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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Wind Monitoring Report for Fort Wainwright's Donnelly Training Area

AC Orrell
DR Dixon, Program Manager

January 18, 2011

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

Using the wind data collected at a location in Fort Wainwright's Donnelly Training Area (DTA) near the Cold Regions Test Center (CRTC) test track, Pacific Northwest National Laboratory (PNNL) estimated the gross and net energy productions that proposed turbine models would have produced, exposed to the wind resource measured by the meteorological tower (met tower) during the year of measurement at this location. Calculations are based on the proposed turbine models' standard atmospheric conditions power curves, the measured annual average wind speeds, wind shear estimates, and standard industry assumptions.

These basic calculations provide a better understanding of the potential energy production at the met tower location, but do not provide hub-height wind speed estimates for heights above the height of the met tower or long-term energy production expectations.

Wind data was collected for 1 year, from October 2009 to October 2010, at the location with coordinates N 63° 55.891' W 145° 44.762'. This location is south and west of the CRTC test track and the western border of this area is the fence that separates DTA land from private land. The collected data indicates that the average annual wind speed is 5.5 m/s at a height of 50 m. This means the site has a high Class 1 to a low Class 2 wind resource. A wind resource less than Class 3 is generally considered too low to support economically feasible wind energy projects.

The wind data was collected using a 50-m XHD met tower provided by NRG Systems. This report supplements the annual wind data summary report provided by Det Norske Veritas (DNV), the globally recognized wind energy consulting firm that installed the met tower and conducted the data collection process on behalf of PNNL.

Fort Wainwright should consider the costs and benefits of pursuing a single turbine installation and reuse the met tower in another location.

While the data collection has indicated there is a low wind resource at the CRTC test track location, a 900-kW turbine project there would have marginal economics and may be a possibility. An Energy Conservation Investment Program (ECIP) funded 900-kW turbine that would replace energy purchased from Golden Valley Electric Association (GVEA) provides the best economic potential with a 0.9 savings-to-investment ratio (SIR) and a 17-year payback, given the cost and performance assumptions. The ECIP metrics could improve if the cost of electricity from GVEA has increased since the rate was originally calculated for PNNL's renewable energy assessment report of Fort Wainwright in 2009.

Because sufficient met tower data has been collected at the CRTC test track site, PNNL recommends that Fort Wainwright move the met tower to another location to determine if a stronger wind resource is available somewhere else in the DTA. Two possible options are Windy Ridge and the Black Rapids Training Center.

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1.0 Background

In November 2008, representatives from Pacific Northwest National Laboratory (PNNL) made a site visit to Fort Wainwright (FWA) to support a renewable energy assessment report of the installation. PNNL submitted a draft of this U.S. Army Installation Management Command (IMCOM) funded report to Fort Wainwright in March 2009 and a final report in October 2009 that recommended a wind resource assessment be conducted for Fort Wainwright's Donnelly Training Area (DTA) to verify the area's exact wind resource (Chvala et al. 2009).

The DTA covers a large amount of land with terrain variations. The renewable energy assessment report originally targeted a site located west of Donnelly Dome, along the southern portion of Windy Ridge adjacent to a telecommunications station operated by AT&T as the location for the assessment to be conducted.

To perform the wind resource assessment, FWA provided funding to PNNL to site, procure, and install a meteorological tower (met tower) and to provide met tower data collection and analysis services for 1 year. To complete this effort, PNNL worked with Det Norske Veritas (DNV), a wind energy consulting firm.

Actual met tower data is needed to verify the exact wind resource at the site of any potential wind energy project. The potential inaccuracy of the Alaska wind resource map as a result of incomplete data for the area and the limitations of modeling further force the necessity. Strong, but inconsistent, Chinook winds from the south may skew the average annual wind speed indicated by the wind resource map. Met tower data provides a precise assessment of the wind resource.

In July 2009, representatives from PNNL and DNV met with representatives from Donnelly Training Area's Range Control, the Cold Regions Test Center (CRTC), and Fort Wainwright's Department of Public Works to discuss possible met tower site locations. Three potential locations were identified and visited: Option 1 is a site east of the Alyeska pipeline, and west of Dome Road and a creek; Option 2 is south and west of the CRTC test track, along the eastern border of non-military land; and, Option 3 is the southern portion of Windy Ridge, near the AT&T tower. These sites are marked in Figure 1.

Options 1 and 3 both had numerous obstacles. Option 1 presented low to no impact to Range Control, but access to the site would have required permission from Alyeska and the area has a low perceived wind resource. Option 3 has the highest wind resource of all the sites considered, according to the wind resource map, but is adjacent to restricted air space and existing communications equipment.

Based on the expected wind resource alone, PNNL initially recommended installing the met tower on the southern end of Windy Ridge (Option 3). However, because of the potential mission conflicts at this site expressed by CRTC representatives, expected delays in obtaining permits and approvals, and the limited construction season available for met tower installation, PNNL did not recommend that the met tower be installed there at that time.

The selected site (Option 2), near the CRTC test track, was chosen because of its lack of mission conflicts to CRTC or Range Control. However, the CRTC meteorologist, Craig Egeland, indicated that the site probably had a low, but consistent wind resource. Therefore, PNNL recommended that if 1 year of data at Option 2 proved that the wind resource there was not feasible, the met tower should be moved to the Windy Ridge area (Option 3). While data was being collected at Option 2, PNNL recommended that FWA coordinate with stakeholders to gain approval to site a met tower at Windy Ridge.

The met tower installation near the CRTC test track was completed October 21, 2009 and data transmittal began October 22, 2009. The 1 year of data collection ended October 22, 2010.

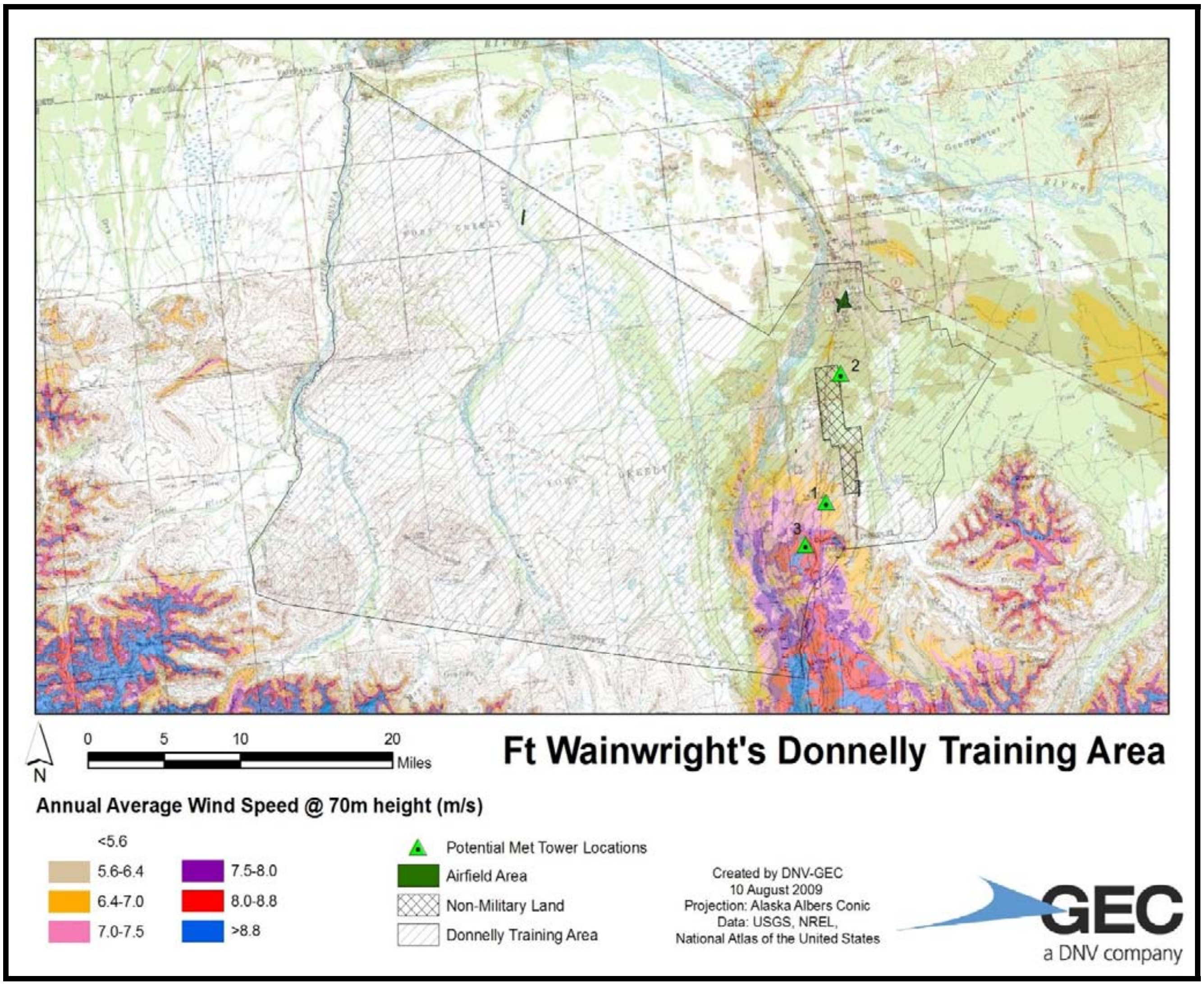

Figure 1. Donnelly Training Area Wind Resource

2.0 Wind Data

The full wind data report is provided in DNV's Annual Wind Resource Data Summary. Table 1 presents the annual average and monthly average wind speeds provided in that report at each of the different anemometer height levels (DNV 2010).

Table 1. Monthly Wind Speed Averages in meters per second (m/s)

Month	Anemometer Heights			
	50 m	**30 m**	**25 m**	**10 m**
November 2009	5.1	4.6	4.6	3.8
December	6.5	5.8	5.6	4.6
January 2010	4.9	4.3	4.4	3.8
February	6.8	6.2	6.4	5.3
March	6.2	5.7	5.6	4.7
April	6.3	5.9	5.9	4.9
May	4.9	4.6	4.5	3.8
June	4.0	3.7	3.6	2.9
July	5.4	5.1	5.0	4.0
August	4.8	4.4	4.5	3.6
September	4.1	3.7	3.7	3.0
October	6.4	5.8	5.9	4.9
Annual Average	**5.5**	**5.0**	**5.0**	**4.1**

Because of icing of the anemometers, the overall data recovery rate was 85% for all anemometer heights (DNV 2010). To establish a wind resource characterization with low uncertainty and to secure favorable project financing, the industry preference is to see at least a 96% rate of data recovery and have a representative long-term data set.

DNV's Annual Wind Resource Data Summary does not provide a representative long-term data set. The information provided in the annual data summary is based on the validated data, but does not include detailed analysis and should be considered preliminary. For example, invalid data, removed because of icing, was not replaced with appropriate estimates based on other sensors on the tower, correlations to other towers, or other data as appropriate. This type of additional analysis is required to establish a representative long-term data set.

According to the wind resource map in Figure 1, the met tower location is predicted to have an annual average wind speed of 5.6 to 6.4 m/s at a 70-m height above ground level. This represents the lower end of the DTA's potential wind resource range. The validated wind data confirms that the wind resource is low at this site, and perhaps lower than anticipated. An average wind speed of 5.5 m/s at 50 m indicates the site has a high Class 1 to a low Class 2 wind resource. Class 1 and Class 2 wind resources are generally considered too low to support economically feasible wind energy projects.

Figure 2. Met Tower

3.0 Turbine Options

The goal of IMCOM-funded renewable energy assessment analyses is to identify economically feasible opportunities for generation of electricity from renewable resources—generation that is significant enough to warrant connection to the grid and/or to contribute in a meaningful way to the aggressive Energy Policy Act (EPAct) and Department of Defense (DOD) renewable energy goals. To support this, PNNL's assessments focus on projects with a size of at least 1 MW, and for wind energy projects, a 1.5-MW turbine model is used for project economic calculations.

In PNNL's renewable energy assessment report for Fort Wainwright, preliminary wind energy project economics were calculated based on wind map data from the Windy Ridge area and a 1.5-MW turbine. Those calculations are not revisited for this report. Now that the wind resource at the selected site has been confirmed as low, and there has not been analysis done to predict the wind speeds at heights greater than the met tower height, there is little value in examining the estimated energy production for a large-scale turbine. Alternately, this report will examine the energy production from a 100-kW turbine and a 900-kW turbine. Ultimately, due diligence of a manufacturer's performance history and turbine site suitability studies are recommended when selecting a turbine model for a project.

Table 2 indicates the estimated gross and net energy productions that a 100-kW turbine model would have produced, exposed to the wind resource measured at the met tower location during the year of measurement. The calculations assume the turbine's standard atmospheric conditions power curve.

Table 2. 100-kW Turbine Energy Production Estimates

	Northern Power Northwind 100
Standard Conditions	1.255 kg/m^3 air density, 0 m above sea level
Turbine Rated Capacity	100 kW
Turbine Hub Height	37 m
Average Annual Wind Speed	5.2 m/s at 37 m
Wind Shear Exponent, 30 – 50 m	0.21
Estimated Gross Annual Energy Production	224,644 kWh
Gross Capacity Factor	25.6%
Estimated Losses	17%
Estimated Net Annual Energy Production	186,455 kWh
Net Capacity Factor	21.3%

This turbine model typically has an installed cost of $550,000 and annual operations and maintenance (O&M) costs are expected to be about $0.01/kWh of energy production.

Table 3 indicates the estimated gross and net energy productions that a 900-kW turbine model would have produced exposed to the wind resource measured at the met tower location during the year of measurement. The calculations assume the turbine's standard atmospheric conditions power curve.

Table 3. 900-kW Turbine Energy Production Estimates

	EWT Direct Wind 54*900
Standard Conditions	1.255 kg/m^3 air density, 0 m above sea level
Turbine Rated Capacity	900 kW
Turbine Hub Height	50 m
Average Annual Wind Speed	5.5 m/s at 50 m
Estimated Gross Annual Energy Production	1,607,727 kWh
Gross Capacity Factor	20.4%
Estimated Losses	17%
Estimated Net Annual Energy Production	1,334,413 kWh
Net Capacity Factor	16.9%

A 900-kW turbine typically has an installed cost of $2,800 to $3,100 per kW. An annual O&M cost of 1% of the installed cost can be assumed.

While 37 meters is the standard hub height for the 100-kW turbine, hub heights of 35, 40, 50 and 75 meters are available for the 900-kW turbine according to the manufacturer (EWT 2010). A 50-m hub height was selected because that is the extent of the wind data available. Also, while a higher hub height would allow for increased energy production, it is reasonable to assume that there may be height limitations placed on a wind energy project sited in DTA because of air operations.

Net energy is gross energy minus any losses. Losses can typically reduce gross energy by between 12% and 25%. Losses come from reduced availability, wake and array effects, turbine performance issues, electrical losses, and icing or other detrimental weather conditions. During the year of data collection, a significant amount of data was lost because of icing of the anemometers on the met tower, as heated anemometers were not used. It can be expected that a wind turbine would experience icing as well, and potentially have lost hours of energy production.

Cold weather modifications can be made to the tower and turbine design to mitigate the impacts of cold weather and icing on turbine performance. For example, a space heater can be added to the nacelle or blades can be painted black to increase their surface temperature to prevent icing.

4.0 Project Economics

In PNNL's renewable energy assessment report for Fort Wainwright, various energy costs were identified. The energy costs relevant to this analysis are shown in Table 4.

Table 4. Energy Costs

Energy Cost, ¢/kWh	Explanation
5.64	Cost of energy from Fort Wainwright's coal-fired plant minus wheeling charges
13.67	Direct energy cost to replace GVEA electricity at Fort Wainwright minus wheeling charges

Wind power provides intermittent power, which may reduce demand costs but is assumed to only reduce direct energy costs. If power is wheeled from a project in Fort Wainwright's DTA to Fort Wainwright in Fairbanks, this wind power can either replace Golden Valley Electric Association (GVEA) electricity at 13.67¢/kWh or power from the coal plant at 5.64¢/kWh. These are net value avoided costs because the wind project's revenue is the avoided cost minus any wheeling charges (the cost of getting the power to Fort Wainwright). These costs do not include wheeling charges because GVEA, not the project, would be the recipient of any wheeling compensation.

To examine the economic potential of these turbine options, the two options were evaluated for Energy Conservation Investment Program (ECIP) eligibility and independent power producer (IPP) project potential. To qualify for ECIP funding, a project must achieve a savings-to-investment ratio (SIR) of 1.0, and its payback is also examined. For the IPP evaluation, the commercial cost of energy (COE) needed to obtain an internal rate of return (IRR) of 10% was calculated. This is assumed to be the minimum IRR required to attract the interest of a wind power project developer. Table 5 lists the assumptions and results of these analyses in 2010 dollars.

Table 5. Economic Assumptions & Results

	Northern Power Northwind 100	**EWT DW 54*900**
Project Size	100 kW, 1 turbine	900 kW, 1 turbine
Installed Cost	$5,500/kW	$2,950/kW
Annual Fixed O&M Cost	$18.70/kW	$29.50/kW
Federal Tax Rate	35%	35%
State Tax Rate	9.4%	9.4%
5-year Accelerated Depreciation	Included	Included
Federal Production Tax Credit	Included	Included
Transmission Costs	Not Included	Not Included
COE Required to Achieve a 10% IRR	37.1¢/kWh	24.2¢/kWh
ECIP Metrics @ 5.64¢/kWh	0.2 SIR, 61 year payback	0.4 SIR, 41 year payback
ECIP Metrics @ 13.67¢/kWh	0.6 SIR, 25 year payback	0.9 SIR, 17 year payback

The COE required to achieve a 10% IRR for either turbine option is higher than Fort Wainwright's current energy costs. But the project economics of both turbine options are slightly more favorable when compared against the cost of replacing electricity from GVEA, than from coal generation. Given the cost and performance assumptions, the ECIP scenario for replacing GVEA electricity with the 900-kW turbine has the best potential. Changes to the assumptions could impact this result. For example, if the cost of electricity from GVEA has increased since PNNL first calculated the rate used in this analysis, that would favorably impact the ECIP metrics. Also, a higher hub height could increase the turbine's energy production which would improve the turbine's capacity factor and thus its project economics as well.

5.0 Delta Junction Wind Farm

Outside of Fort Wainwright's DTA is the privately owned Delta Junction Wind Farm. It has one Northwind 100-kW turbine from Northern Power and one Directwind 900-kW turbine from EWT. The 100-kW was commissioned in October 2008 (AEP 2010) and the 900-kW turbine went online at the end of July 2010. The turbines are situated on a knoll that gives the site an elevation of 1,350 feet. The Fort Wainwright met tower site is approximately 800 feet in elevation.

In November 2010, the Delta Junction Wind Farm was experiencing wind speeds of between 10.6 and 13.4 m/s at a height of 75 m on at least a few days. This site may have a higher wind resource than the Fort Wainwright site because of its elevation. However, average, annual wind speeds for the Delta Junction Wind Farm are unknown.

Mike Craft of Alaska Environmental Power (AEP), the owner of the wind farm, has shared some data with PNNL and Fort Wainwright about his turbines. Table 6 displays PNNL's estimations of the turbines' performance, based on the minimal data provided. Mike Craft told Fort Wainwright staff that the 900-kW turbine cost $1.8 million and the overall installed project cost was about $2.6 million[1]. This is a total installed cost of approximately $2,900/kW.

Table 6. Delta Junction Wind Farm Energy Production Estimates

	EWT DW 54*900	**Northern Power Northwind 100**
Turbine Rated Capacity	900 kW	100 kW
Turbine Hub Height	75 m	37 m
July 2009 Data		
Total Energy Produced	-	77,404 kWh
Time Available	-	5,508 hours
Calculated Gross Capacity Factor	-	14%
November 2010 Data		
Total Energy Produced	447,438 kWh	125,096 kWh
Time Available	2,592 hours	7,781 hours
Calculated Gross Capacity Factor	19%	16%

These calculations provide just a snapshot of the turbines' energy productions. These calculations are based on the limited data provided[2], and may not be an accurate representation of the project's overall, annual performance. AEP's website says the farm added 900,000 kWh to the grid in 2009 (AEP 2010).

[1] Emails from Mike Craft to Ashish Agrawal shared with PNNL.
[2] Emails from Mike Craft to Ashish Agrawal shared with PNNL.

6.0 Fort Wainwright Energy Consumption

When Fort Wainwright's steam turbines are not operating at full capacity, or there is excessive electricity demand on site, Fort Wainwright buys supplementary electricity from Golden Valley Electric Authority (GVEA). In FY 2008, GVEA supplied 11,578 MWh to Fort Wainwright, with a maximum demand of 8.5 MW. In FY 2007, however, GVEA supplied Fort Wainwright with 24,580 MWh of electricity, with a maximum demand of 13.8 MW. The variation is primarily a function of generator operation. It is estimated that Fort Wainwright's typical demand is about 20 MW, although self-generated electricity is not metered and therefore an exact figure is unknown (Chvala et al. 2009).

In 2005, Fort Wainwright conducted a study of its existing loads and projected future loads. These projections are presented in Table 7 (Fort Wainwright 2005). Also in Table 7 are the electricity amounts, based on those projections, that need to be supplied by renewable energy, per the EPAct mandate and DOD goal.

Table 7. Fort Wainwright Projected Energy Consumption

2013 Projected Electricity Consumption	2025 Projected Electricity Consumption	Amount of Electricity Required to meet 7.5% of 2013 Electricity Consumption (EPAct Requirement)	Amount of Energy Required to meet 25% of 2025 Electricity Consumption (DOD goal)
160,000 MWh, 29 MW	200,000 MWh, 37 MW	12,000 MWh	50,000 MWh

Using the estimated energy production calculations, Table 8 presents how many turbines of each model, and the project costs, it would require to meet the EPAct requirement and DOD goal.

Table 8. Wind Energy Requirements to Meet Goals

Turbine	Estimated Energy Production per Turbine	Number of Turbines Required to Meet EPAct Requirement	Estimated Project Cost to Meet EPAct Requirement	Number of Turbines Required to Meet DOD Goal	Estimated Project Cost to Meet DOD Goal
100 kW	186 MWh	64	$35,200,000	268	$147,400,000
900 kW	1.33 MWh	9	$23,895,000	37	$98,235,000

The large number of turbines required demonstrates that smaller turbines, or small projects in general, will not be sufficient in meeting renewable energy goals at Fort Wainwright. The project economics in Section 4 also demonstrate that the larger turbine option has better economics.

7.0 Recommendations

Fort Wainwright should consider the costs and benefits of pursuing a single turbine installation and reuse the met tower in another location.

While the data collection has indicated there is a low wind resource at the CRTC test track location, a 900-kW turbine project there would have marginal economics and may be a possibility. An ECIP-funded 900-kW turbine that would replace energy purchased from GVEA provides the best economic potential with a 0.9 SIR and a 17-year payback, given the cost and performance assumptions. These ECIP metrics could improve if the cost of electricity from GVEA has increased since the rate was calculated for PNNL's renewable energy assessment report.

While the Army is strongly encouraging ECIP proposals for renewable energy projects, one 900-kW turbine would not contribute significantly to Fort Wainwright meeting its renewable energy consumption mandates. And a multiple 900-kW turbine project is unlikely to attract the interest of a third-party developer based on the high cost of energy it requires to achieve a 10% IRR. However, the neighboring Delta Junction Wind Farm has succeeded, and Fort Wainwright may benefit from that project's experience and knowledge.

Because sufficient met tower data has been collected at the CRTC test track site, PNNL recommends that Fort Wainwright move the met tower to another location to determine if a stronger wind resource is available somewhere else in the Donnelly Training Area. Two possible options are Windy Ridge and the Black Rapids Training Center.

Windy Ridge is indicated on the map in Figure 1 as site option 3 and was the site originally identified by PNNL in its assessment report as having high potential for a wind energy project because of the high expected wind resource of the area. According to the wind resource map, this area has an annual average wind speed of 7.0 m/s or greater at a 70-m height above ground level. The accuracy of this rating is unknown at this time. Strong, but inconsistent, winds in this area may skew the average annual wind speed indicated by the wind resource map. Mr. Egeland has indicated that this area receives strong Chinook winds from the south, but that these winds are inconsistent and only occur between 15% and 20% of the year. In addition, he says that Granite Mountain typically blocks the more consistent winds from the east. CRTC has no existing meteorological stations in this area.

The site is located west of Donnelly Dome, along the southern portion of Windy Ridge adjacent to a telecommunications station operated by AT&T. Because of its elevation, this site will most likely require an archeological review. In addition, this site is on the edge of restricted air space. Range Control indicated that a minimum 300-m setback distance would be required from the restricted air space boundary.

Another possible location would be the Black Rapids Training Center. Fort Wainwright has received ECIP funding for a 200-kW wind project at the Black Rapids Training Center. Depending on project and funding timing and weather, the met tower could be deployed to support this project.

8.0 References

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