



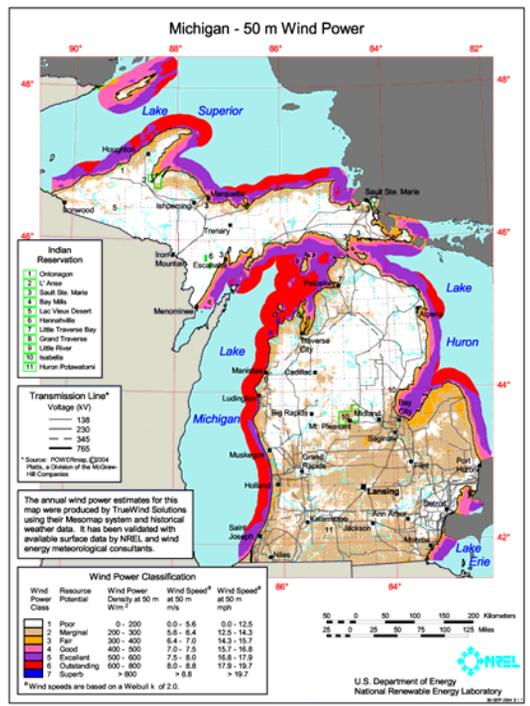
# Michigan Wind Resources

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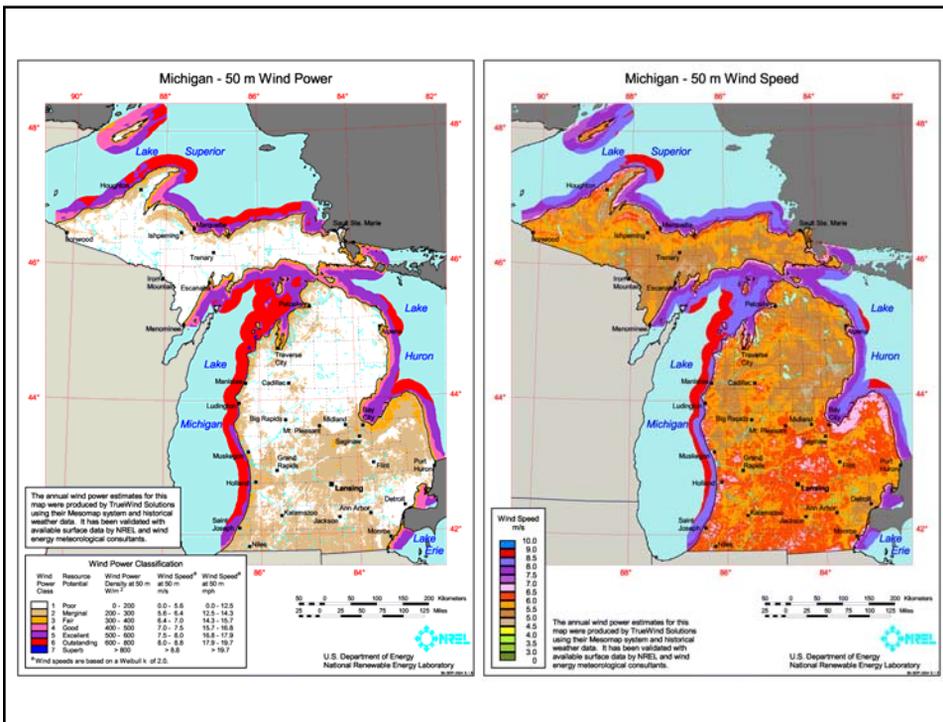
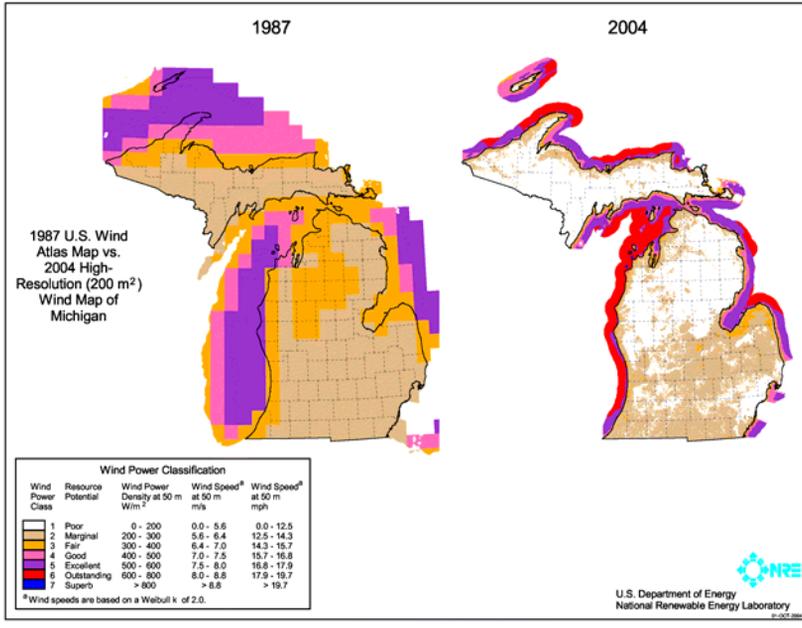
Michigan Wind Working Group Meeting  
Lansing, Michigan  
October 5, 2004

## 2004 Michigan Wind Power Map

- Preliminary map produced by AWS Truewind
- Preliminary maps of annual average 50-m wind power and wind speed validated by NREL and wind energy consultants
- Final maps produced by AWS Truewind with approval by NREL



# “Old” vs. “New” Michigan Wind Maps





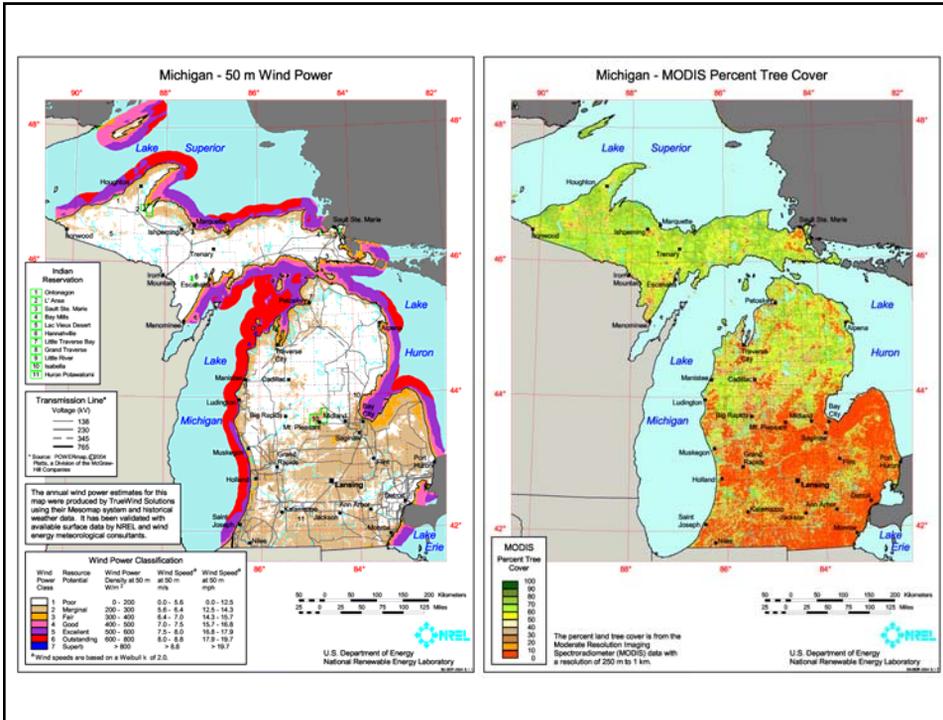
## High-Resolution Wind Mapping Approach

- Produces 200 m resolution wind resource maps
- AWS Truwind uses a numerical weather model with climatic data and wind flow model to produce the preliminary maps
- Does not depend on high-quality surface wind data
- Maps designed for regional wind mapping and not micrositing
- Preliminary maps of 50-m annual average wind resource validated by NREL and meteorological consultants
- Final maps developed based on revision of preliminary maps from validation results



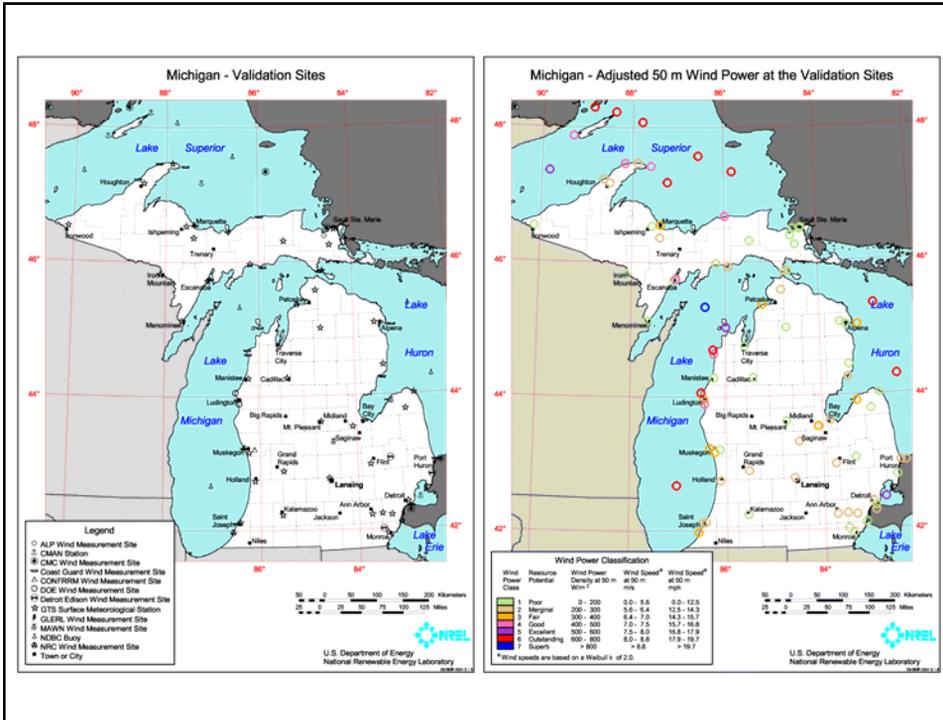
## Validation Process

- NREL produced a spreadsheet used in the validation processed
  - Each measurement location
    - Site coordinates and elevation
    - Measurement heights and period of record
    - Measured speed and power
    - Adjusted speed and power to map height
    - Map estimates for speed and power
    - Qualitative comments
- NREL & AWS Truwind review validation results
- AWS Truwind adjusted preliminary maps based on quantitative and qualitative inputs



## NREL's Michigan Validation

- Over 90 measurement stations used for validation
  - 57 GTS NOAA National Climatic Data Center (35 Airport, 2 Non-Airport, 20 Coast Guard)
  - 11 NOAA National Data Buoy Center (4 Coastal Marine Automated Network, 7 Buoy)
  - 2 NOAA Great Lakes Environmental Research Laboratory
  - 4 DOE/NREL (2 Candidate Site, 1 CONFRRM, 1 ALP)
  - 2 Nuclear Regulatory Commission
  - 3 Detroit Edison
  - 2 Michigan Agricultural Weather Network
  - 5 GTS Canadian Meteorological Centre
  - 7 Proprietary
- Accuracy comparable to other updated state maps
  - Within 10% of annual speed and 20% of annual power at 80+% of individual sites



## Quantifying Available Windy Lands and Electric Potential by DOE/NREL (2004)

- Class 4 and higher resource areas (good-to-excellent for utility-scale applications) used as base for available windy lands
- Environmental Exclusions
- Land-use Exclusions
- Other Factors



## Environmental Exclusions

- 100% Exclusions
  - National Park Service, Fish and Wildlife Service
  - Wildlife, Wilderness, and Recreation Areas on federal land of any designation (predominately Forest Service lands)
  - State and private environmental lands (from the Michigan GAP data)
- 50% Exclusions
  - Remaining U.S. Forest Service and DOD lands



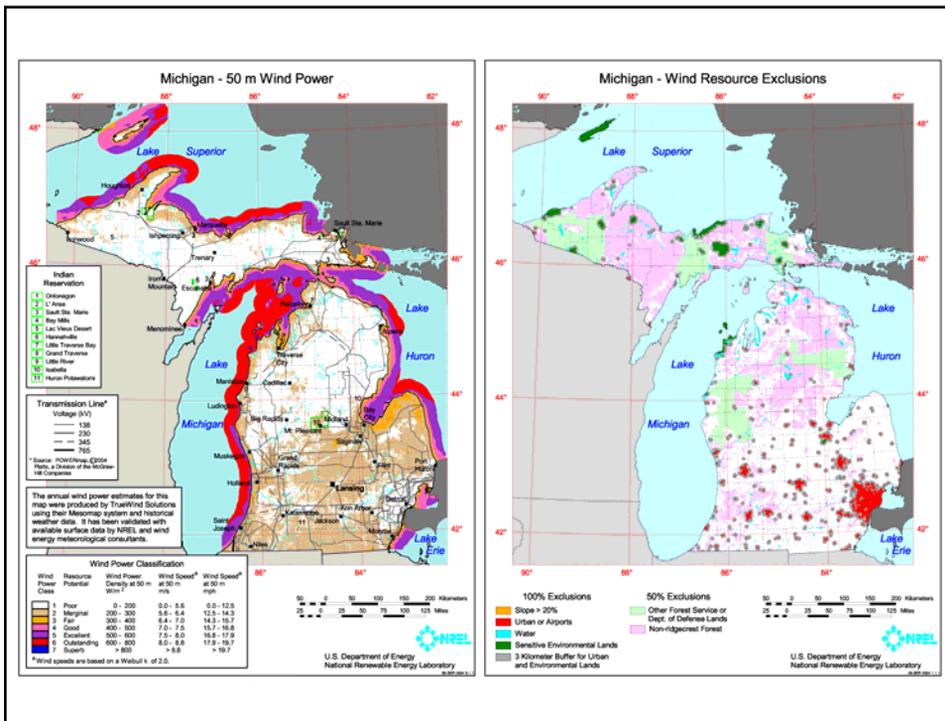
## Land-Use Exclusions

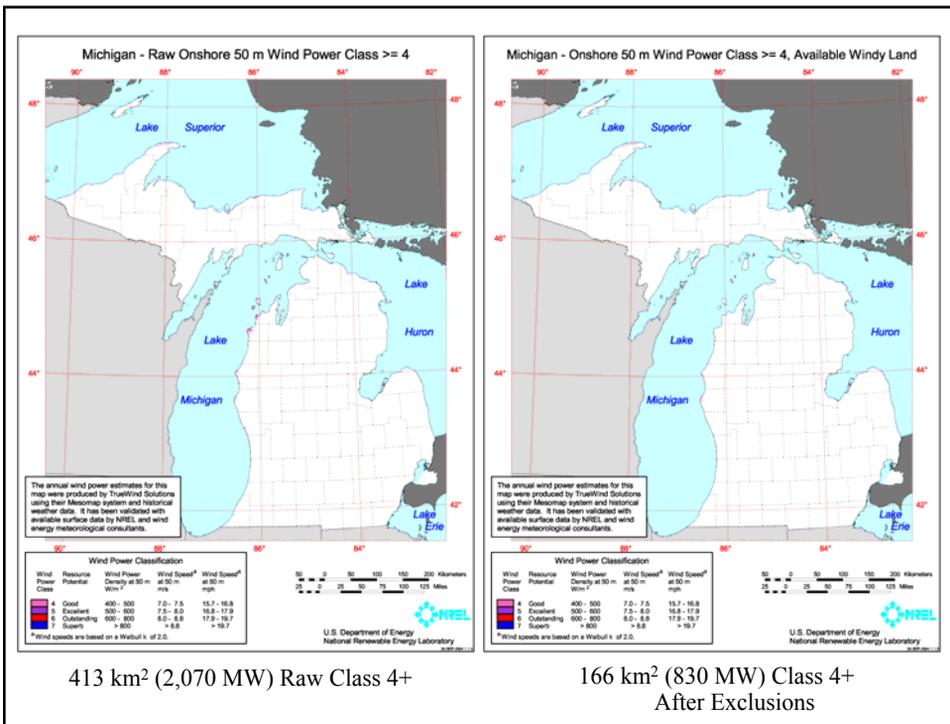
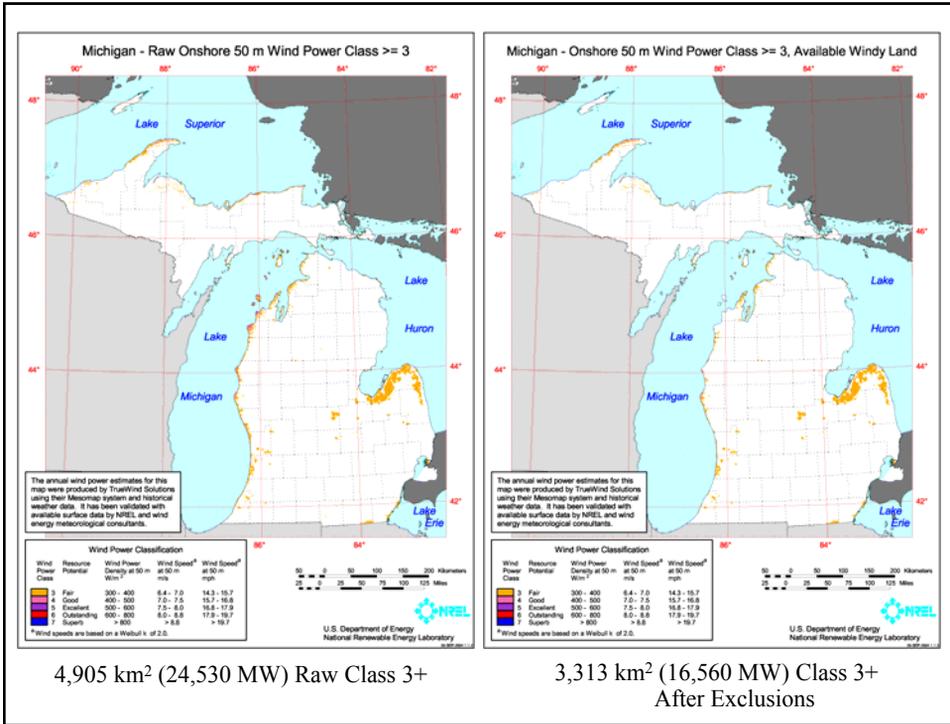
- 100% Exclusions
  - Urban areas and airports
  - Wetlands
  - Water bodies
- 50% Exclusions
  - Non ridge crest forest
- 0% Exclusions
  - Ridge crest forest
  - Agriculture lands



## Additional Windy Land Factors

- Slope Exclusions
  - Slopes greater than 20% excluded
- 3 km buffer around airports and the 100% exclusion areas, except for water bodies
- Windy grid cell contiguity/density factor
- New methodology slightly less restrictive than used in 1991-93
- Distance from transmission lines not included in windy land calculations
- Windy land → electric potential
  - Direct conversion from sq. km to potential installed capacity- 5 MW per km<sup>2</sup> of available windy land

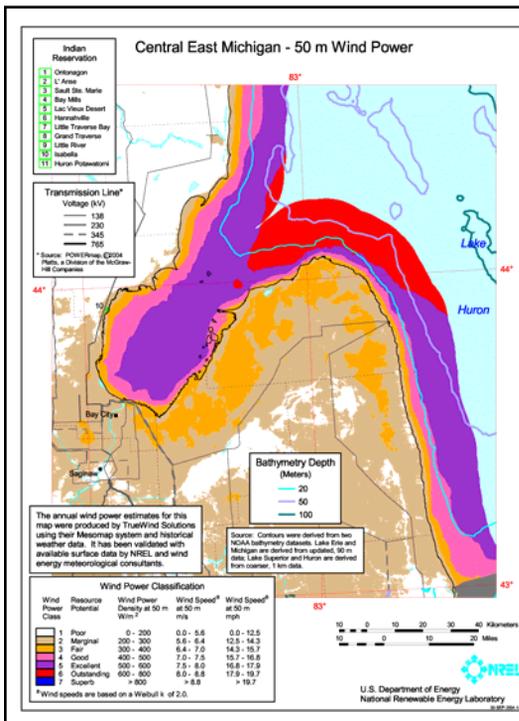






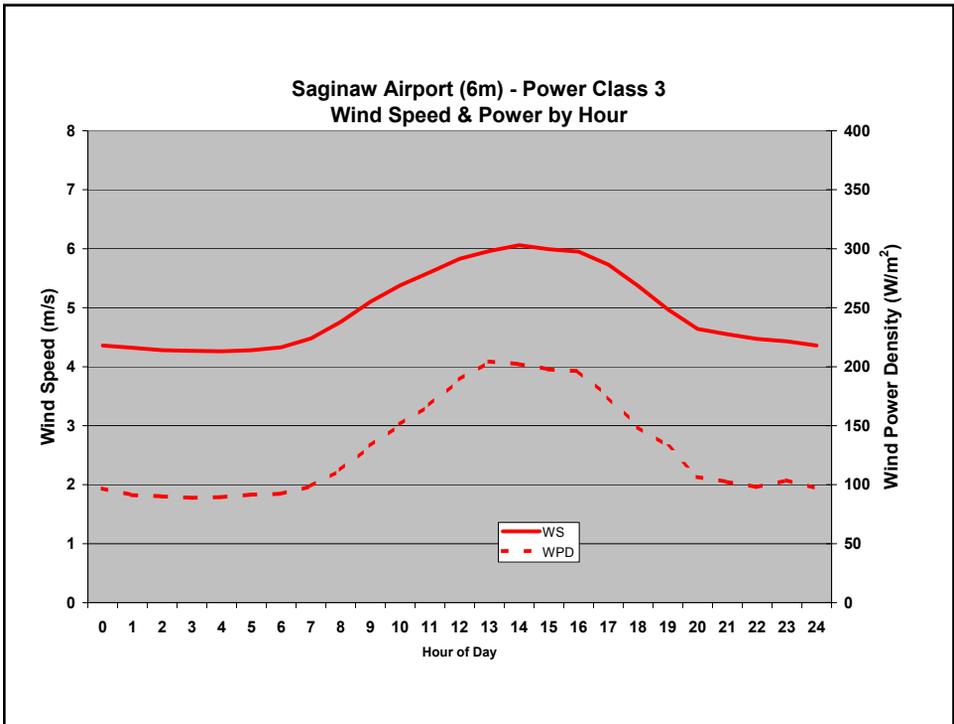
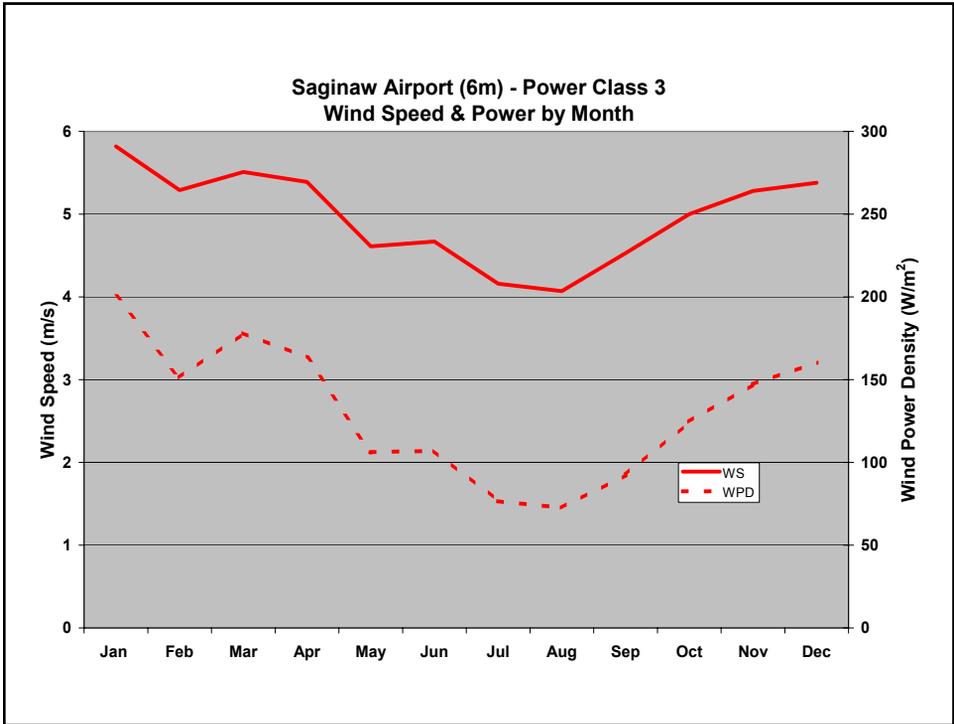
## Michigan Wind Electric Potential (Installed Capacity)

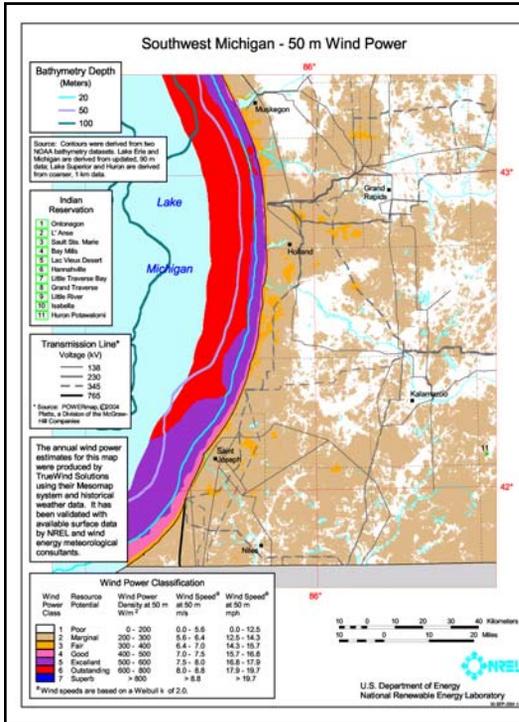
- |             | Total before exclusions | Developable |
|-------------|-------------------------|-------------|
| • Class 3 + | 24,530 MW               | 16,560 MW   |
| • Class 4 + | 2,070 MW                | 830 MW      |
| • Class 5 + | 390 MW                  | 110 MW      |
| • Class 6 + | 70 MW                   | 13 MW       |
- 32% of the raw Class 3+ lands excluded
  - 60% of the raw Class 4+ lands excluded
  - 1993 Michigan potential for Class 4+ was 4,070 MW
    - 1993 based on 7 MW per sq. km versus 5 MW in 2004
    - 1993 was 581 sq. km windy land versus 166 sq km in 2004



### Central East Michigan

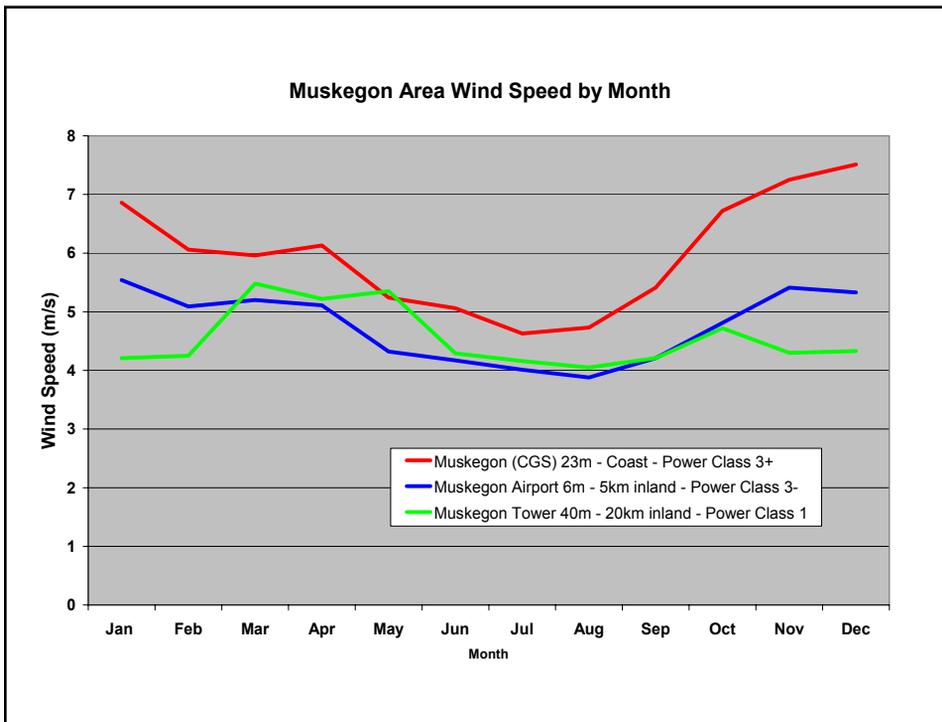
- Saginaw airport is windiest (tied with Muskegon airport) in Michigan – Class 3
- Saginaw River Coast Guard and Pigeon Agricultural Station data also indicate Class 3
- Prevailing strong winds from southwest
- Nov – Apr maximum resource
- Onshore areas of the “Thumb” east of Saginaw estimated to have significant areas of Class 3
- Shallow water (<20 m depth) in Saginaw Bay and Class 5 resource

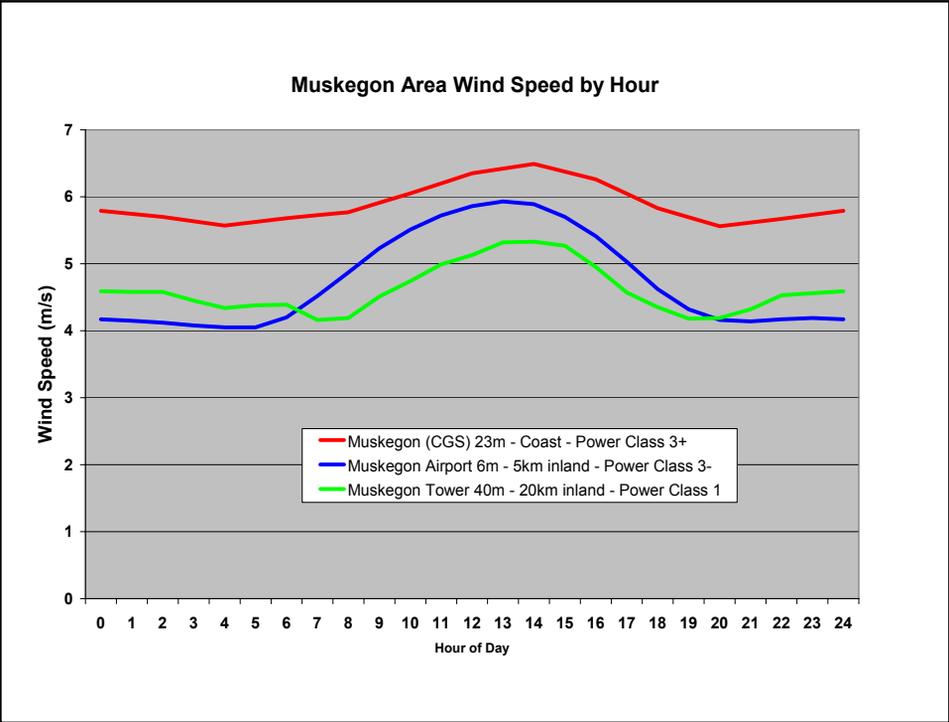
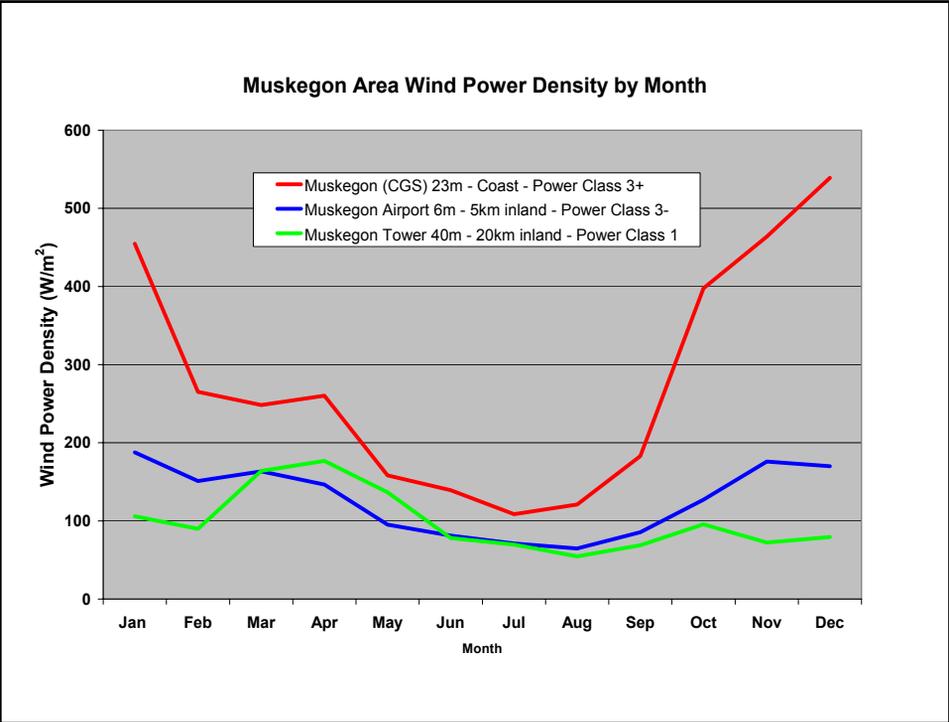


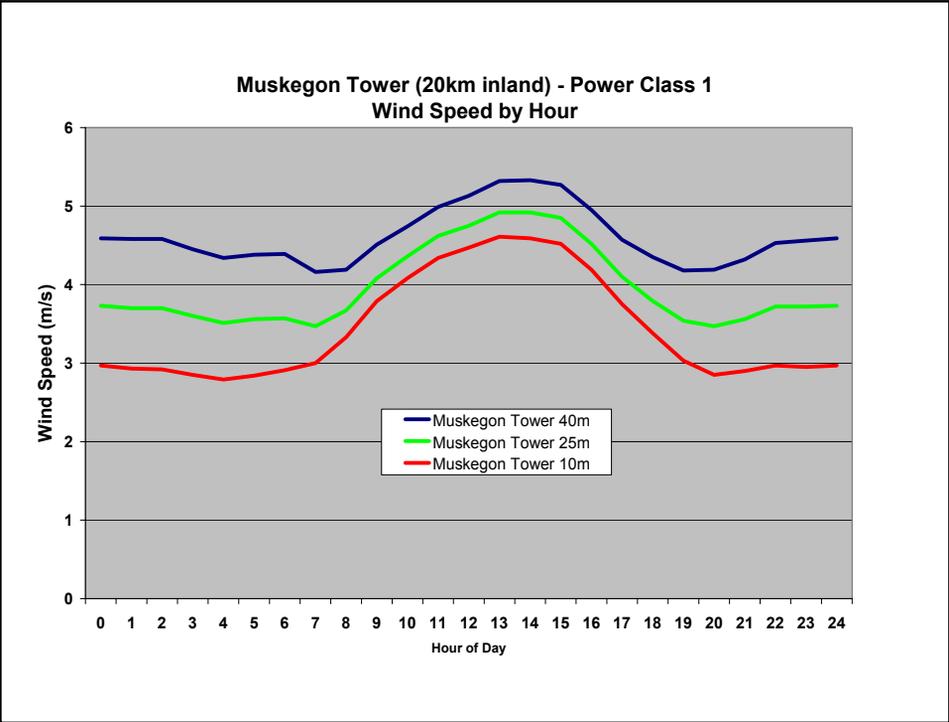
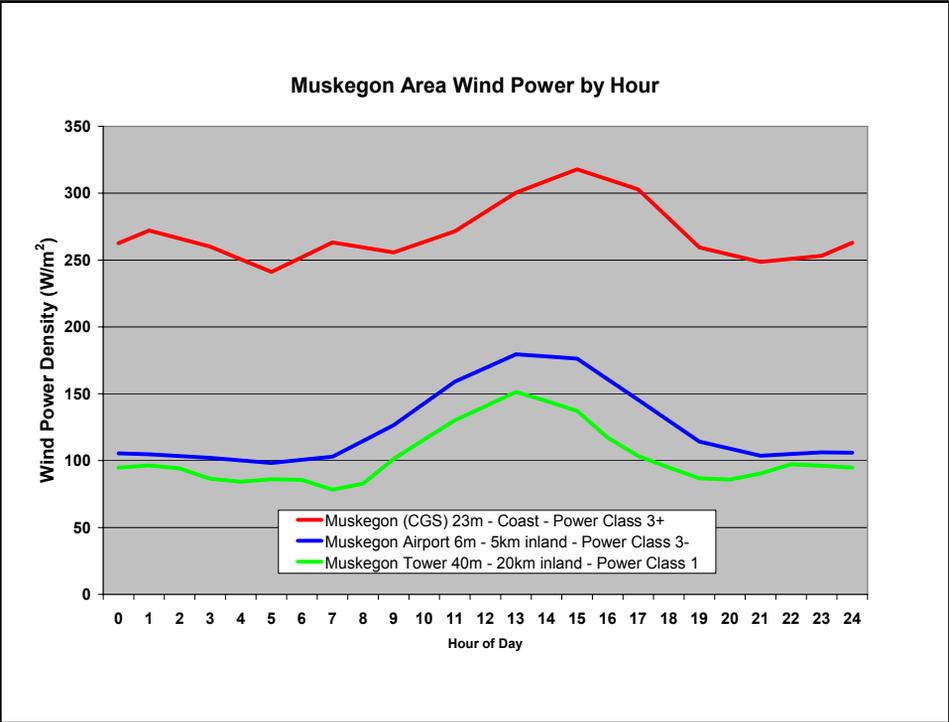


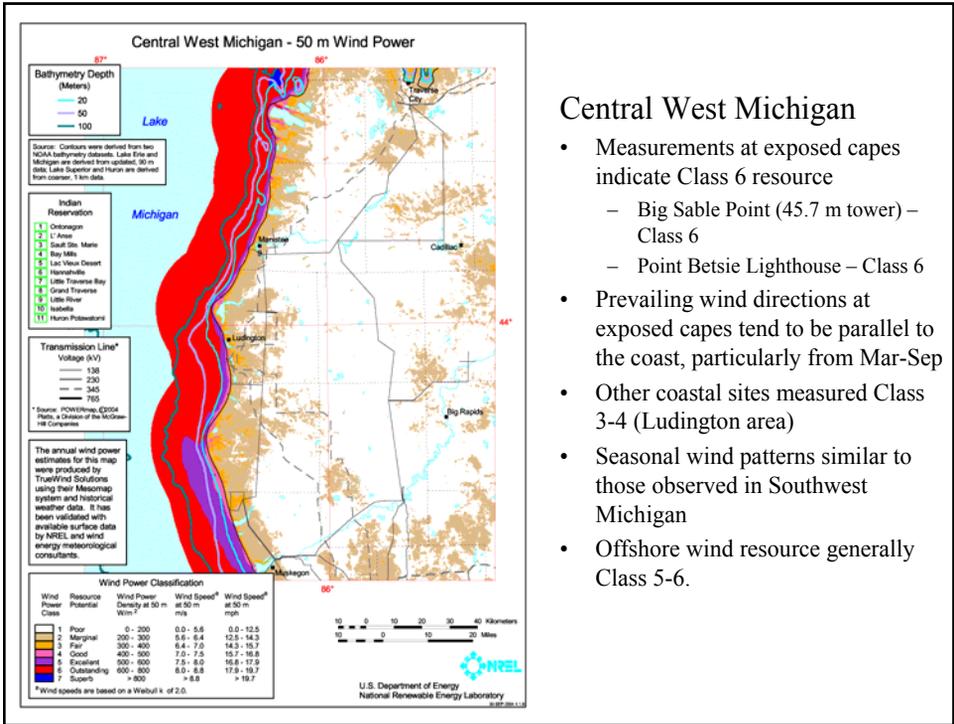
## Southwest Michigan

- **Muskegon area measurements verify strong resource gradients in the coastal-onshore area**
  - Coastal stations – Class 3+
  - Muskegon airport (5 km inland) – Class 3
  - Muskegon 40-m tower (20 km inland) – Class 1
- **Prevailing power producing winds from the south**
  - Secondary directions of strong winds from west-northwest
- **Seasonal wind resources**
  - Exposed coastal areas have strong maximum resource Oct-Jan and secondary maximum Feb-Apr
  - Inland sites generally have a broad maximum resource Nov-Apr
- **Offshore resource**
  - Strong gradients in near offshore areas with resource increasing to class 5-6 within 5-10 km of coast



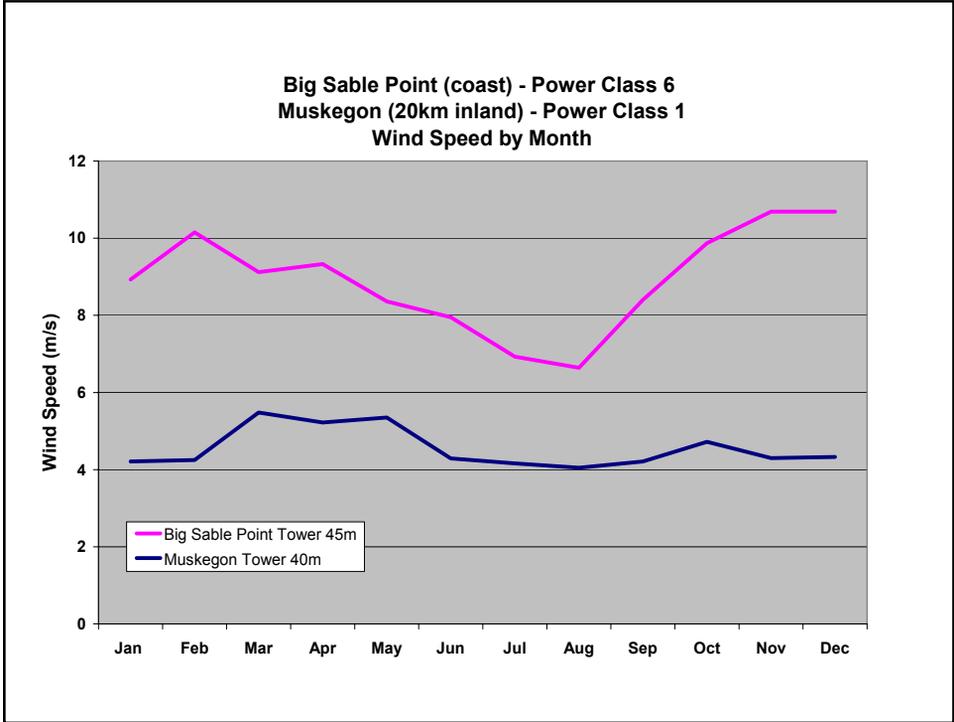


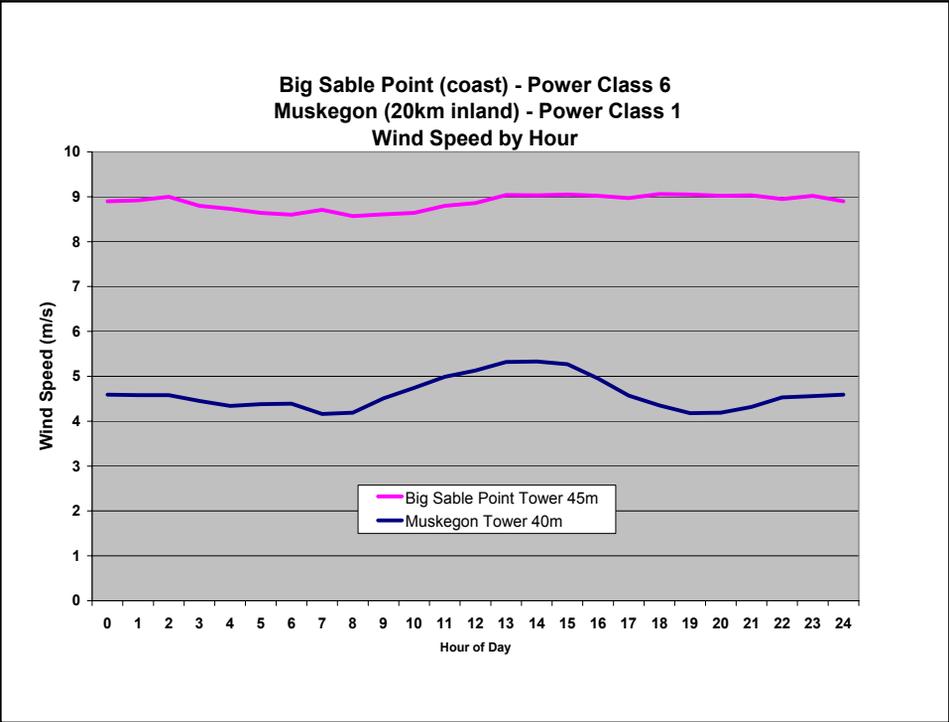
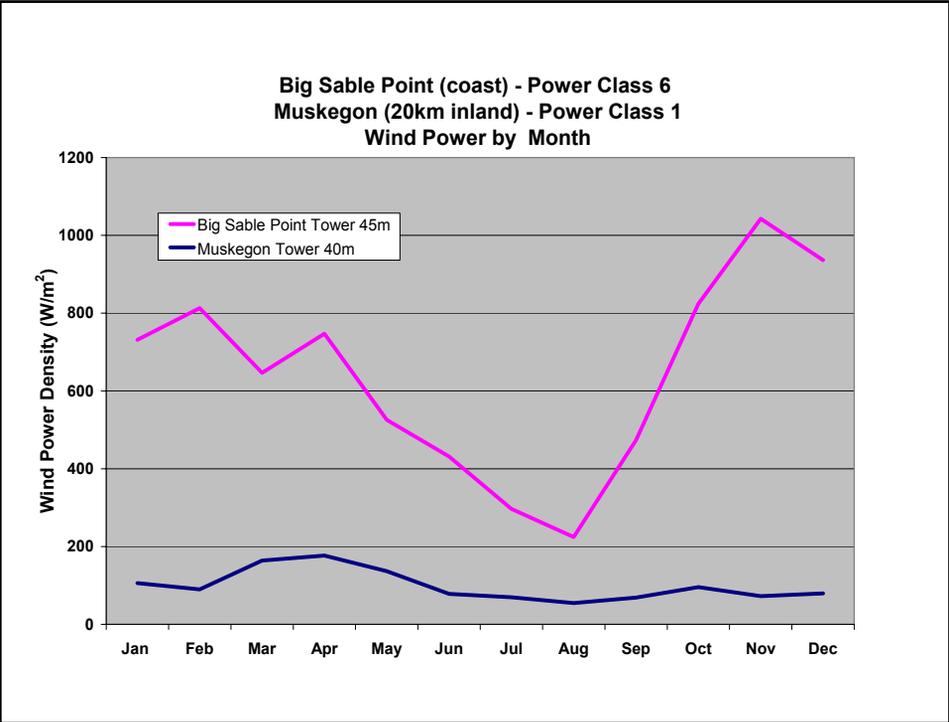




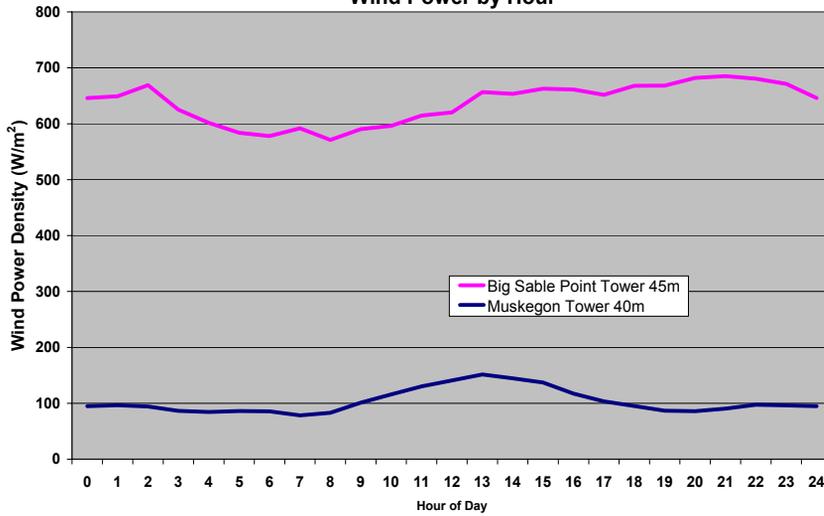
### Central West Michigan

- Measurements at exposed capes indicate Class 6 resource
  - Big Sable Point (45.7 m tower) – Class 6
  - Point Betsie Lighthouse – Class 6
- Prevailing wind directions at exposed capes tend to be parallel to the coast, particularly from Mar-Sep
- Other coastal sites measured Class 3-4 (Ludington area)
- Seasonal wind patterns similar to those observed in Southwest Michigan
- Offshore wind resource generally Class 5-6.



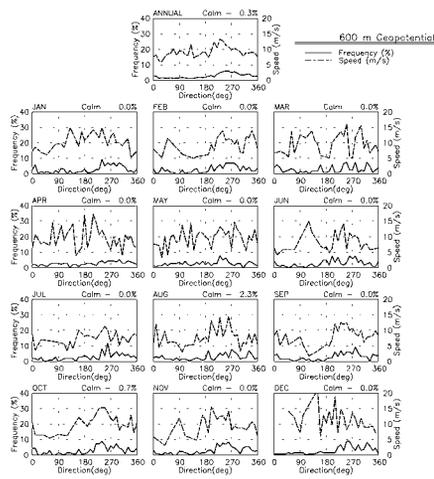


**Big Sable Point (coast) - Power Class 6  
Muskegon (20km inland) - Power Class 1  
Wind Power by Hour**



FREQUENCY & SPEED BY DIRECTION

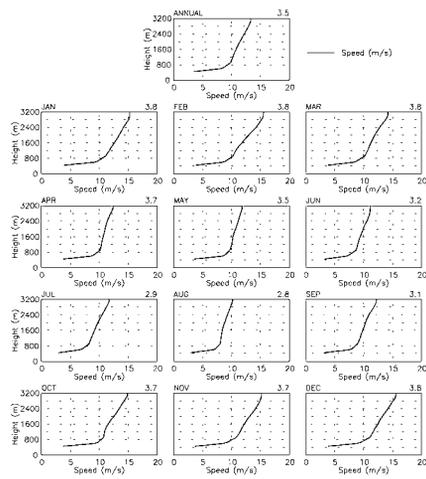
Gaylord - /2634 - 0/00 LST  
44° 55' N 84° 43' W - Elev 446m  
05/96-05/02



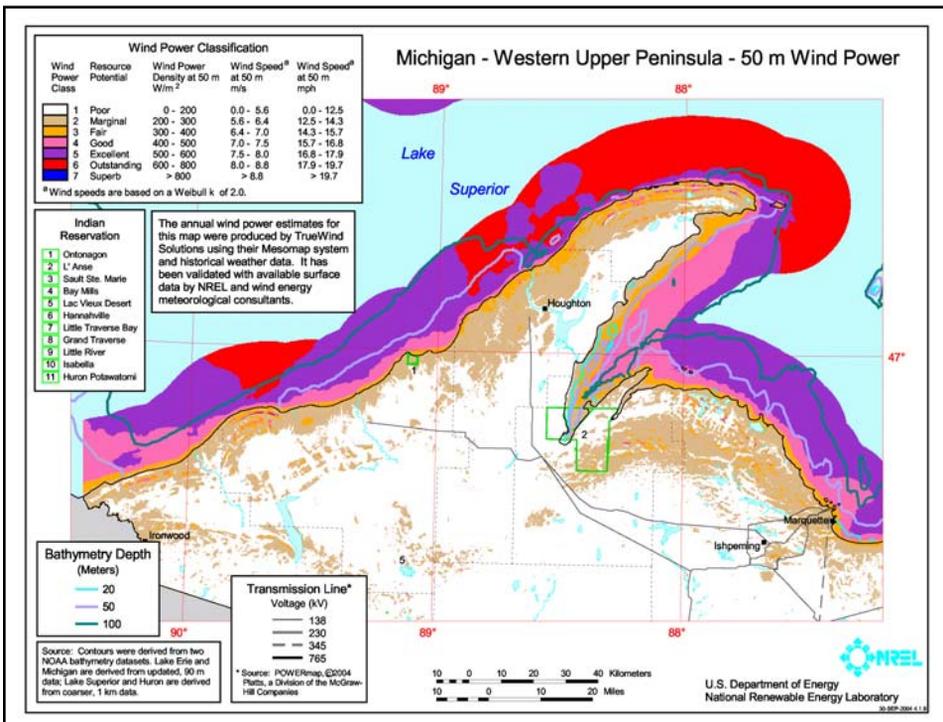
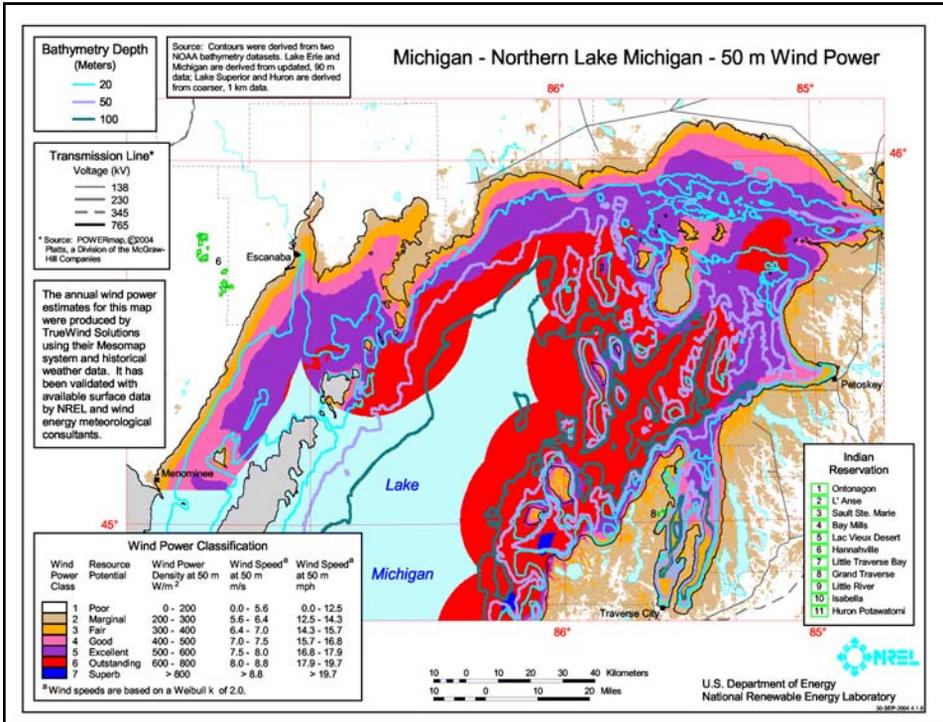
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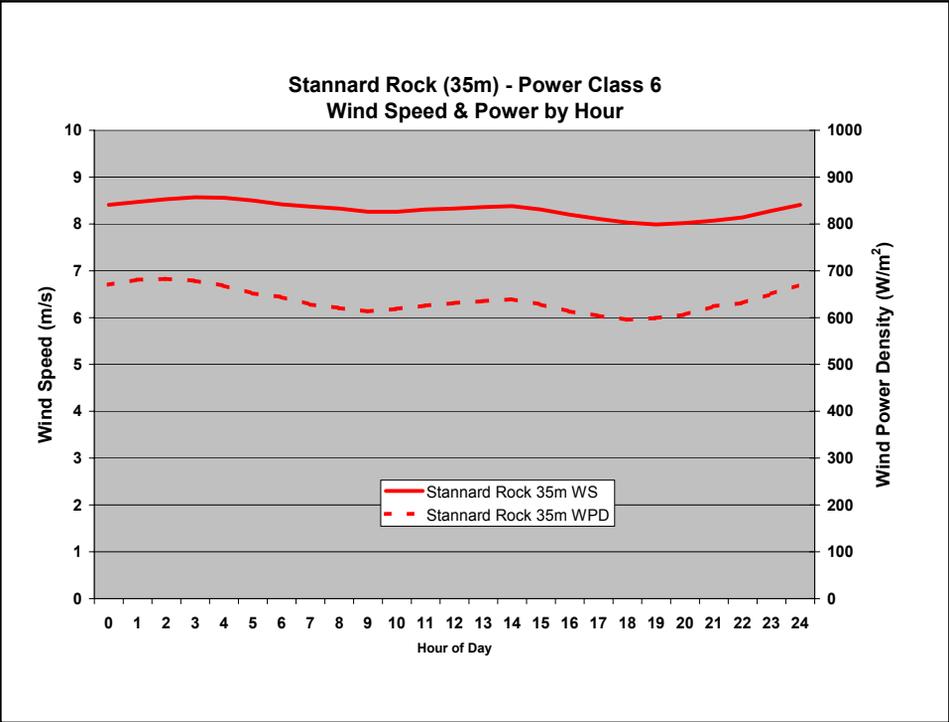
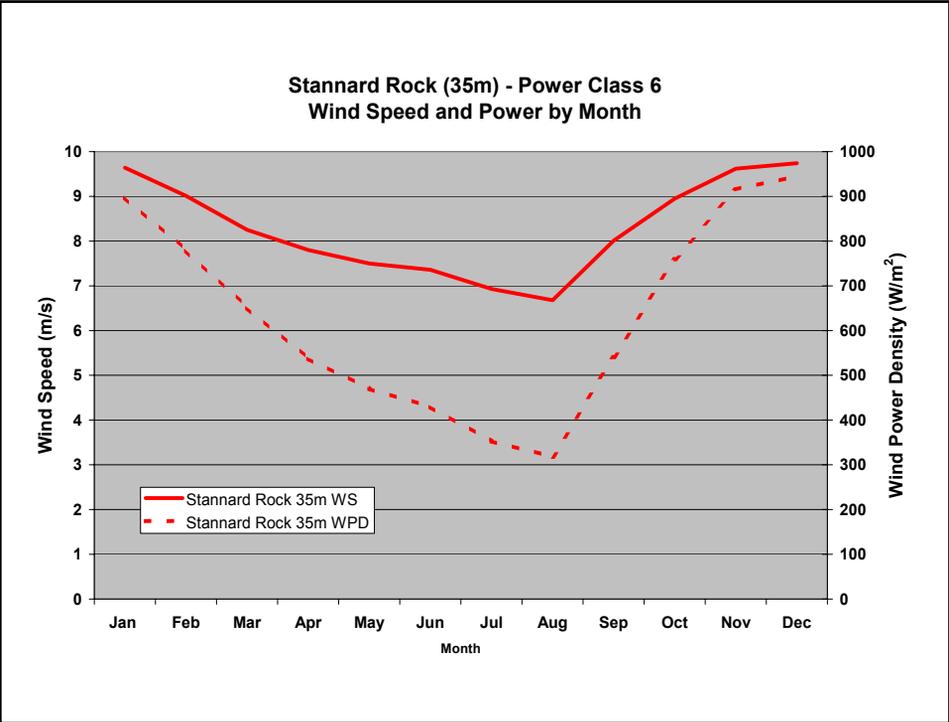
VERTICAL WIND SPEED PROFILE BY HEIGHT

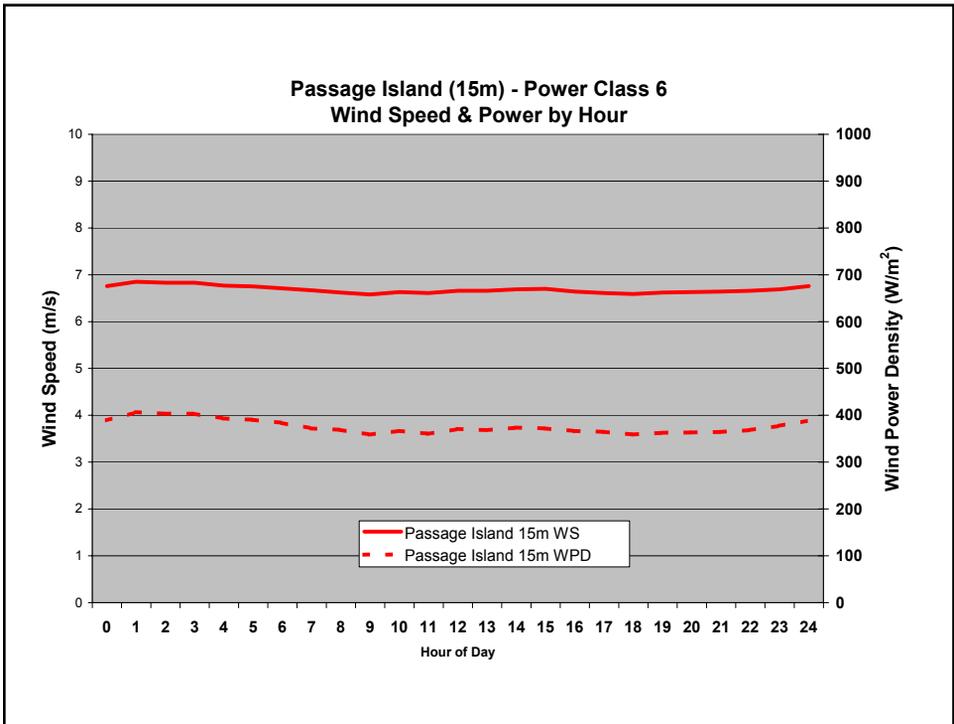
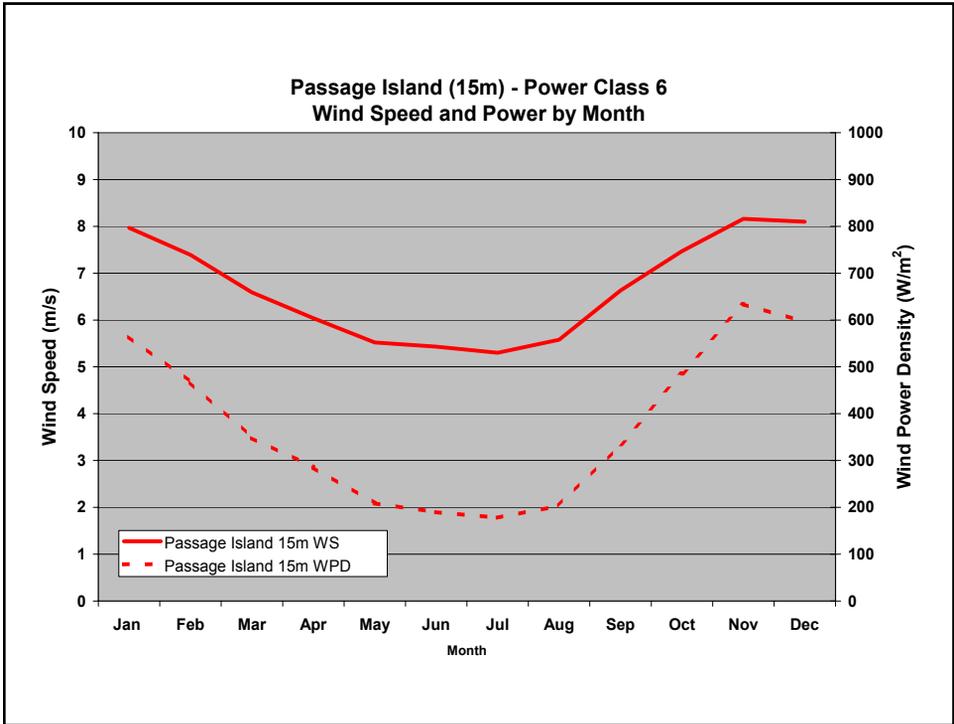
Gaylord - /2634 - 0/00 LST  
44° 55' N 84° 43' W - Elev 446m  
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Thu Sep 30 10:08:28 2004









## Summary of Michigan Wind Resource

- Onshore areas of Class 4 and above generally found on immediate coast of Lake Michigan and Lake Superior
- Offshore areas of Lakes Huron, Michigan, and Superior are generally Class 5 and above (excellent)
- There is large gradient of the wind resource in the coastal areas. The wind resource can go from Class 4 and above to Class 1-2 in just a few kilometers.
- Onshore areas of the “Thumb” east of Saginaw Bay estimated to have significant areas of Class 3 resource
- The best exposed locations along the coast and offshore have a fall-early winter resource maximum
- Lower resource inland sites tend to have a winter-spring resource maximum
- The power producing winds tend to be from the south to the west-northwest.



## Summary of Michigan Wind Potential

- Good and excellent onshore wind resource areas concentrated in a few exposed coastal areas and islands
  - 166 sq. km of Class 4 and higher of available windy land
    - 830 MW of installed capacity
- If Class 3 areas included, the wind resource is significantly greater
  - 3313 sq. km of Class 3 and higher of available windy land
    - 16,560 MW of installed capacity
  - Class 3 area potentially suitable for advanced low wind speed turbine technology