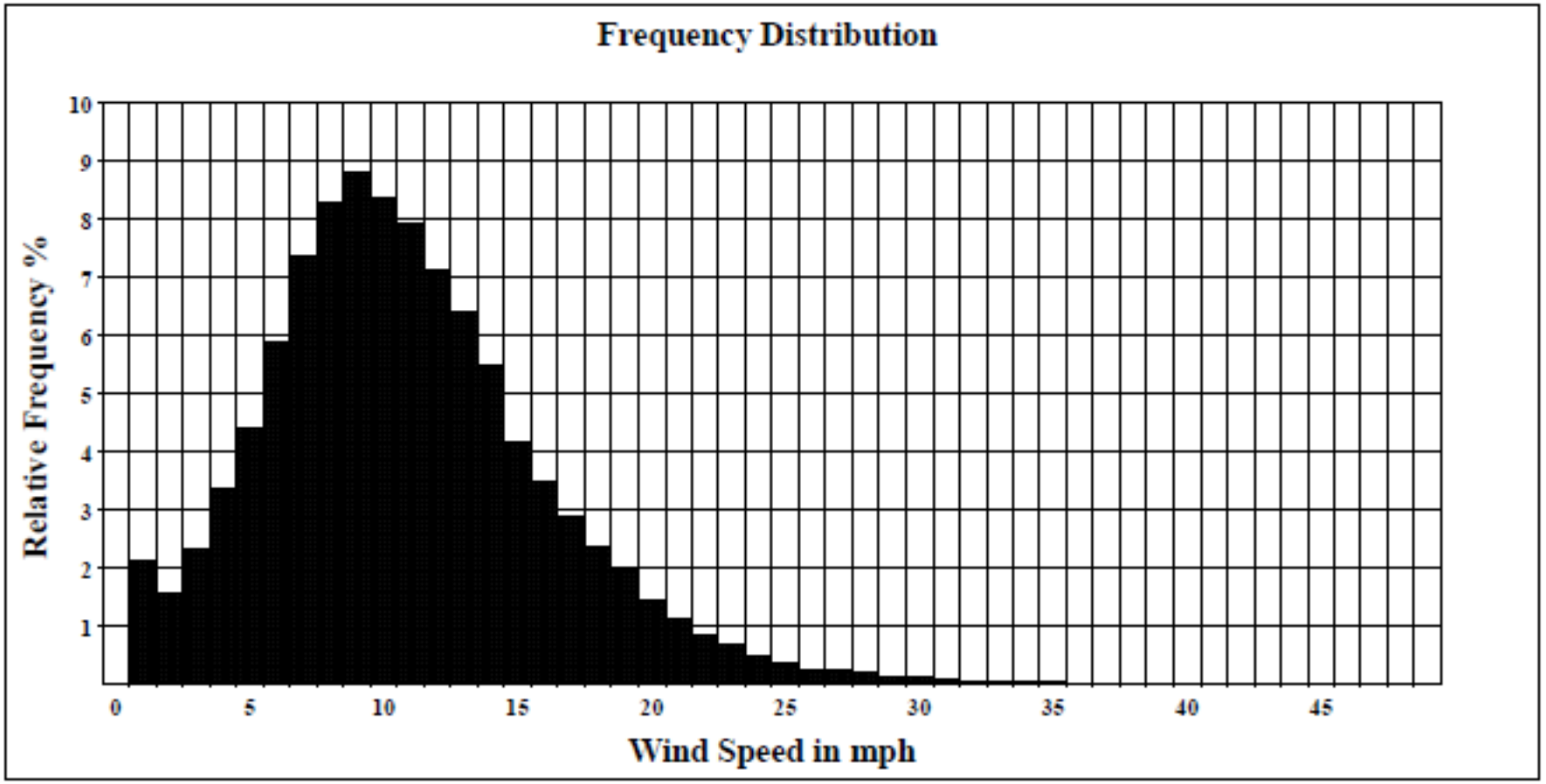
Serial #: SN:

4/18/2009 to 4/17/2010

Frequency Distribution Ch 5

SITE 1620

Sawyer



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Site Information:

Project: MSU Tall Towers

Location: Sawyer

Elevation: 670

Sensor on channel 1:

NRG #40 Anem. mph

Height: 328 ft

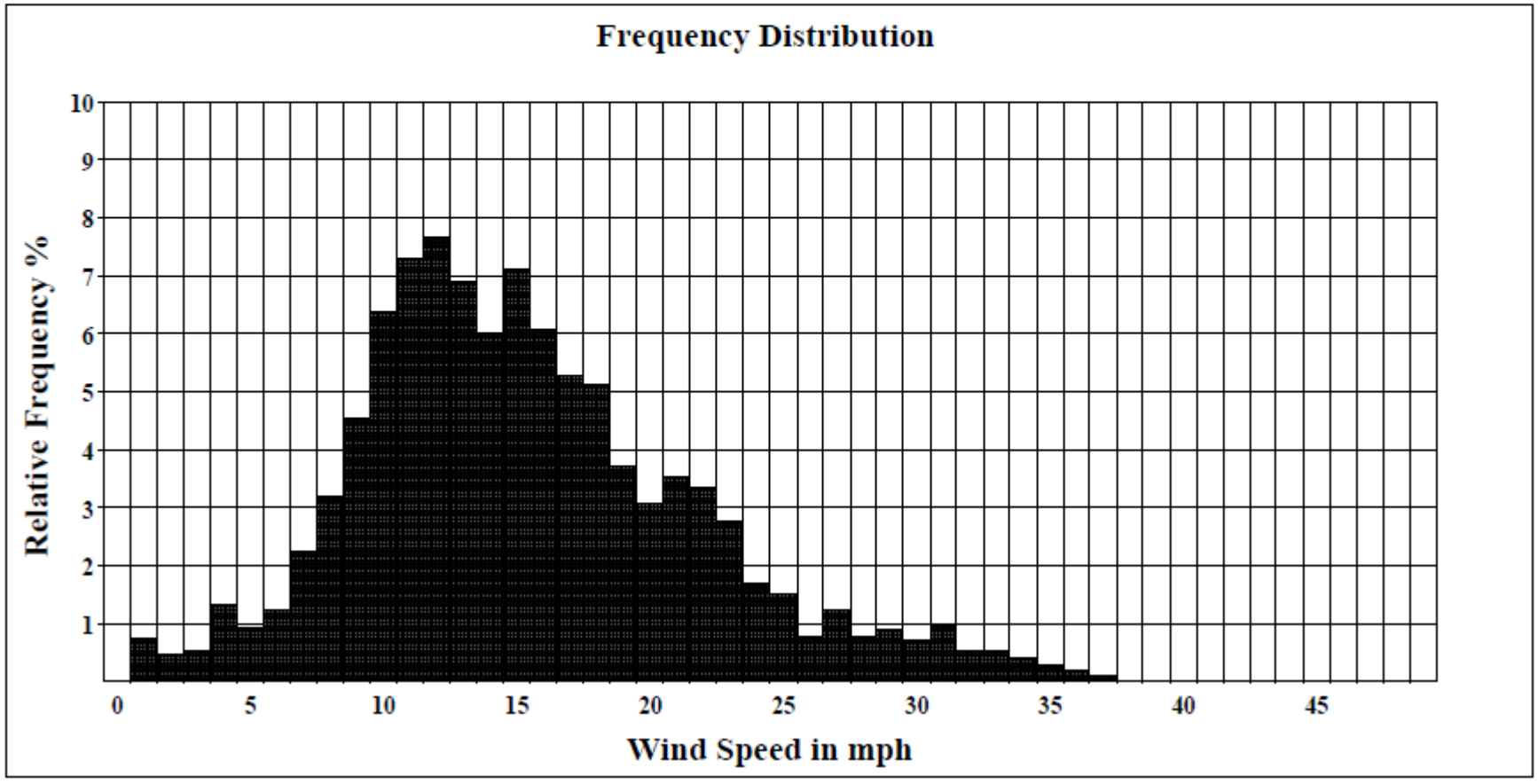
Serial #: SN:

December 2009

Frequency Distribution Ch 1

SITE 1620

Sawyer



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Site Information:

Project: MSU Tall Towers

Location: Sawyer

Elevation: 670

Sensor on channel 1:

NRG #40 Anem. mph

Height: 328 ft Units: mph

Serial #: SN:

December 2009

Hourly Averages Table Ch 1

SITE 1620

Sawyer

	Hour																							
Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
1	20.9	23.3	20.9	21.8	21.1	19.0	15.9	17.2	14.7	11.1	9.5	10.2	11.8	12.5	17.9	18.0	17.5	20.7	22.4	21.7	18.1	16.9	20.3	19.3	17.6
2	18.5	18.5	16.8	15.9	15.3	14.0	11.1	11.2	12.4	9.1	4.1	1.8	4.0	8.7	10.1	12.6	11.9	16.0	17.7	18.5	21.9	22.4	21.7	21.8	14.0
3	22.2	26.2	23.1	21.9	17.3	22.5	24.5	24.6	23.6	20.9	17.8	14.4	14.2	13.5	14.9	18.4	19.9	19.2	22.0	21.3	22.1	21.8	23.3	23.5	20.5
4	21.6	20.6	20.7	16.4	17.9	18.8	21.9	18.0	15.6	16.8	15.8	16.9	17.8	17.5	15.5	15.6	16.9	16.2	15.4	15.5	16.2	16.9	14.8	14.5	17.2
5	13.8	15.1	13.6	13.7	14.6	15.9	13.6	12.4	13.2	13.5	15.1	14.3	14.8	14.4	11.7	9.3	8.2	8.2	13.0	15.3	14.6	15.5	15.4	14.6	13.5
6	16.0	18.1	16.4	14.9	15.2	15.4	15.3	17.6	16.8	16.7	15.1	14.0	13.9	14.5	12.6	9.4	11.3	12.5	12.8	12.8	12.3	12.3	12.3	12.4	14.2
7	11.4	10.4	7.9	8.3	9.4	3.8	4.7	8.8	8.6	8.2	7.4	9.5	9.6	11.5	14.6	16.6	14.7	11.9	11.7	11.9	14.6	12.8	13.3	11.5	10.5
8	12.0	6.1	5.9	7.3	10.1	10.1	9.9	9.4	9.4	10.2	8.8	9.3	9.7	12.9	12.4	14.7	19.3	20.8	21.5	20.9	21.5	20.7	22.5	21.4	13.6
9	23.7	20.6	18.8	17.9	17.5	21.7	23.8	25.3	24.4	23.7	27.9	29.3	32.4	31.2	33.0	32.8	32.3	32.1	36.0	34.5	32.6	30.8	29.6	30.4	27.6
10	28.5	26.6	26.9	25.2	24.0	27.9	28.5	32.9	24.0	29.0	29.9	30.8	30.4	28.5	30.1	29.0	28.7	27.7	23.9	22.4	24.6	24.5	28.1	32.5	27.7
11	31.7	35.7	34.3	31.7	30.4	26.6	24.0	22.3	19.3	18.3	17.4	20.5	17.5	14.5	14.8	15.2	9.4	13.0	14.1	14.4	14.2	13.4	12.1	12.3	19.9
12	15.1	17.7	19.9	17.8	17.4	18.0	18.2	16.8	15.0	13.2	11.9	13.7	13.1	13.9	16.6	16.9	18.9	20.7	21.3	21.5	23.1	24.0	22.6	20.7	17.8
13	9.9	8.7	9.5	7.9	9.8	11.6	13.6	12.6	13.8	14.1	14.9	14.5	14.6	11.3	9.2	8.1	7.0	3.3	1.1	8.4	10.8	8.6	7.7	9.9	10.0
14	9.8	12.0	12.3	12.4	13.6	14.7	11.4	10.4	9.3	10.0	10.0	10.6	9.7	10.8	11.6	12.7	16.9	19.1	18.4	19.5	21.1	23.0	19.6	20.6	14.1
15	22.9	23.3	21.6	21.2	21.8	21.0	19.4	21.5	23.0	22.2	23.5	23.1	21.1	22.8	21.7	19.5	17.9	17.5	16.9	16.3	15.8	15.8	14.9	13.8	19.9
16	14.9	15.0	14.9	15.4	13.4	13.9	13.5	12.0	8.0	10.4	11.7	9.8	10.5	9.2	8.9	6.9	5.4	2.9	1.0	2.8	5.4	4.1	3.4	5.6	9.1
17	9.5	12.5	15.7	17.2	15.8	14.3	13.7	14.3	13.7	12.4	11.2	12.6	13.1	14.8	12.7	13.2	15.9	17.6	15.2	15.4	12.4	16.3	13.2	8.8	13.8
18	11.1	11.2	9.8	12.7	12.1	9.7	7.6	6.1	5.7	5.0	4.4	4.1	5.6	7.5	9.4	7.6	10.7	10.9	11.2	9.9	8.8	9.4	10.3	10.5	8.8
19	10.4	11.7	11.3	12.3	13.3	12.9	11.8	11.1	10.5	9.0	7.5	7.9	7.6	7.9	9.9	9.6	9.5	9.0	9.5	12.1	11.5	10.6	6.6	4.7	9.9
20	2.1	0.8	1.4	1.4	4.3	4.3	6.2	6.5	9.7	9.1	6.5	9.1	14.2	13.5	12.6	11.9	10.9	8.4	8.8	11.0	12.0	12.4	12.4	10.8	8.3
21	9.5	9.3	9.3	10.3	11.0	11.7	11.3	10.5	11.3	11.6	12.0	11.3	11.3	12.7	13.1	10.8	10.4	8.6	9.1	9.9	7.5	8.6	8.9	9.6	10.4
22	10.2	11.2	11.3	10.1	9.6	7.1	4.3	7.0	10.9	11.1	12.8	10.9	12.1	10.6	10.1	12.4	14.6	16.8	17.5	18.8	18.3	15.6	15.0	15.3	12.2
23	13.3	15.3	15.9	17.4	17.0	18.2	16.5	16.6	17.5	17.0	18.4	16.8	16.9	17.7	17.1	18.0	15.7	18.1	19.7	21.2	21.0	20.2	18.8	17.6	17.6
24	18.1	17.3	16.1	16.0	17.0	15.7	17.3	16.9	18.8	18.9	19.4	17.1	19.2	19.8	16.8	16.5	16.6	16.6	15.8	16.3	16.5	18.4	20.9	19.2	17.6
25	21.7	21.5	22.3	23.5	24.7	23.6	23.6	26.8	30.0	29.4	25.9	22.7	21.6	20.5	16.4	16.8	18.9	17.7	20.5	21.9	19.5	19.2	15.5	14.6	21.6
26	12.4	13.9	12.4	17.3	12.1	10.3	10.8	13.3	12.5	13.0	15.0	16.2	15.1	14.0	15.1	12.0	9.9	8.6	11.3	12.9	12.0	14.6	13.3	11.3	12.9
27	12.3	16.6	14.8	15.4	15.2	15.4	13.9	14.6	13.7	11.9	10.3	8.3	8.9	8.5	7.9	7.3	8.8	12.0	11.0	17.3	17.6	17.5	17.9	19.1	13.2
28	19.4	20.3	18.4	15.6	15.5	19.7	21.5	22.4	23.8	24.2	26.3	27.6	26.7	28.4	30.3	32.6	31.2	27.8	28.6	26.7	25.9	24.5	22.3	20.8	24.2
29	19.7	20.0	18.6	16.8	13.7	14.0	13.2	12.2	10.6	9.2	6.0	4.7	7.2	7.3	6.8	6.9	4.0	1.8	10.8	10.9	12.8	12.8	11.4	11.3	10.9
30	13.6	14.3	13.6	12.7	13.6	13.5	15.2	14.7	15.7	13.8	12.5	13.3	11.4	10.3	9.7	10.4	12.5	11.2	11.0	11.2	12.2	11.6	12.0	12.3	12.6
31	11.8	11.5	11.0	10.3	10.0	11.1	12.0	11.4	10.8	10.6	12.9	13.0	15.3	15.7	15.3	15.5	17.2	18.6	22.7	21.1	22.3	18.6	16.5	16.9	14.7
AVG	15.7	16.3	15.7	15.4	15.3	15.4	15.1	15.4	15.0	14.6	14.3	14.1	14.5	14.7	14.8	14.7	14.9	15.0	15.9	16.6	16.7	16.6	16.0	15.7	15.4

Generated Friday, January 08, 2010

Total 10-minute intervals: 4464 Intervals used in calculations: 4464 Percent data used: 100

NRG Systems SDR Version 6.00

Site Information:

Project: MSU Tall Towers

Location: Sawyer

Elevation: 670

Sensor on channel 1:

NRG #40 Anem. mph

Height: 328 ft

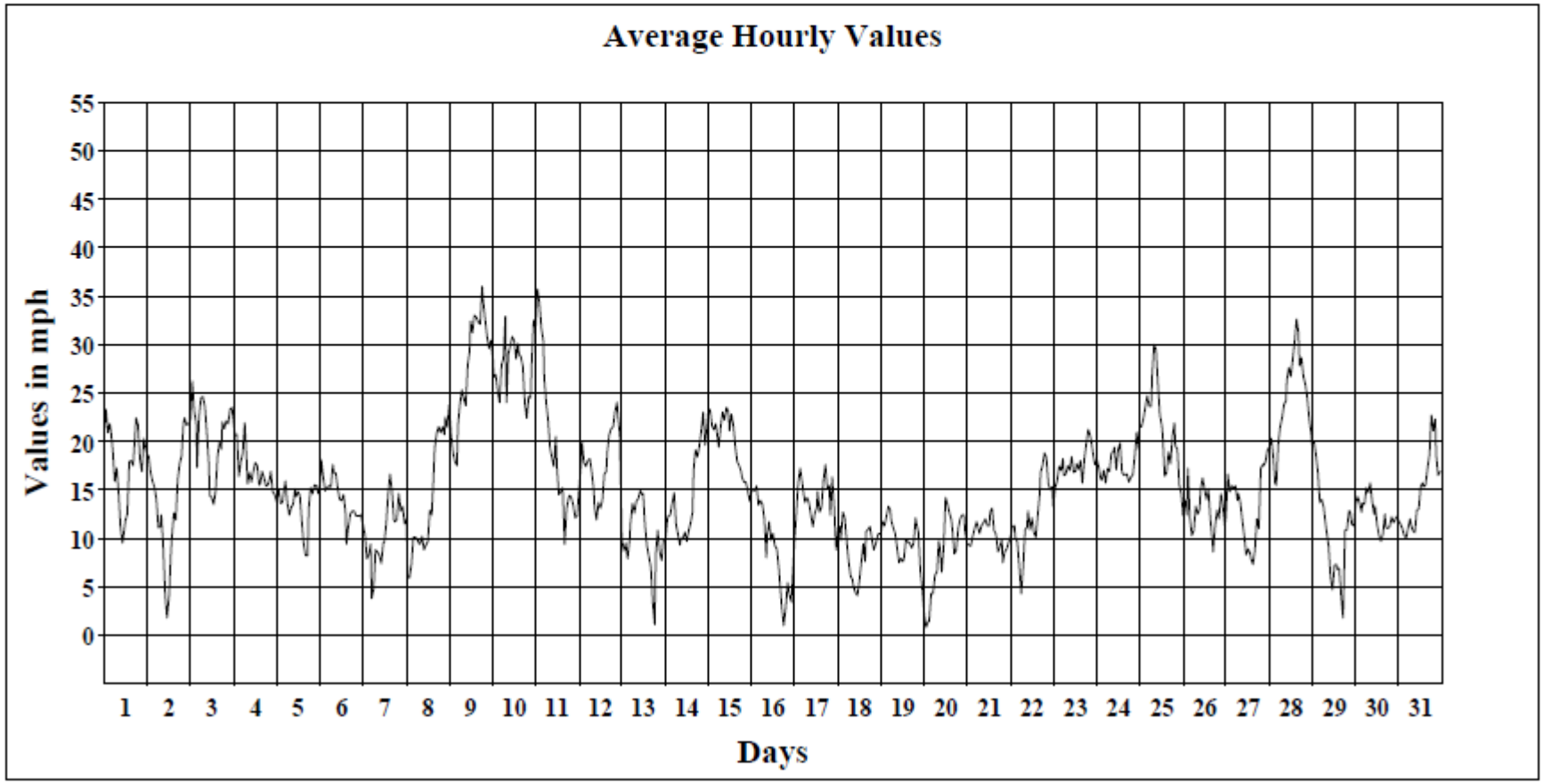
Serial #: SN:

December 2009

Hourly Averages Graph Ch 1

SITE 1620

Sawyer



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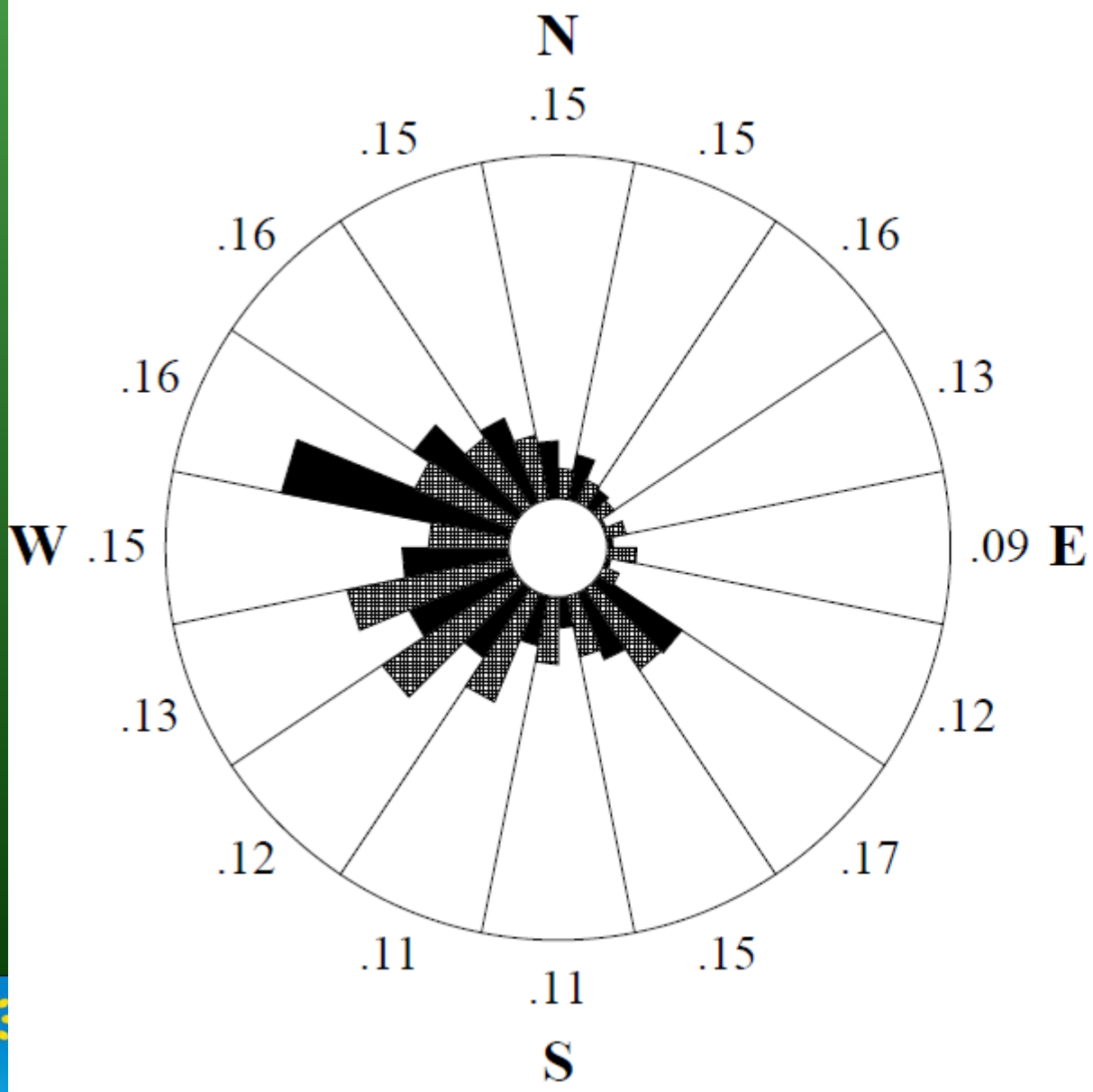

December 2009

Wind Rose Ch 1, 7

SITE 1620

Sawyer

Site Information:

Project: MSU Tall Towers

Location: Sawyer

Elevation: 670

Anemometer on channel 1:

NRG #40 Anem. mph

Height: 328 ft

Serial #: SN:

Vane on channel 7:

#200P Wind Vane

Height: 328 ft

Serial #: SN:

Outer Numbers are Average TIs for speeds greater than 10 mph

Inner Circle = 0%

Outer Circle = 30%

Percent of Total Wind Energy

Percent of Total Time

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Site Information:

Project: MSU Tall Towers

Location: Sawyer

Elevation: 670

Sensor on channel 9:

NRG 110S Temp, F

Height: 20 ft

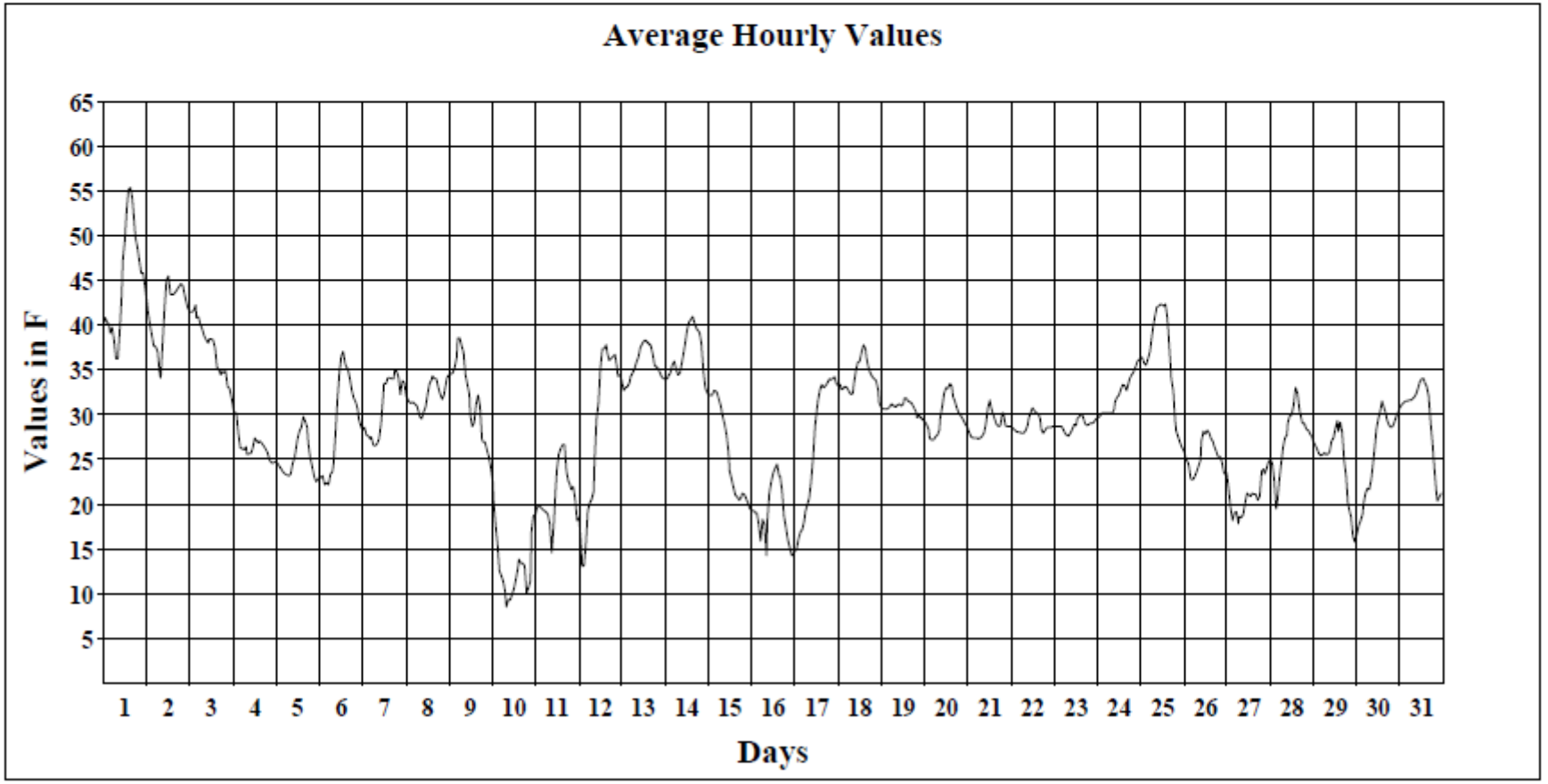
Serial #: SN:

December 2009

Hourly Averages Graph Ch 9

SITE 1620

Sawyer



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Site Information:

Project: MSU Tall Towers

Location: Sawyer

Elevation: 670

Sensor on channel 10:

BP-20 Barom. mb

Height: 3 m

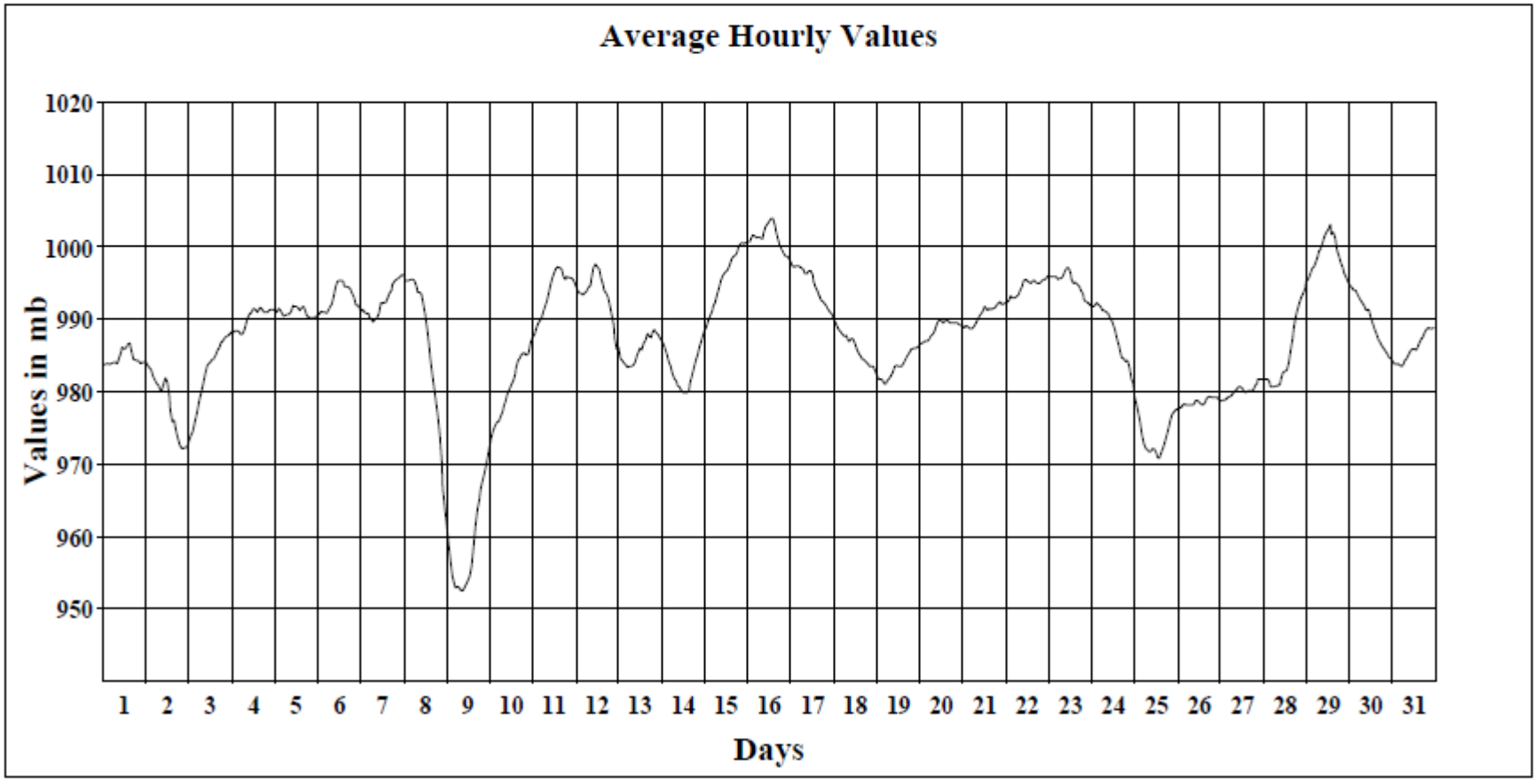
Serial #: SN:

December 2009

Hourly Averages Graph Ch 10

SITE 1620

Sawyer



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RAW DATA FOR DOWNLOAD

Date	Time	CH1Avg	CH1SD	CH1Max	CH1Min	CH2Avg	CH2SD	CH2Max	CH2Min	CH3Avg	CH3SD	CH3Max	CH3Min	CH4Avg
4/18/2009	0:00:00	5.2	0.4	5.9	4.2	6.1	0.4	6.8	5.9	4.4	0.4	5.1	3.3	5.5	0.4	5.9	5.1	3.8	1.2	6.8	1.6
4/18/2009	0:10:00	6.2	0.8	7.6	5.1	6.9	0.4	7.6	5.9	4.6	0.4	5.9	3.3	6.1	0.4	6.8	5.1	5.7	0.5	6.8	4.2
4/18/2009	0:20:00	7.1	0.5	8.5	5.9	7.6	0.4	8.5	6.8	4.9	0.4	5.9	4.2	6.9	0.5	7.6	5.9	6.2	0.5	7.6	5.1
4/18/2009	0:30:00	7.4	0.4	8.5	5.9	7.8	0.4	8.5	6.8	5.4	0.4	5.9	4.2	7.3	0.4	7.6	6.8	6.3	0.4	7.6	5.1
4/18/2009	0:40:00	7.4	0.6	8.5	5.9	8.1	0.5	9.3	6.8	6.6	1	8.5	5.1	8.2	0.5	9.3	6.8	6.7	0.8	8.5	5.1	6
4/18/2009	0:50:00	7.9	0.6	8.5	6.8	8.7	0.4	9.3	7.6	7.8	0.5	8.5	6.8	8.7	0.4	9.3	8.5	8.1	0.4	9.3	7.6
4/18/2009	1:00:00	8.3	0.5	9.3	6.8	8.9	0.4	10.2	7.6	8.3	0.5	9.3	6.8	9.2	0.3	10.2	8.5	8.5	0.4	9.3	7
4/18/2009	1:10:00	8	0.6	9.3	6.8	8.8	0.4	10.2	7.6	8.4	0.5	9.3	6.8	9.2	0.4	10.2	8.5	8.5	0.4	9.3	7.6
4/18/2009	1:20:00	8.3	0.5	9.3	6.8	9.1	0.4	10.2	8.5	8.9	0.5	10.2	7.6	9.5	0.4	10.2	8.5	8.8	0.4	9.3	
4/18/2009	1:30:00	8.2	0.7	9.3	6.8	9.4	0.4	10.2	8.5	9.7	0.8	11.1	7.6	9.9	0.4	11.1	9.3	9.3	0.5	10.2	
4/18/2009	1:40:00	7.8	0.6	9.3	5.9	9	0.6	10.2	7.6	9.9	0.5	11.1	8.5	9.6	0.5	11.1	7.6	9.6	0.6	11.1	8
4/18/2009	1:50:00	8.9	0.6	11.1	7.6	9.3	0.5	11.1	8.5	9.8	0.4	11.1	8.5	9.4	0.4	10.2	8.5	9.7	0.7	11.	
4/18/2009	2:00:00	10.2	0.5	11.1	8.5	10.1	0.5	11.1	8.5	9.6	0.6	11.1	8.5	9.2	0.6	10.2	7.6	10	0.6	11	
4/18/2009	2:10:00	9.9	0.5	11.1	8.5	9.8	0.5	11.1	8.5	9	0.6	10.2	7.6	8.5	0.6	9.3	6.8	9.3	0.6	11.1	7
4/18/2009	2:20:00	9.1	0.6	10.2	8.5	9	0.6	10.2	7.6	7.7	0.6	9.3	6.8	7.2	0.6	8.5	5.9	7.8	0.7	9.3	5.9
4/18/2009	2:30:00	7.6	0.5	9.3	6.8	7.5	0.5	8.5	5.9	6.7	0.5	7.6	5.9	6.2	0.5	7.6	5.1	7.6	0.5	8.5	6.8
4/18/2009	2:40:00	7.2	0.6	8.5	5.9	7.3	0.7	9.3	5.9	8.3	1.1	11.1	5.9	7.9	1.1	10.2	5.9	10.1	1.1	11.9	
4/18/2009	2:50:00	7.1	0.5	8.5	5.9	7.1	0.5	8.5	5.9	8.3	0.5	9.3	7.6	7.8	0.5	9.3	6.8	9.8	0.5	11.1	8.
4/18/2009	3:00:00	7.5	0.3	8.5	6.8	7.4	0.4	8.5	6.8	8.6	0.5	9.3	7.6	8.1	0.5	9.3	6.8	10.1	0.7	11.9	9
4/18/2009	3:10:00	7.5	0.4	8.5	6.8	7.6	0.4	8.5	6.8	8.9	0.4	9.3	8.5	8.5	0.4	9.3	7.6	10.4	0.4	11.9	9
4/18/2009	3:20:00	7.5	0.3	8.5	6.8	7.5	0.4	8.5	6.8	8.8	0.4	9.3	8.5	8.3	0.4	9.3	7.6	9.7	0.5	11.1	8.
4/18/2009	3:30:00	8.7	0.6	9.3	7.6	8.7	0.6	9.3	7.6	9.6	0.6	11.1	8.5	9.1	0.6	10.2	7.6	10.6	0.7	11.9	
4/18/2009	3:40:00	8.9	0.5	10.2	7.6	8.8	0.6	10.2	7.6	9.4	0.4	10.2	8.5	8.9	0.4	9.3	8.5	10.2	0.4	11.	
4/18/2009	3:50:00	8.4	0.6	10.2	7.6	8.3	0.6	9.3	7.6	9.2	0.4	10.2	8.5	8.7	0.4	9.3	7.6	9.6	0.4	11.1	
4/18/2009	4:00:00	8.7	0.5	9.3	7.6	8.6	0.4	9.3	7.6	10	0.4	11.1	9.3	9.4	0.5	10.2	8.5	10.5	0.6	11.9	

One year of data = 2.5 million data elements

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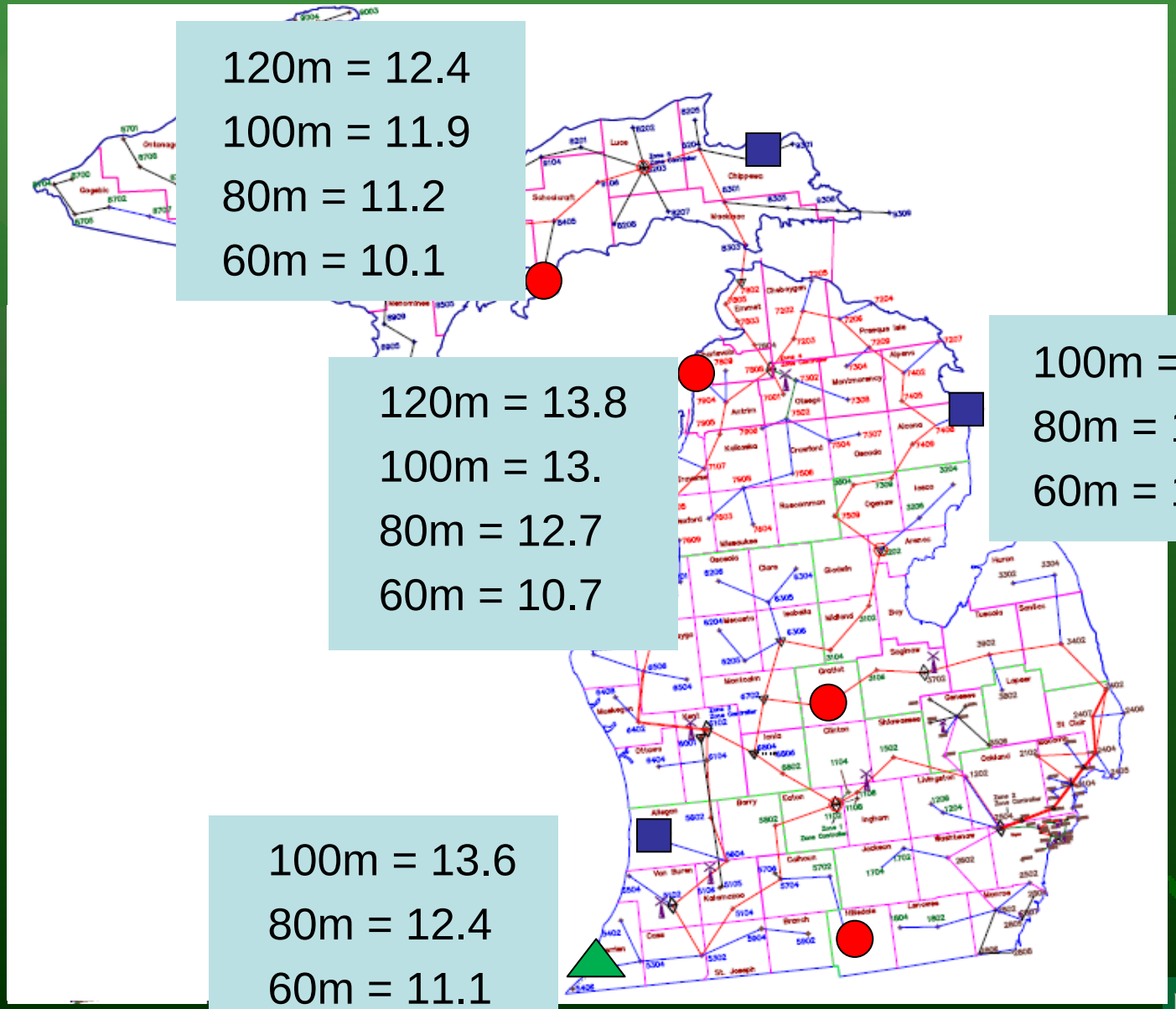
WIND SPEEDS (MPH)



120m = 12.4
100m = 11.9
80m = 11.2
60m = 10.1

120m = 13.8
100m = 13.
80m = 12.7
60m = 10.7

100m = 12.5
80m = 11.9
60m = 10.6

100m = 13.6
80m = 12.4
60m = 11.1

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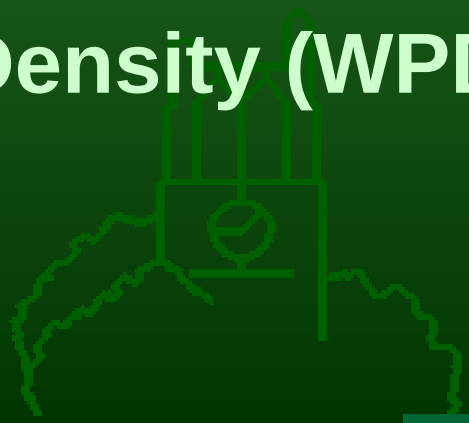
WIND DATA COMPARISONS

- There are a number of options for doing these comparisons
- In the South Haven – Albemarle project a comparison was made between two 60-meter sites 5 miles apart ($R^2 = 0.98$)
- Will make comparisons with both wind speed and Wind Power Density (WPD)



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Phase 1

Phase 2 – Project Selected

Phase 2 – SWOT Selected

Airport AWAS Data

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COMMUNITY WIND

- **What is community wind?**
  - Locally-owned, utility-scale wind projects
    - **Studies indicate they have a greater impact on local economic development (wage, jobs, community income & taxes paid)**
  - Generally smaller projects
    - **Often less than 20 turbines**
  - A small but growing segment of wind project ownership
    - **Minnesota is a leader in this area**
  - Ownership can take several forms
    - **Locally owned LLC, schools and universities, rural electric cooperatives, municipal utilities, and others**

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EXAMPLES OF COMMUNITY WIND EFFORTS IN MICHIGAN

- **Wyandotte Municipal Project**
  - 1- 2 Turbines
- **City of South Haven - Albemarle Corp.**
- **Great Lakes Wind, LLC**
  - Joint with Exelon (John Deere)
- **Beebe Community Wind Farm, LLC**
  - Received USDA grant to do feasibility analysis

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http://www.miwind.info

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