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Assessing the Feasibility of Wind Power Production for the University of Rhode Island's Bay Campus

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Feasibility of Wind Power Production at the URI Bay Campus

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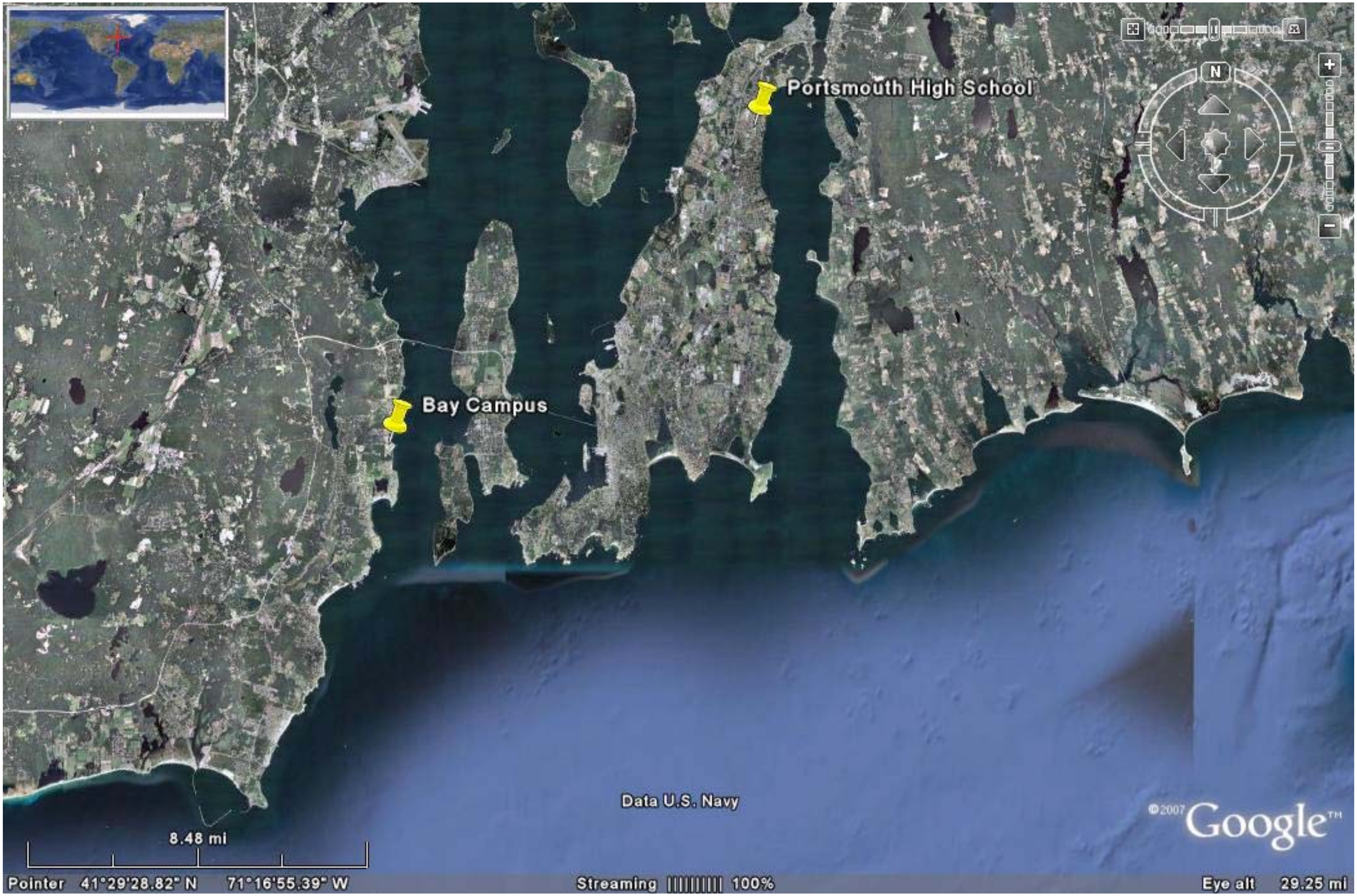
Advising Professor: Dr. Malcolm Spaulding

Ocean Engineering

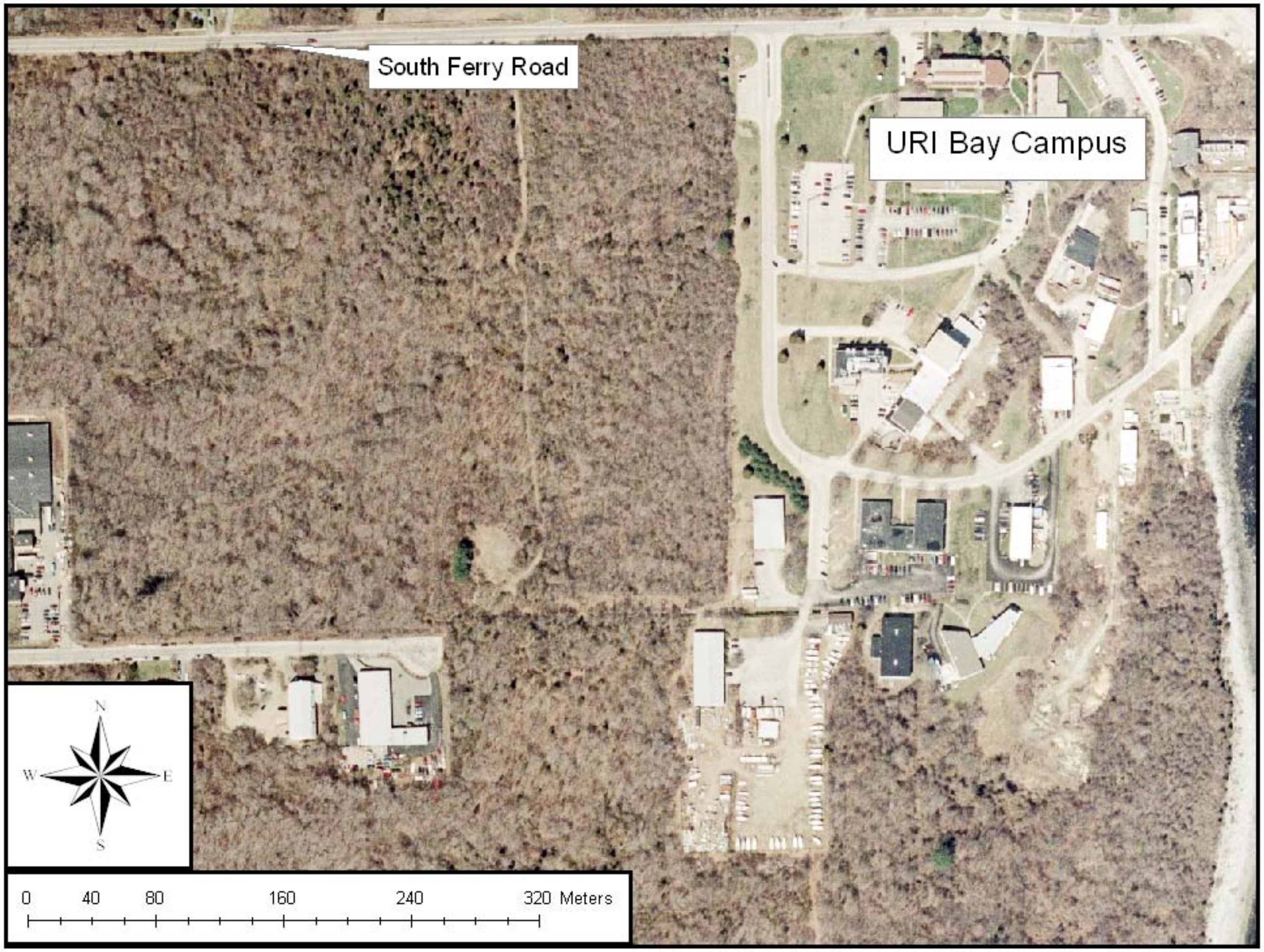
Overview

- Site Description and Selection
  - Land use, topography, and adequate space
- Characterize Demand on the Bay Campus
  - Yearly trends (2003-2008), and monthly trends
- Available Wind Data and Scaling
  - Pt. Judith (2005-2007), and WIS 79 model data(1980-1999)
- GE 1.5MW WTG
- Characterize Wind Power Production Potential
  - Annual production, monthly production, directionality
- Standards and Regulatory Environment
  - RI standards and international standards
  - Special use permitting, net-metering, environmental regulation
- Summary of Major Results
- Summary of Cost and Return

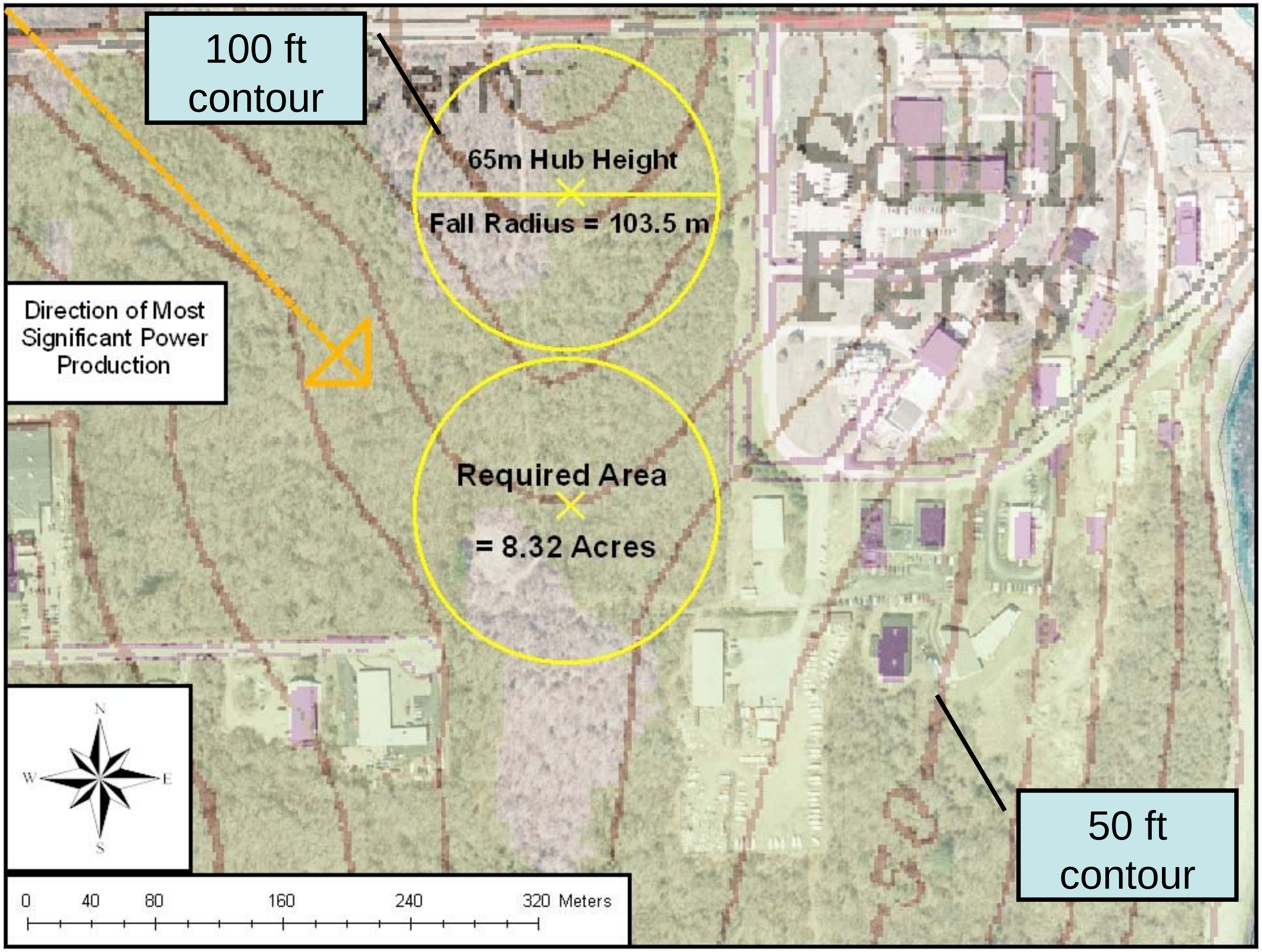
Lower Narragansett Bay and Points of Interest



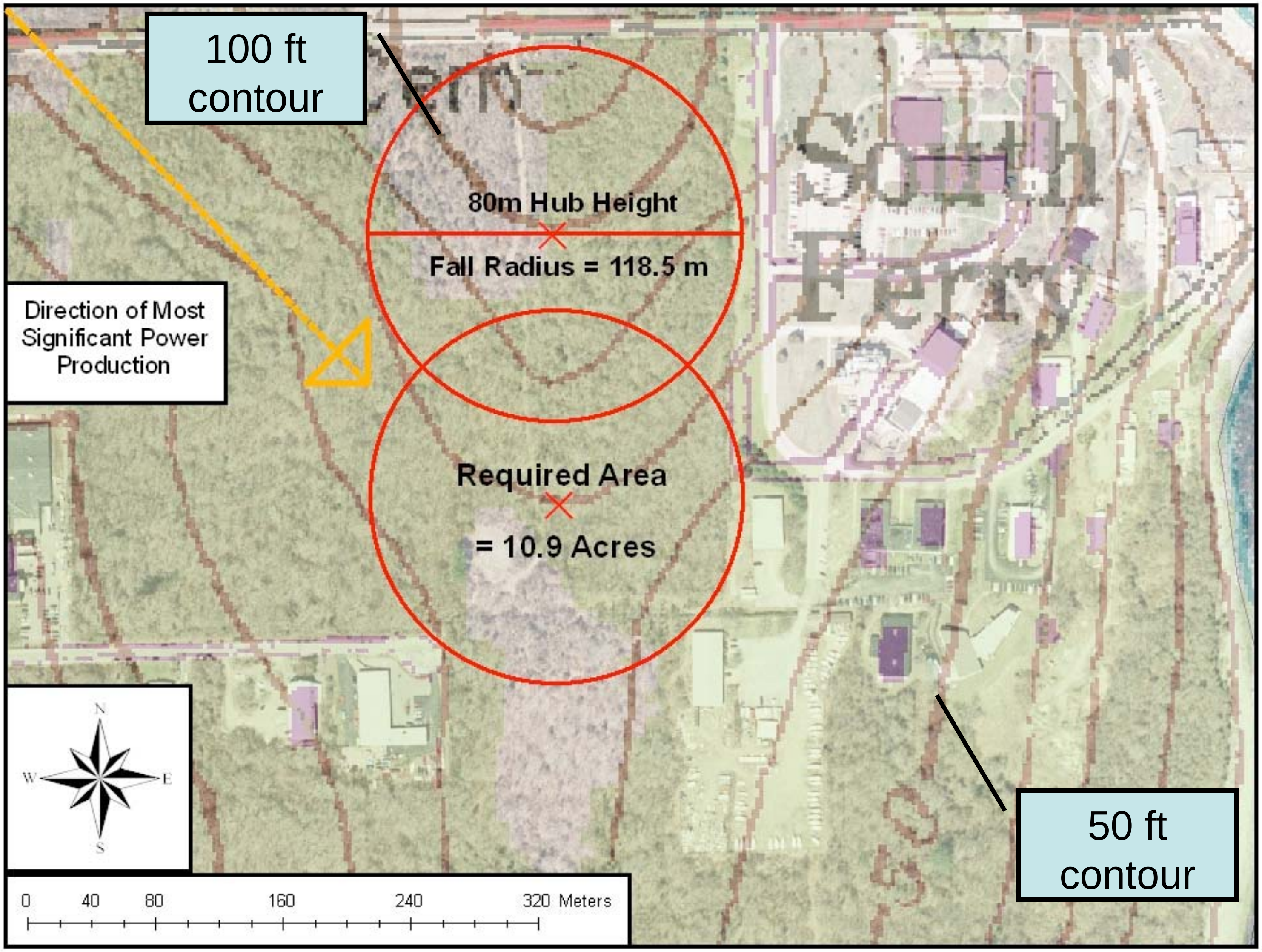
Site Description and Selection



Possible Locations for 65m Hub

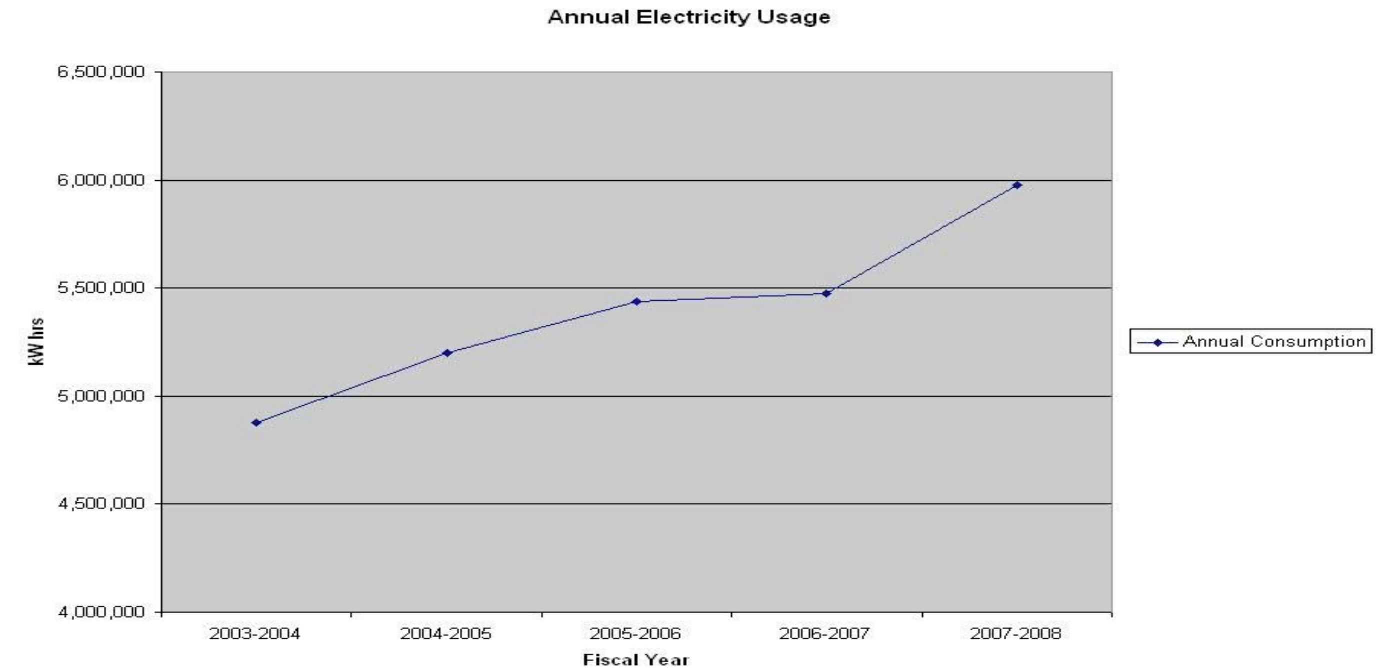


Possible Locations for 80m Hub

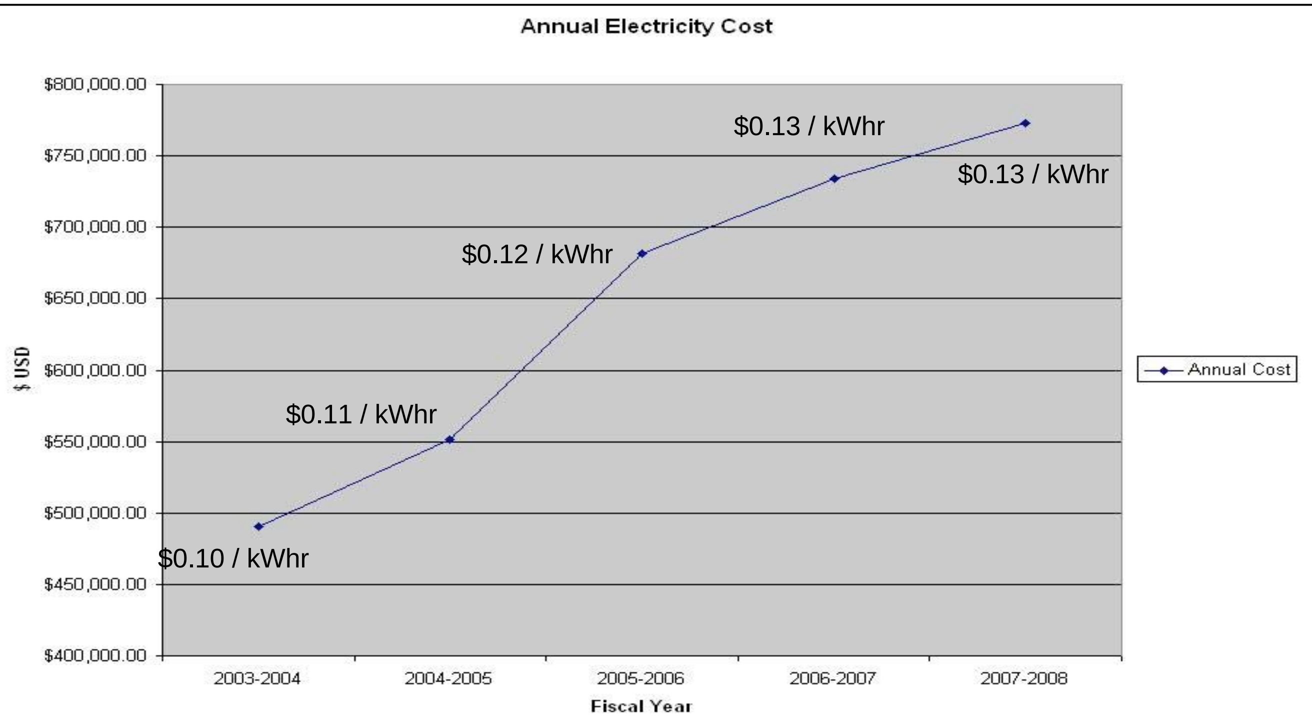


Characterization of Demand

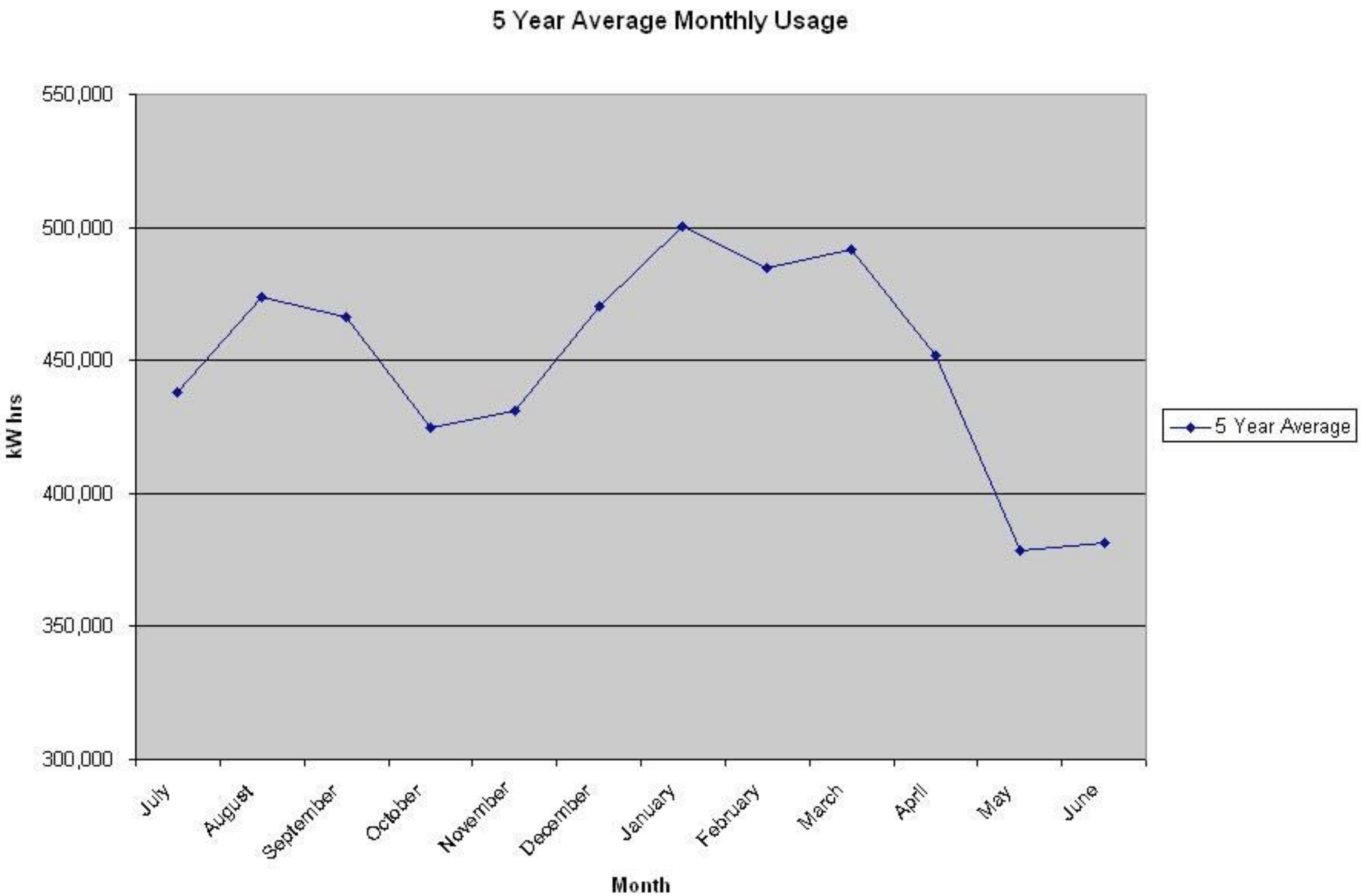
- 5 years of electricity data (2003 – 2008)
- Annual Power Usage
  - 4.88 e6 kWhrs (2003) - 5.97 e6 kWhrs (2008)
  - Increases annually
- Total Annual Cost of Electricity
  - $491k (2003) - $773k (2008)
  - Cost per kWhr and usage increases
- Monthly Variations in Power Usage
  - Greatest from December to March
  - Least in May and June



Annual Electricity Usage
6,500,000
6,000,000
5,500,000
5,000,000
4,500,000
4,000,000
kW hrs
2003-2004
2004-2005
2005-2006
2006-2007
2007-2008
Fiscal Year
Annual Consumption



Annual Electricity Cost
$800,000.00
$750,000.00
$700,000.00
$650,000.00
$600,000.00
$550,000.00
$500,000.00
$450,000.00
$400,000.00
$ USD
$0.10 / kWhr
$0.11 / kWhr
$0.12 / kWhr
$0.13 / kWhr
$0.13 / kWhr
2003-2004
2004-2005
2005-2006
2006-2007
2007-2008
Fiscal Year
Annual Cost



5 Year Average Monthly Usage
550,000
500,000
450,000
400,000
350,000
300,000
kW hrs
July
August
September
October
November
December
January
February
March
April
May
June
Month
5 Year Average

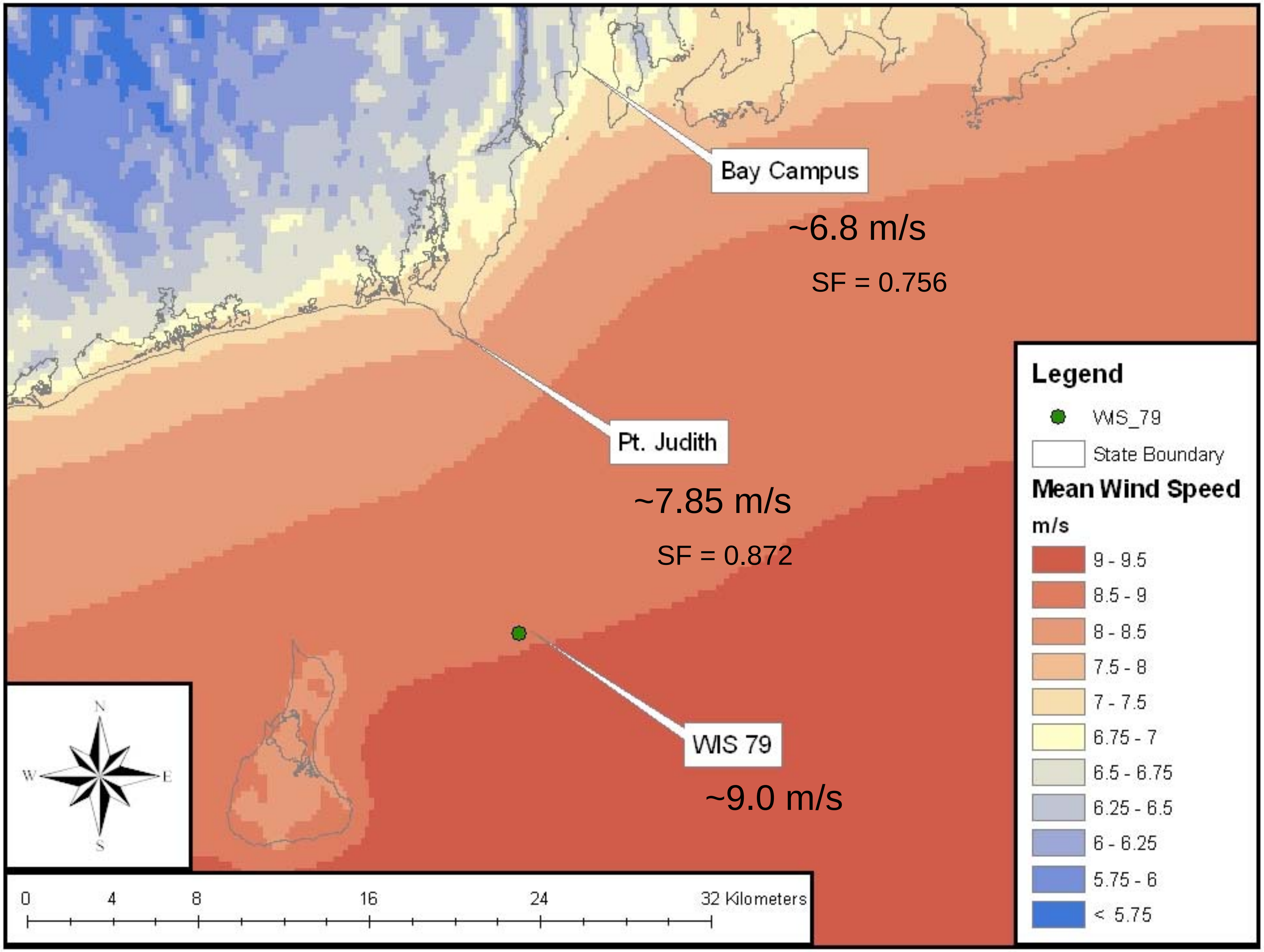
Selection of Wind Data and Scaling

- Limited Available Wind Data
  - AWS Truewinds (2006)
    - Mean Annual Wind Speed at 80m for all of RI and coastal ocean
  - Pt. Judith Lighthouse
    - 3 years of hourly mean wind speed at 22.5m elevation (2005-2007)
  - Army Corp WIS Station 79
    - 20 years of hourly mean wind speed at 10m elevation (1980-1999)

- Scale WIS Wind Speed Time History to Represent Site
- Assume Scale Factor Constant for All Wind Speeds
  - Method used by ATM (2007) for Portsmouth Assessment

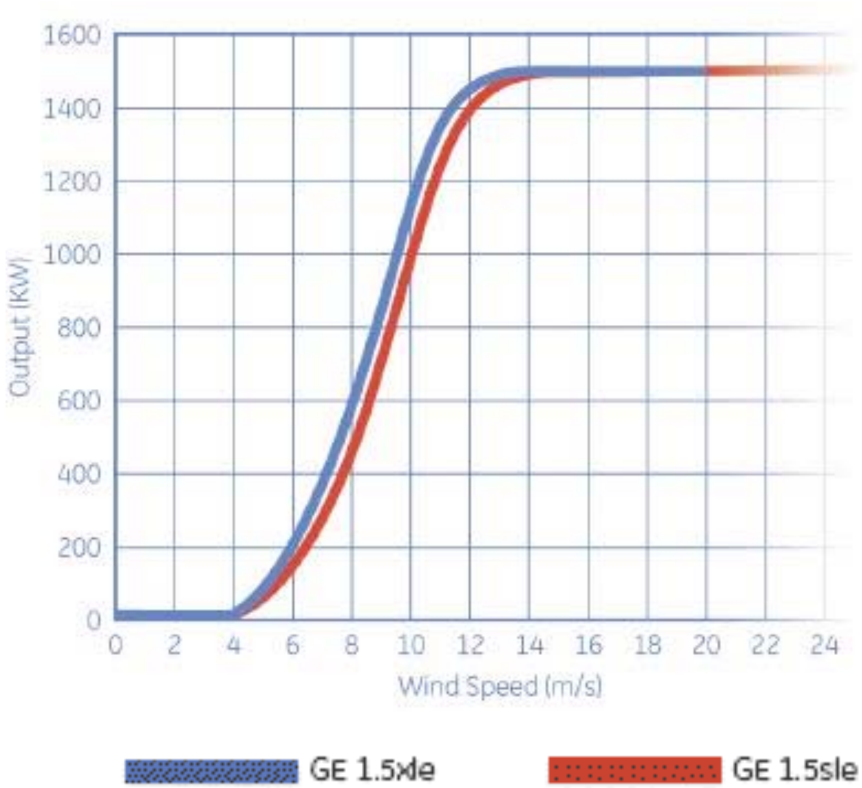
- Scale WIS Station 79 Data to Site
  - Scale Factor is the ratio of AWS mean annual wind speeds
  - Verify assumption with Pt. Judith wind data
    - Calculate mean annual wind speed of WIS and Pt. Judith data
    - Scale Factor from data is within 3% of AWS Scale Factor

Mean Annual Wind Speed at 80m derived from AWS TrueWinds



GE 1.5 MW Turbine

- Power Production Estimates Based on the GE 1.5sle Turbine



- Turbine swept area is 4657 m^2
- Cut-in Speed = 4 m/s
- Cut-out Speed = 25 m/s
- Rated Speed = 14 m/s

~GE 1.5MW Turbine Product Brochure

Annual Power Production at Bay Campus

Annual Power from Scaled WIS Station 79 Data Set @ 80m
where $\alpha = 0.143$ and $SF_{AWS} = 0.756$

Mean Wind Speed, U_{ave} (m/s)	Standard Deviation (m/s)	Power Density (W/m^2)	Wind Energy (kWhrs)	Turbine Energy (kWhrs)	Extracted resource
6.80	3.05	371.2	15.143 e6	4.217 e6	27.8 %

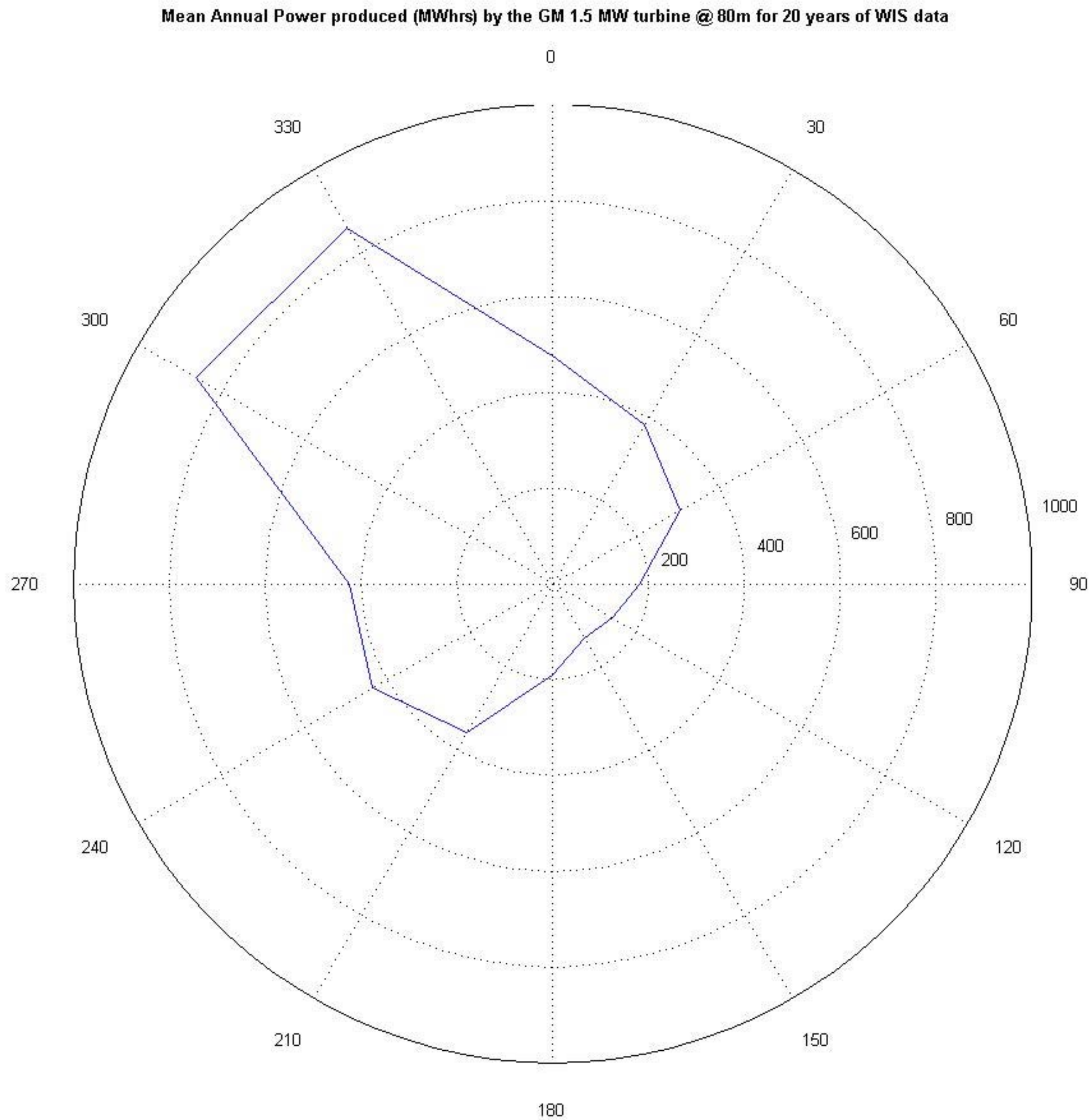
Varying α and Hub Height w/ $SF_{AWS} = 0.756$

$kWhrs_{turb}$	α=0.143 (Stable atm)	α=0.19 (AWS)
H = 65m	3.97 e6 kWhrs	4.70 e6 kWhrs
H = 80m	4.22 e6 kWhrs	5.04 e6 kWhrs

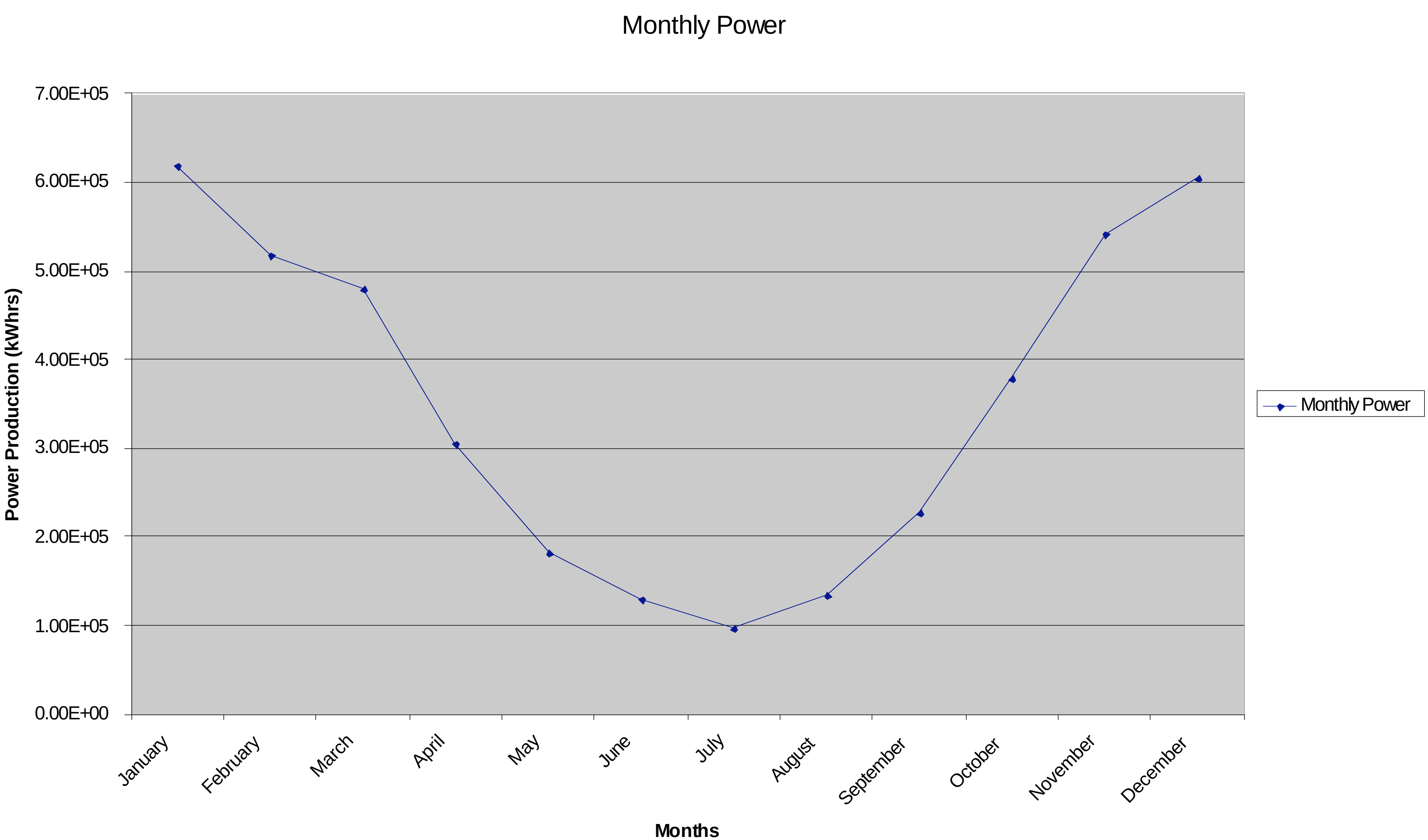
Varying Scale Factors @ 80m w/ $\alpha = 0.143$

SF	U_{ave} (m/s)	Data Set Energy (kWhrs)
0.72	6.403	3.936 e6
0.74	6.581	4.181 e6
0.76	6.759	4.431 e6

1.5 MW GE Directional Power Production



Estimated Monthly Power Production



Monthly Mean Wind Speeds and Power Production

- Hub Height = 80m, SF = 0.756, and α=0.143

Month	Mean Wind Speed U_{ave} (m/s)	Standard Dev. (m/s)	Power Density (W/m^2)	Available Resource in Swept Area (kWhrs)	Data Set Turbine Power (kWhrs)	Extracted Resource (%)
Jan	9.23	3.62	59.40	2.42 e6	6.19 e5	25.5
Feb	8.75	3.61	47.91	1.95 e6	5.18 e5	26.5
Mar	7.95	3.64	42.83	1.75 e6	4.8 e5	27.5
Apr	6.44	3.25	24.47	1.00 e6	3.05 e5	30.6
May	5.12	2.70	13.22	5.39 e5	1.82 e5	33.8
Jun	4.75	2.33	9.48	3.87 e5	1.3 e5	33.6
Jul	4.44	2.08	7.76	3.16 e5	0.97 e5	30.8
Aug	4.82	2.32	10.27	4.19 e5	1.34 e5	32
Sep	5.85	2.75	17.25	7.04 e5	2.28 e5	32.4
Oct	7.10	3.13	29.88	1.22 e6	3.78 e5	31
Nov	8.69	3.46	48.73	1.99 e6	5.42 e5	27.3
Dec	9.16	3.71	60.01	2.45 e6	6.04 e5	24.7

Standards and Regulatory Environment

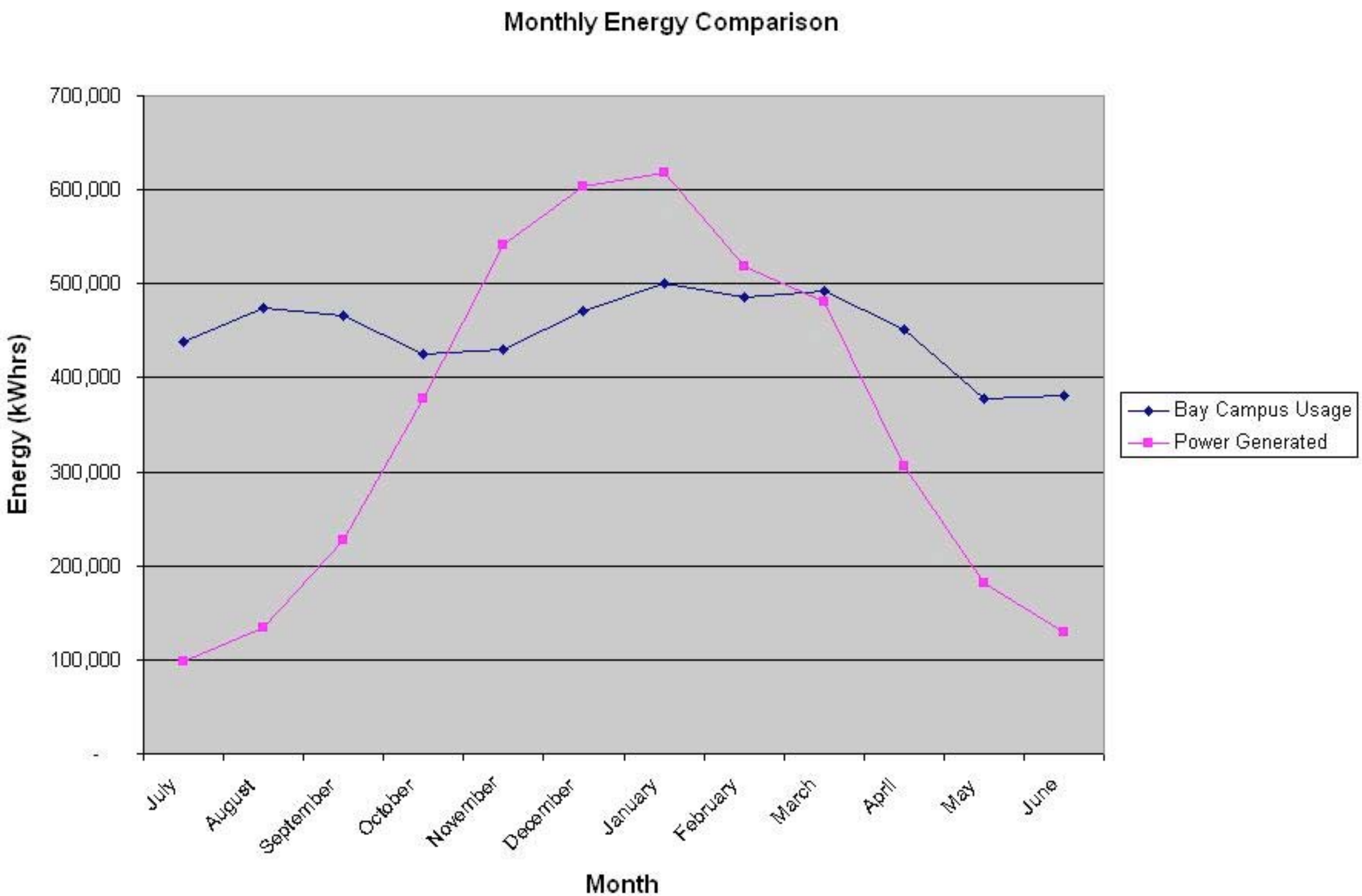
- AWEA suggests IEC international standard
  - Compatibility with foreign market for turbine selection
- Rhode Island Standard Building Codes
  - International Building Code 2006 (SBC-3)
  - National Electric Code (NEC) (SBC-5)
- Special Use Permits
  - A permit must be filed with the town of Narragansett
  - Subjective criteria is reviewed by the zoning board
    - Access, Safety, Noise, Health, Compatibility with surrounding environment, etc…
- Net-Metering Legislation
  - Actively being changed yearly to best suit project development
  - Recently municipalities given consideration
  - State facilities likely to soon be granted consideration
    - South County Wind Energy Forum (URI Energy Center)
- Environmental Assessment and Permitting through DEM

Summary of Major Results

- Comparison of Portsmouth Project to Bay Campus Project

	Mean Annual Wind Speed (m/s)	Annual Power Demand (kWhrs/year)	Power Produced by Turbine (kWhrs/year)	% Energy Used on Site
Portsmouth High	6.74	954,000	3,719,000	25%
Bay Campus	6.80	5,960,000	4,220,000	100%

- Percentage of campus energy generated
  - 70 - 84 % campus usage produced by wind turbine for 2008
- Greatest power generated at max. demand from November – March
  - Demand and Production ≈ 500k-600k (kWhrs)
- Expected useful life of turbine is 20 years


Monthly Energy Comparison
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
Energy (kWhrs)
July
August
September
October
November
December
January
February
March
April
May
June
Month
Bay Campus Usage
Power Generated

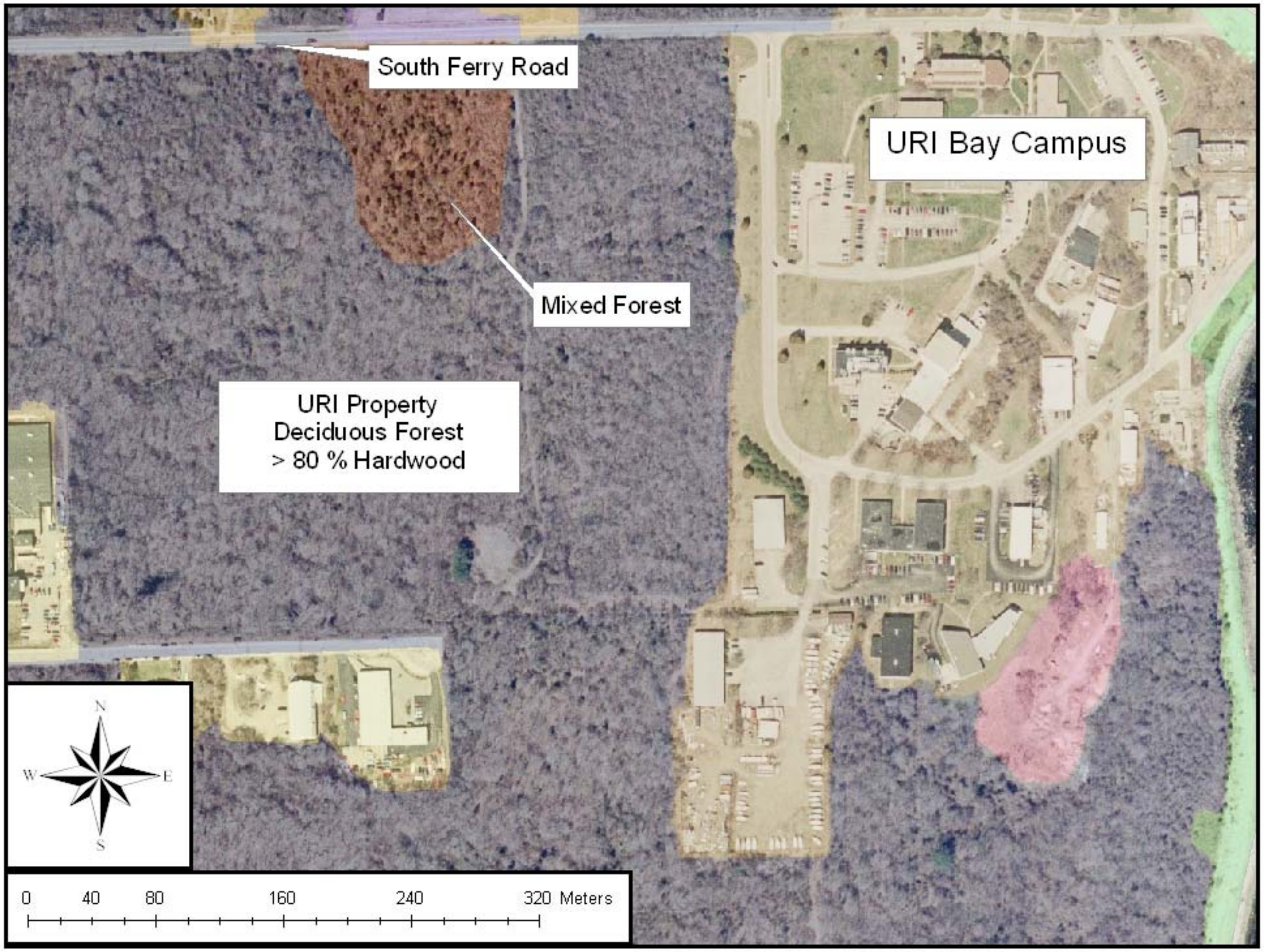
Summary of Cost and Return

- Potential Annual Electricity Savings
  - Behind meter savings from electricity
    - 4.22 e6 kWhrs * 0.13 $/kWhr ≈ $550,000 per year
  - Expected grid sale price
    - 4.22 e6 kWhrs * 0.0776 $/kWhr ≈ $325,000 per year
- Approximate Capital Cost
  - Portsmouth High 1.5 MW installment
    - Estimated at $3.23 Million (ATM 2007)
    - $2.9 Million actual cost
- Estimated Operation and Maintenance Costs
  - O&M ≈ $68k per year (ATM 2007)
- Clean Renewable Energy Bonds (CREB)
  - Tax credit bond that is equivalent to interest free loan
  - Portsmouth Financed in this manner
  - Qualified projects have pay-back period approximately 12 years
- Bay Campus Break-Even Point
  - Behind meter pay back period
    - Approximately 6 - 7 years
  - In front of the meter
    - Approximately 12 years

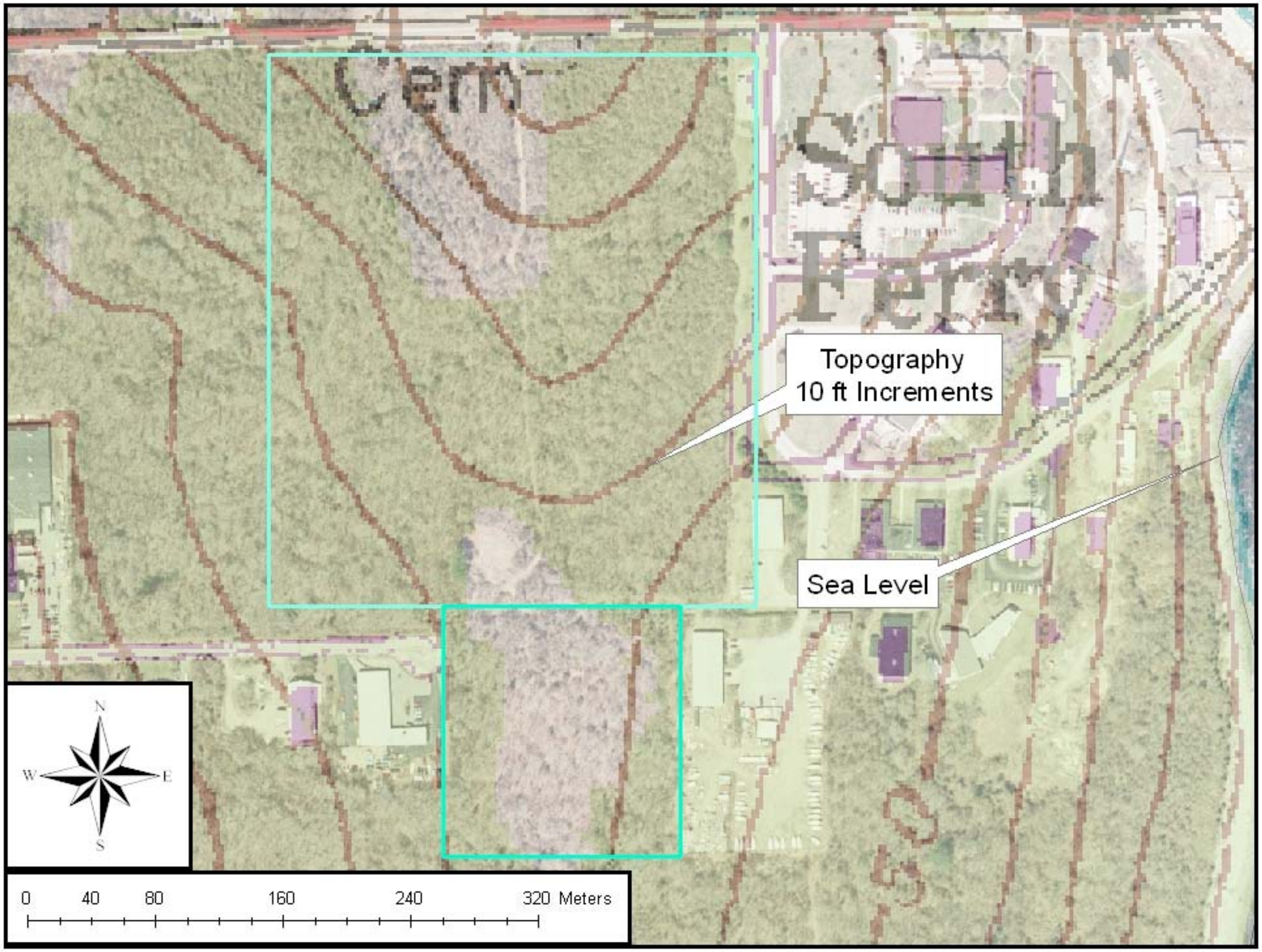
Questions?

Extra Slides

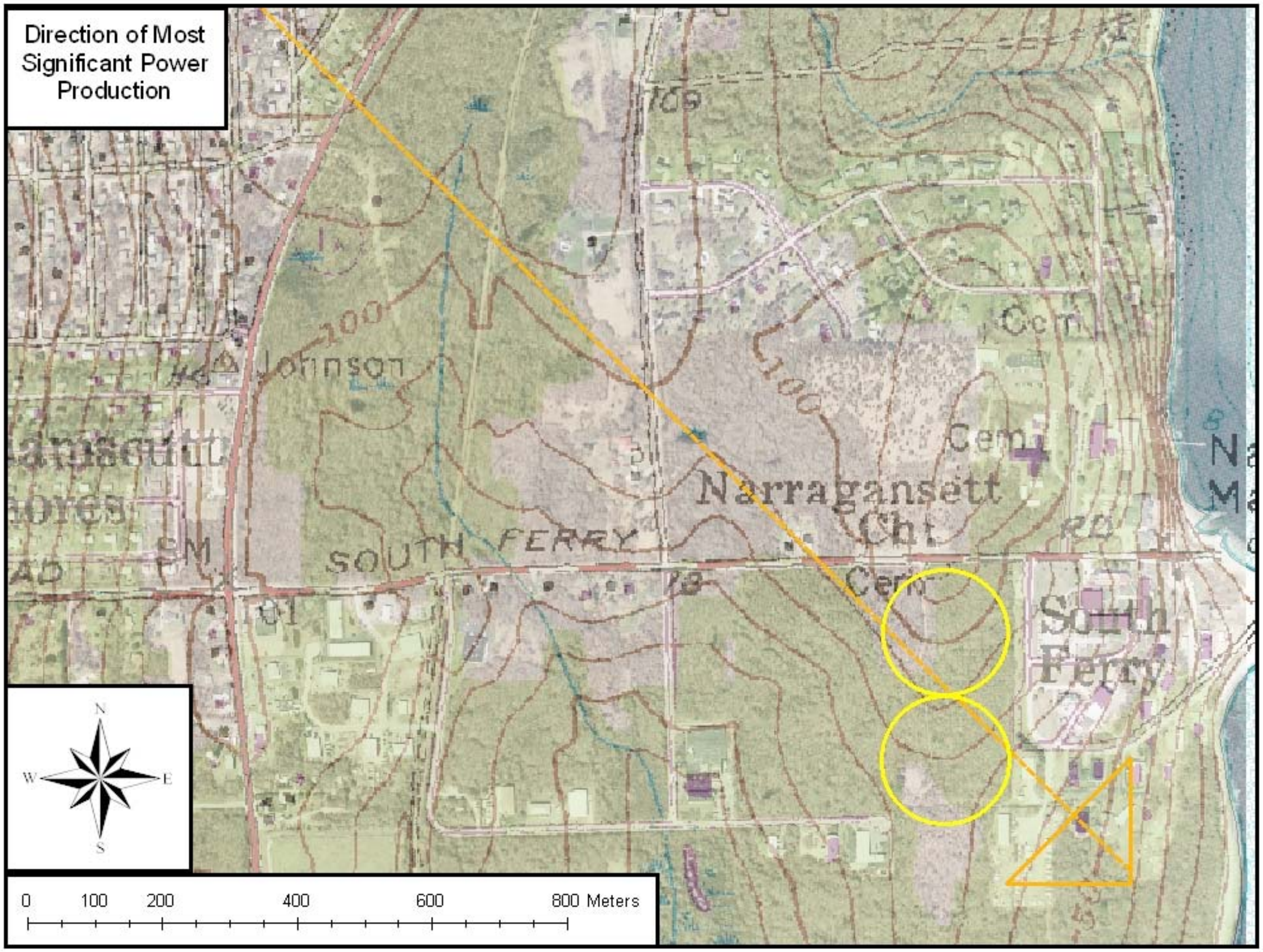
Land Use and Description

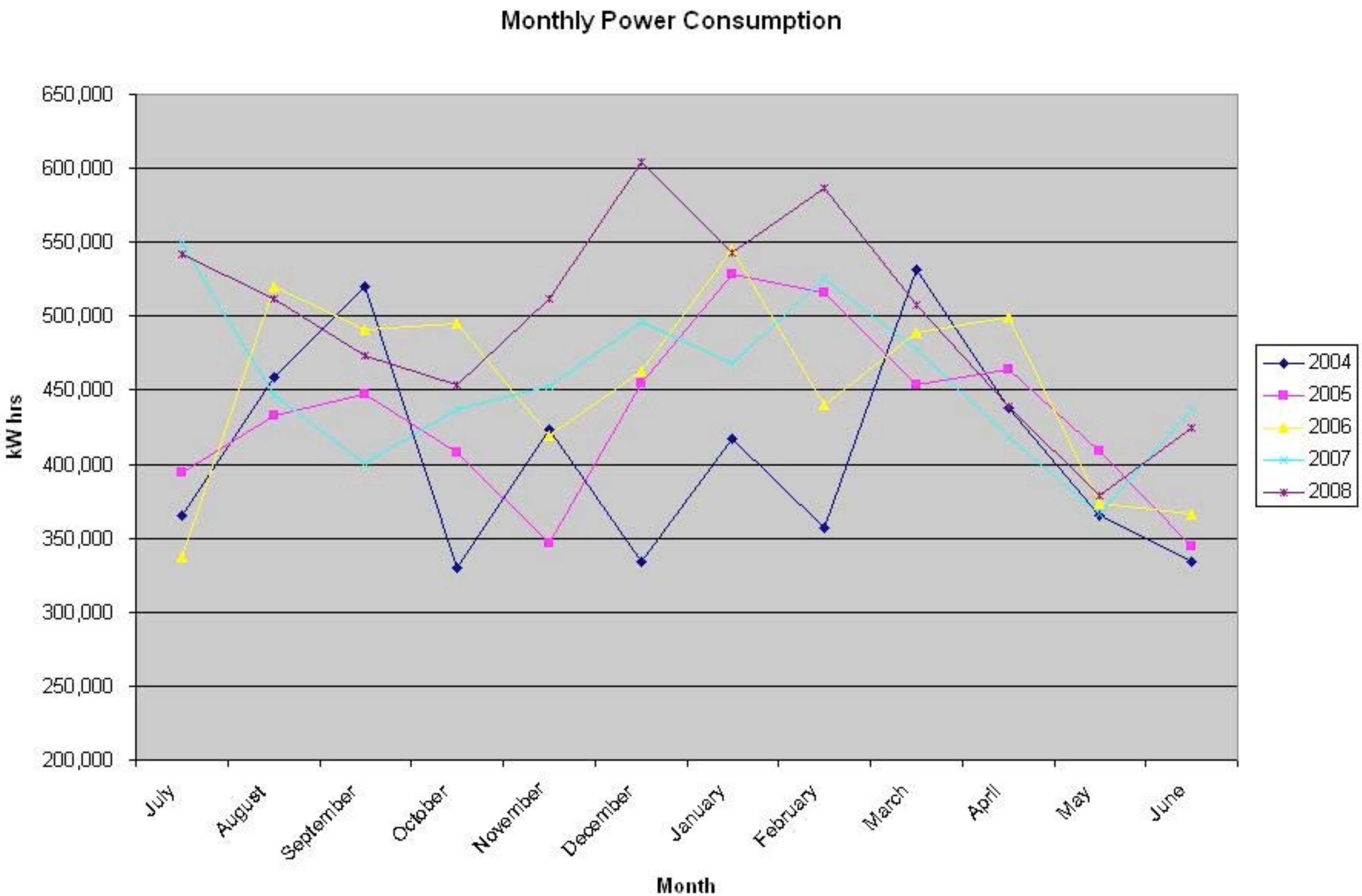


Possible Area and Topography

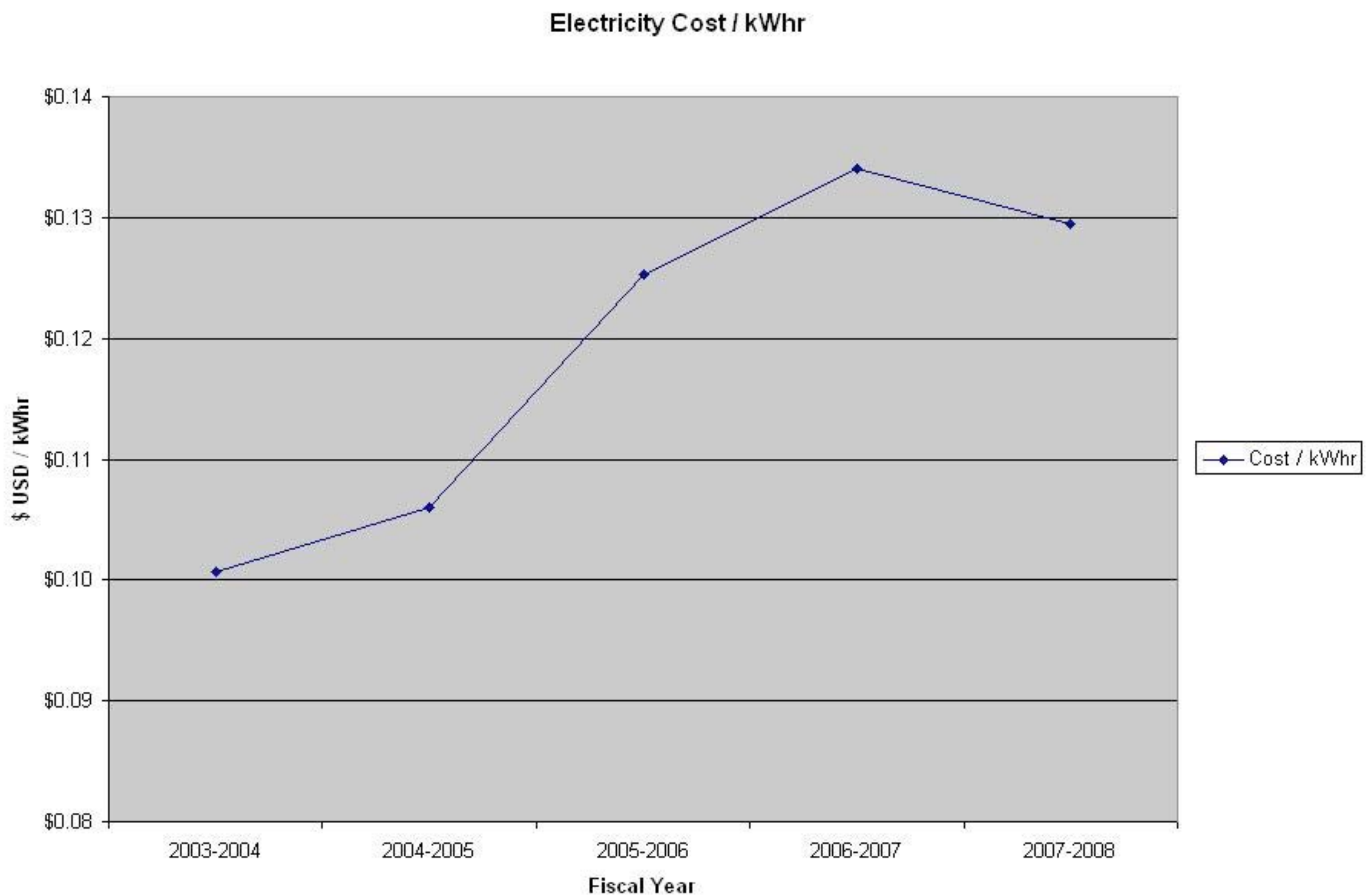


Local Topography and Obstructions





Monthly Power Consumption
650,000
600,000
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
kW hrs
July
August
September
October
November
December
January
February
March
April
May
June
Month
2004
2005
2006
2007
2008


Electricity Cost / kWhr
$0.14
$0.13
$0.12
$0.11
$0.10
$0.09
$0.08
$ USD / kWhr
2003-2004
2004-2005
2005-2006
2006-2007
2007-2008
Fiscal Year
Cost / kWhr

Assessing Appropriate Scaling Factor

	Data U_{ave} @ 10m	Data U_{ave} @ 80m	AWS $U_{ave\ @}$ 80 m
WIS	6.73	8.89	9
PT Judith	5.7	7.54	7.85
Bay Campus			6.802

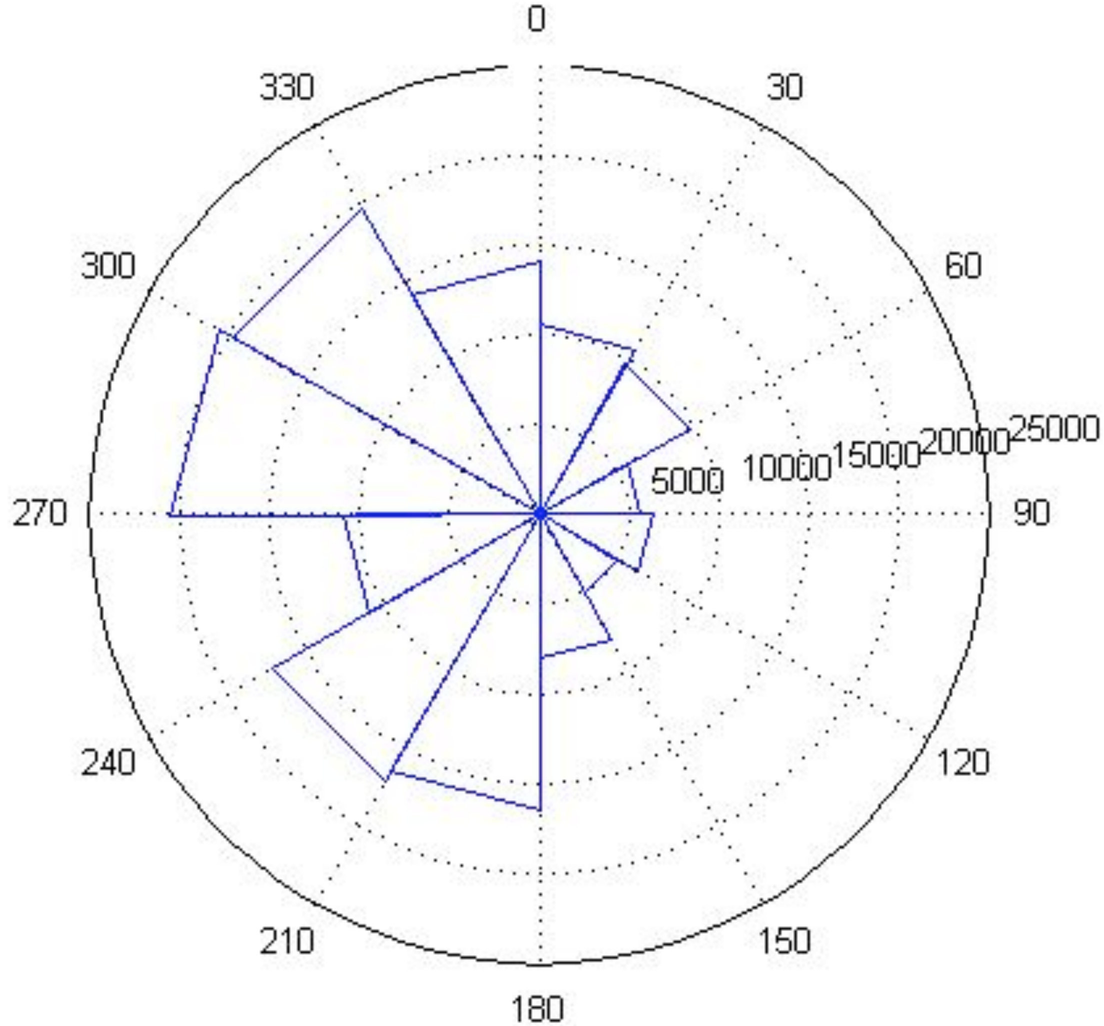
- SF from WIS data to Pt. Judith data is 0.848 and 0.872 from AWS Data
  - Factors are within approximately 3%
  - 3 Years of data is not sufficient to suggest AWS not appropriate

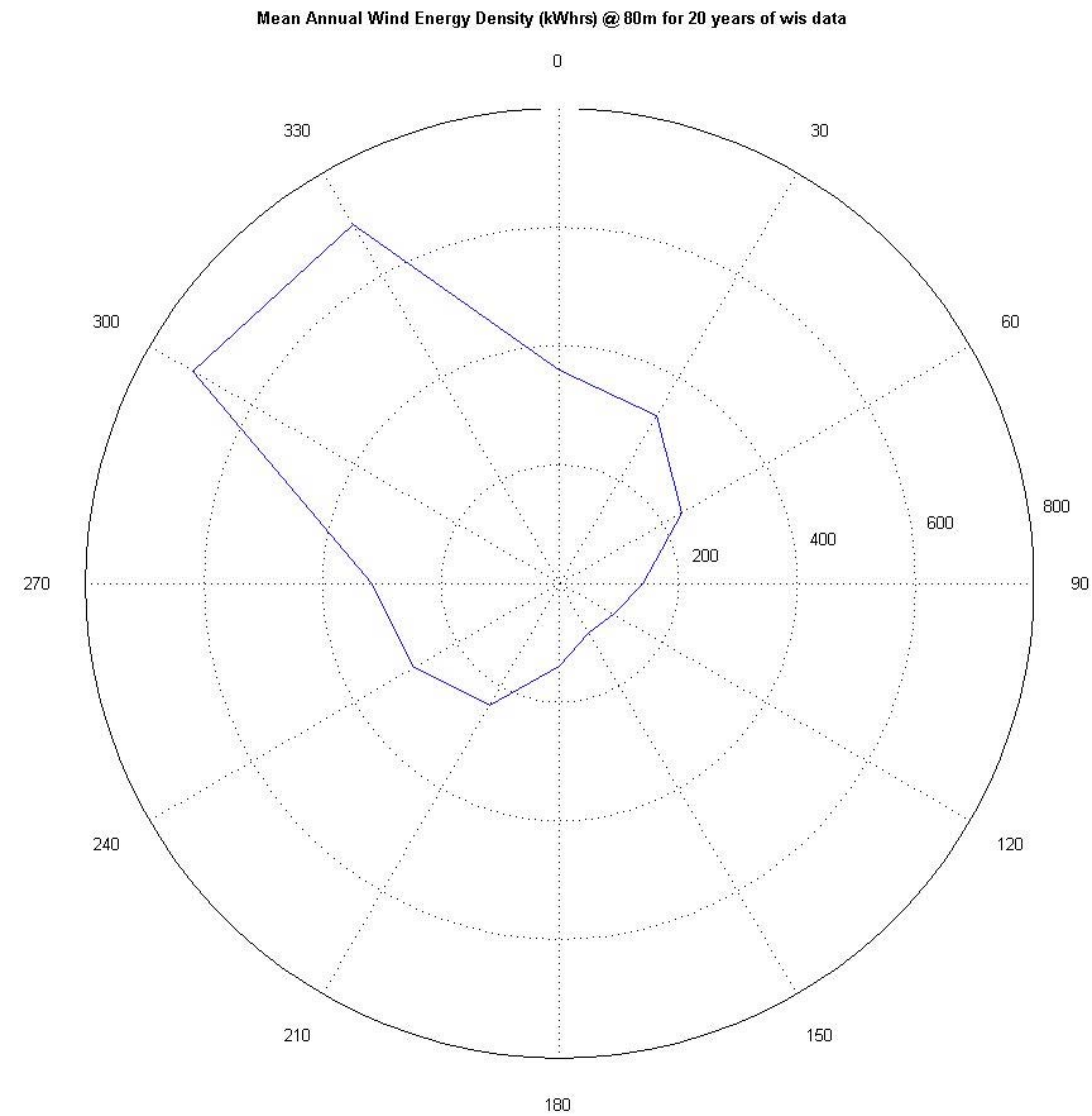
- Scaling Factor for wind speeds @ 80m transformed to Site from AWS
  - Suggested SF_{AWS} = 0.756

Estimated Annual Power Production Potential

- Mean Annual Wind Speed and Standard Deviation
- Mean Annual Power Density
  - Available Resource
- Power Production of GE 1.5MW turbine
  - % resource extracted
- Variations of Alpha Coefficient and Hub Heights
  - Conservative stable atmosphere $\alpha=0.143$, AWS estimate $\alpha\approx0.19$
- Sensitivity to Scaling Factors
- Directional Variations
  - Turbine Output Power

Frequency of Direction for 20 Years (1980-1999) of WIS79 Data




Mean Annual Wind Energy Density (kWhrs) @ 80m for 20 years of wis data
0
30
60
90
120
150
180
210
240
270
300
330
200
400
600
800

Monthly and Seasonal Variations in the Wind Resource

- Hub Height = 80m, SF = 0.756, and α=0.143
  - Monthly Mean Wind Speeds
  - Standard Deviation
  - Monthly Mean Energy Density
- Directional and Seasonal Variations

  Winter: Dec-Feb,

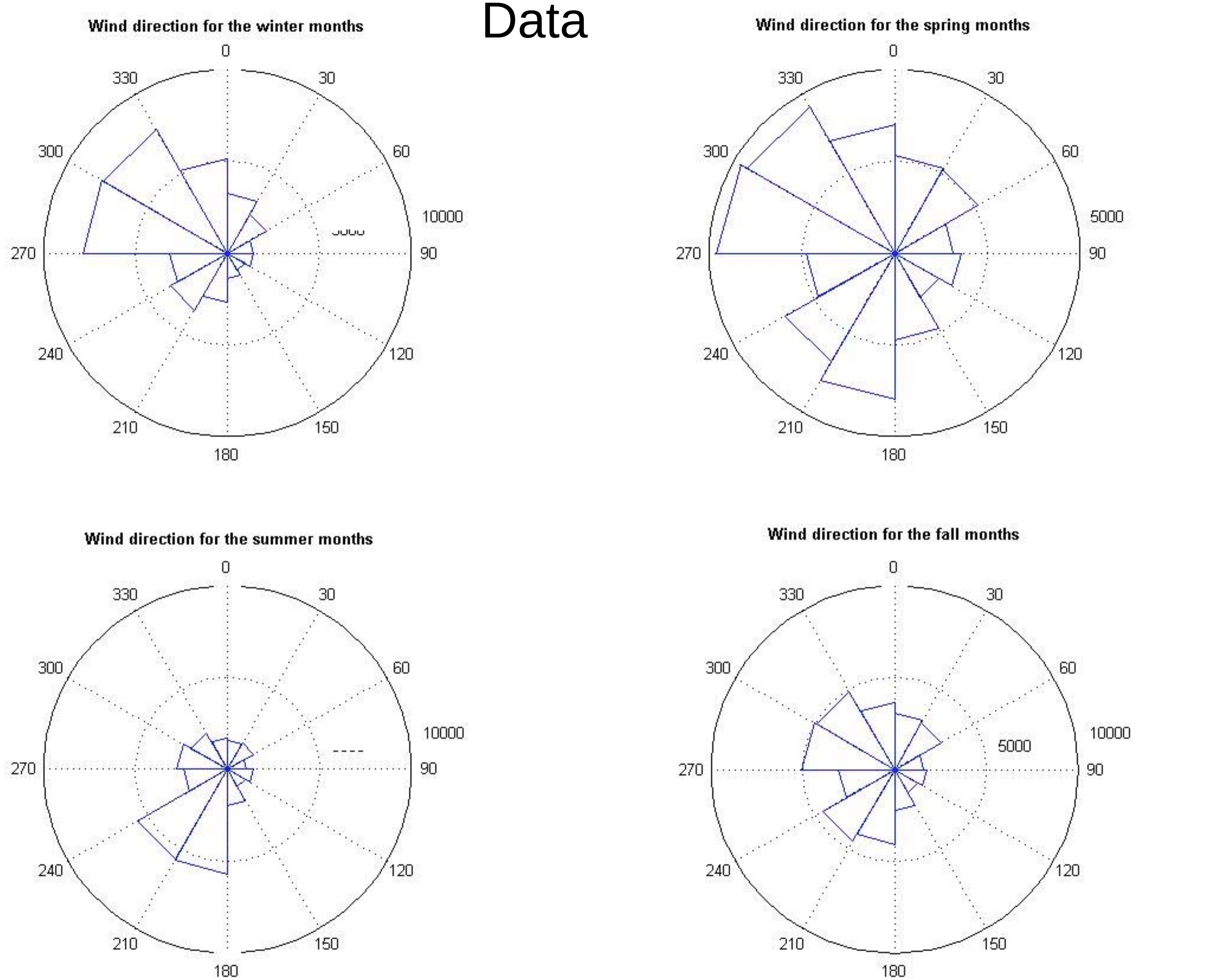
  Spring: Mar-May,

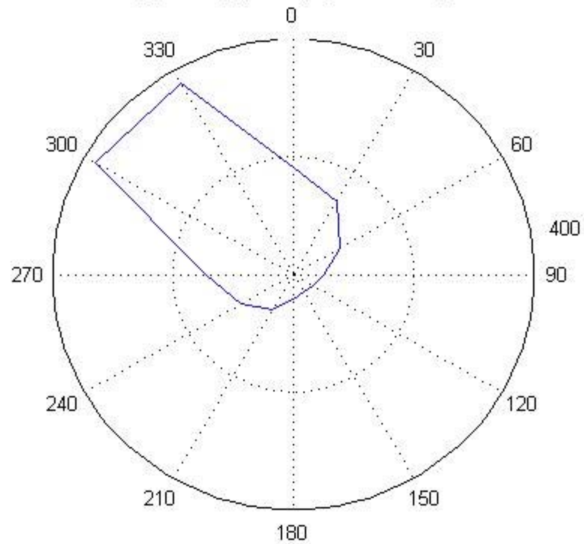
  Summer: Jun-Jul,

  Fall: Aug-Nov

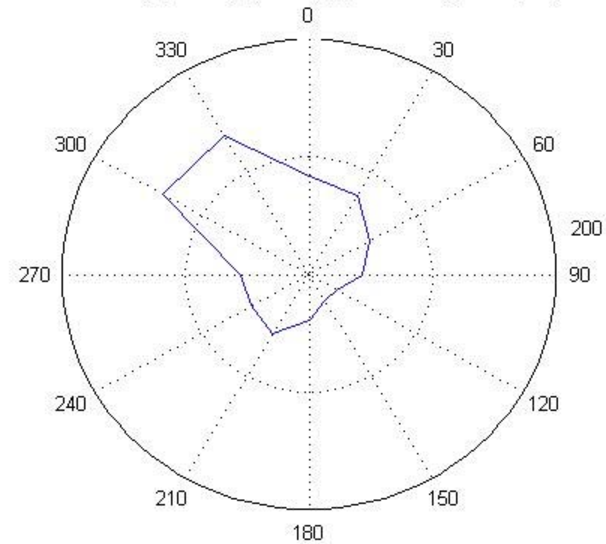
  - Turbine Output Power

Frequency of Directions for 20 years (1980-1999) of WIS79 Data

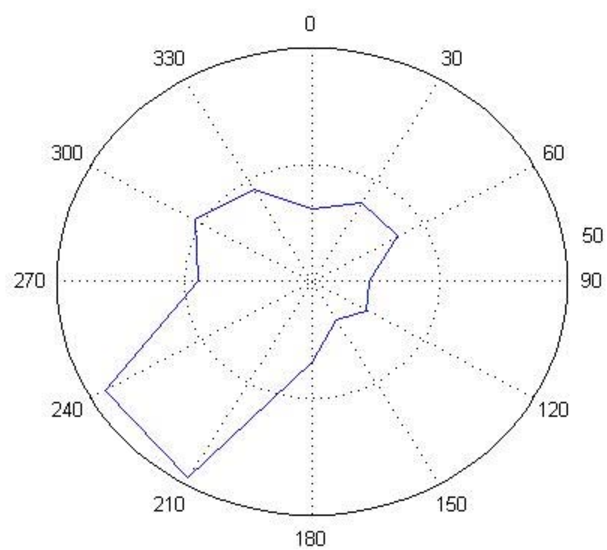




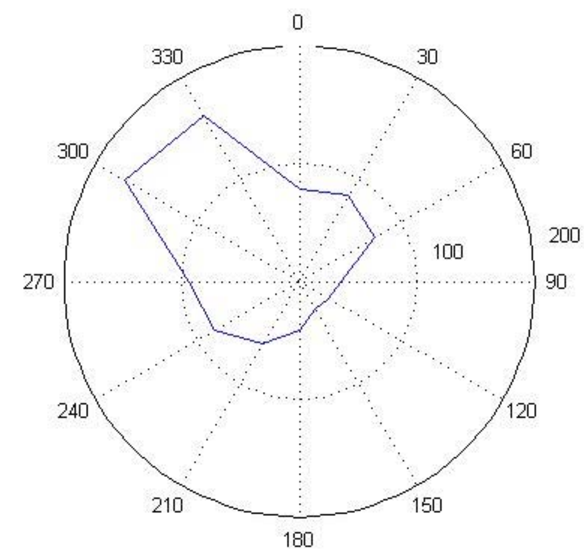
Annual Wind Energy Density (kWhrs) @ 80m during the winter months



Annual Wind Energy Density (kWhrs) @ 80m during the spring months



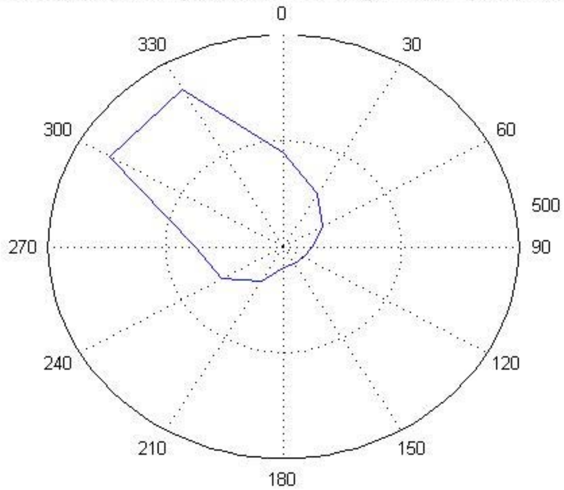
Annual Wind Energy Density (kWhrs) @ 80m during the summer months



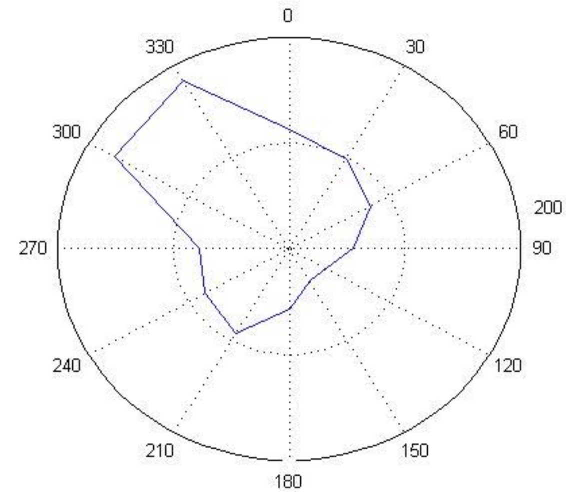
Annual Wind Energy Density (kWhrs) @ 80m during the fall months

Directional and Seasonal Variations

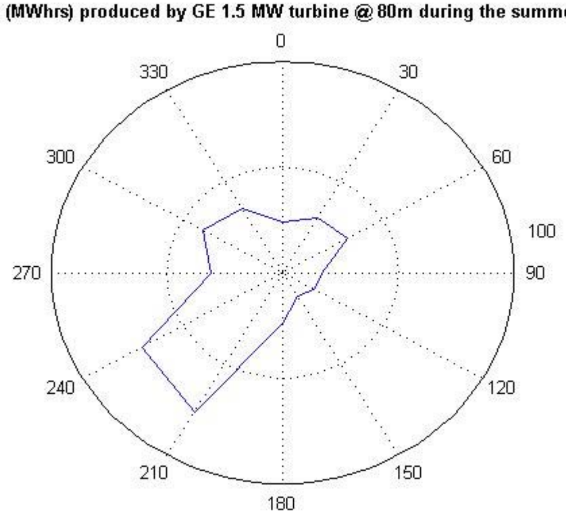
Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the winter months annually



Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the spring months annually



Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the summer months annually



Directional Power (MWhrs) produced by GE 1.5 MW turbine @ 80m during the fall months annually