Yellowknife Area Wind Potential

Prepared for

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Summary

This project is part of the assessment of potential sites for wind energy development in the Northwest Territories. Currently the Yellowknife area is experiencing very little load growth, however with the potential for new mining activity nearby (TerraX Minerals) and the uncertainty about drought cycles, wind energy potential around the area is being further investigated. Using previous studies, wind modelling tools and new wind measurements. The two main areas identified are the Bluefish hills, 22 km north of Yellowknife and the Southbelt area, located by the shoreline of Great Slave Lake, 7 km south of the city.

For most wind projects in the north a long term annual mean wind speed of at least 6.0 m/s is desirable for considering their economics. Using a wind modelling tool, the wind speeds for the Bluefish hills and the Southbelt location were calculated to be 5.88 and 6.25 m/s at a wind turbine hub-height of 50 m above ground level (AGL), respectively. The wind model has been compared to local measurements and are considered slightly optimistic but within the margin of uncertainty. According to the wind model, the mean winds are expected to increase during the winter months and are generally from the southeast and northwest. The Southbelt location has an advantage of being closer to Yellowknife, which would mean reduced powerline and road costs compared to the Bluefish hills.

To confirm the estimates, wind measurements at one or both sites are recommended. There is possible icing at the two sites and heated instruments powered by onsite generation may be needed.

Introduction

A recent study titled 'North Slave Resilience Study' concluded that a wind energy project in the Yellowknife area could be feasible if a large load growth was forecasted (such as a mine). With advanced drill programs underway at the TerraX Mineral site near Yellowknife this study expands the ongoing effort to quantify the wind energy potential for the Yellowknife area. Wind energy can play a complimentary role to hydro, biomass, solar and other renewables to help displace fossil fuels in electricity generation for industry, commercial and residential appliances as well as space heating and transportation. In this report, previous studies are revisited and a wind model mapping tool is used to estimate wind speed in various locations around Yellowknife.

For most wind projects in the north a long term annual mean wind speed of at least 6.0 m/s is desirable for considering their economics. Even more desirable is wind energy that is more plentiful during the winter months to meet the increased energy demand. However, those stronger winter winds can be impacted by winter inversions at lower elevations.

Inversions occur during the winter months when normal atmospheric conditions (cool air above, warm air below) become inverted. Inversions trap a dense layer of cold air under a layer of warm air. Even very shallow valleys can act like a bowl, with cold, dense air pooling at the bottom. The snow-covered valley floors reflect rather than absorb the heat from the sun, preventing the normal vertical mixing of warm and cold air. The cold heavy air tends to prevent the stronger winter winds above from reaching down toward the surface. At 350 m above sea level (ASL) or higher in the Yellowknife area, the winds are expected to be above the winter inversion layer, and so should exhibit stronger winter winds (Pinard and Trimble, 2015).

In the City of Yellowknife wind speed measurements were made in 2006-2007 at the Jackfish communication tower (196 m ASL; Pinard et al. 2008) and in 2011 on a 50-m meteorological mast at the Giant Mine site (205 m ASL; Genivar, 2012). Long term mean wind speeds at the Jackfish tower were found to be 5.1 m/s (projected to 50 m AGL) and the short-term (eight-month period) measurements from the Giant tower were 5.11 m/s. Measurements at Jackfish showed wind speeds were lower in the winter, however, there are some evidence of icing when compared to data from the Yellowknife airport.

A measurement campaign at the Northwestel tower on the hills near Snare Dam started in December 2015, and the ongoing analysis of the data is addressed in the next section. A summary of the wind speeds compared to each other are shown in Table 1.

Analysis Update of Snare Tower Wind Measurements

The elevation of Northwestelʾs Snare tower site is approximately 365 m ASL. Two heated wind sensors were installed on the tower at 25 and 53 m AGL, and started collecting data on December 11, 2015. An update report (Pinard, 2016) using the first three months of wind measurements correlated to the Fort Smith upper air measurements indicated that long term wind speeds were estimated to be 6.68 m/s at 50 m AGL (or 415m ASL).

A further update of this measurement campaign is made here and used to validate the results from the wind model. The period of measurement for this study is from December 11, 2015 to March 6, 2017. The wind speeds at the Snare site were again compared to upper air wind measurements from a station in Fort Smith located 440 km southeast of Snare. Weather balloon data from this site includes wind speed and direction recorded at 400 m ASL.

The wind speeds that were measured at the Snare tower for the 11 December 2015 to 6 March 2017 period were 5.84 and 6.54 m/s at 25 and 53 m AGL, respectively. During the same monitoring period, the Fort Smith upper air measurements were 6.49 m/s (400 m ASL). The five-year (2012-2016) average wind speed for Fort Smith upper air measurements were found to be about 2% faster at 6.64 m/s at 400 m ASL. A MCP (Measure-Correlate-Predict) correlation using a matrix time series (a more reliable correlation method than the linear least square method, both available in the Windographer wind analysis tool used for this study) calculated that the five-year mean wind speed at the Snare site is estimated to be 6.6 m/s at 50 m AGL.

Table 1. Historical wind measurements in the Yellowknife area, with projected and modelled values.

	Snare Tower		**Jackfish Tower**	**Giant Mine**
Site Elevation (m ASL)	365		196	205
Sensor Height (m AGL)	25	53	38	50
Total Measurement Elevation (m ASL)	390	418	234	255
Mean wind speeds measured (m/s)	**5.84**	**6.54**	**4.39 (with icing)**	**5.11 (with icing)**
Long-term mean wind speeds projected to 50 m AGL		**6.6**	**5.11**	**NA**
Wind model long-term wind speed at 50 m AGL		**6.76**	**5.42**	**5.58**

Wind Modelling Estimates

The AWS Truepower's WindNavigator modelling tool was used to estimate the wind speeds in the Yellowknife area. The modelling tool uses topography, roughness, and vegetation for surface data, as well as 15 years of global reanalysis, weather balloon data, and weather station data for mesoscale simulation on a 2.5 km grid. The mesoscale data is then simulated at a microscale level with 200 m resolution grid using local terrain elevation and surface roughness and adjusted using local weather station data, in this case would be the Yellowknife airport station. The numerical modelling tool is accessible through their website at: https://dashboards.awstruepower.com/wsa and requires an account and a fee for use.

The wind model calculations are compared to measurements made at Jackfish tower and Northwestel's Snare tower. At the Jackfish tower the wind model calculated the 50 m AGL wind speed to be 5.42 m/s, about 0.3 m/s higher than the measured and projected wind speed of 5.11 m/s at the Jackfish tower. At the Giant Mine tower the wind model calculated the 50 m AGL wind speed to be 5.58 m/s, about 0.47 m/s higher than the measured wind speed of 5.11 m/s at the Giant Mine tower. Note here that the Giant Mine tower measurements are only for eight months and not reflective of long term wind speeds at this site. At the Snare tower the wind model calculated the 50 m AGL wind speed to be 6.76 m/s, which is 0.16 m/s faster than the 6.6 m/s long term winds based on the measurements there. While the wind model shows a slightly optimistic prediction of the wind speed, these differences are within the wind model's uncertainty of ± 0.35 m/s. The wind model reports are shown in appendices A, B, and C and the wind speeds are also shown in Table 1.

Investigation of Possible Wind Energy Sites in the Yellowknife Area

Berry Hill is being considered as a candidate site since it is the highest point, at 275 m ASL, in the surrounding Yellowknife area. It only has room, however, for one wind turbine (1-3 MW size) to be installed thus limiting the site's potential for growth, especially considering that a road and powerline will be a significant cost portion of the project.

The Bluefish hills are located less than 5 km from the Bluefish dam and the power line and there are several locations there that peak at just over 260 m ASL. The Bluefish hills are 60 m and 50 m higher in elevation compared to Jackfish and Giant Mine, respectively. This may give the Bluefish hills an advantage in terms of winter winds, but icing may be a concern. Suggested locations for a meteorological wind monitoring tower at Bluefish are shown in Figures 1 and 2. There is room for a dozen wind turbines on this hill complex, and it is located about 22 km from Yellowknife and may need about 10-12 km of new road to the site. According to the wind model, at the Bluefish 3 location, the 50 m AGL wind speeds are calculated to be 5.88 m/s. At the other two locations, Bluefish 1 and 2, the 50 m AGL wind speeds are calculated to be 5.63 and 5.77 m/s, respectively. The wind model predicts that the winds are stronger in the wintertime and come mainly from the east to southeast with a secondary component from the northwest. The wind model report for Bluefish 3 is shown in Appendix D. Based on upper air measurements the author estimated winds to range from 5.8 to 6 m/s at 300 m ASL or the 50 m AGL level on the Bluefish hills, which are at 260 m ASL.

The Southbelt area is located about 7 km south of Yellowknife and is shown in Figures 1, 3, and 4. This area is on the shore of the Great Slave Lake and could have room for a dozen wind turbines (1-3 MW

each). The Inner Whalebacks weather station, operated by Environment Canada, is located on an island 63 km southeast of the Southbelt located and it measured a long-term average wind speed of 6.57 m/s at 10 m AGL. The Inner Whalebacks station also measured stronger winter wind speeds of 8 m/s during the months of October and November. At the Southbelt location, shown in Figure 4, the wind model calculated the long-term winds to be 6.25 m/s at 50 m AGL. This predicted with speed is about 6% faster than at the Bluefish hills. The wind model predicts that the winds are stronger in the winter and will be mainly from northwest and southeast. More detailed results for this site can be found in Appendix E.

Conclusions and Recommendations

The two areas that are identified for potential wind sites within the TerraX properties are the Bluefish hills north of Yellowknife and the Southbelt location by the shoreline south of Yellowknife. According to the wind model, the Southbelt location is shown to have wind speeds that are about 6% faster than the Bluefish hills area.

Because the Southbelt location is closer to Yellowknife and is estimated to have better wind speeds than the Bluefish hills, it is more likely that the economics of a wind project will be better at the Southbelt location. A new measurement campaign is recommended for the Southbelt location. Icing may be a concern and should be considered when choosing wind monitoring equipment.

References

Genivar, 2012, **Technical Report for Giant Wind Monitoring: Data Summary Report NT-Giant Mine 1-50HD (2703)**. Prepared for the GNWT, Yellowknife, NT.

Pinard, JP, John F. Maissan, and Pippa Seccombe-Hett (Ed.), 2008, **Yellowknife Wind Energy Pre-Feasibility Report.** Prepared for Aurora Research Institute, Inuvik, NT.

Pinard, JP, and Annika Trimble (Ed.), 2015, **Potential Wind Farm Locations for the Yellowknife Area.** Prepared for Aurora Research Institute, Inuvik, NT.

Pinard, JP, 2016, **Snare Wind Monitoring Update 2016**. Prepared for Aurora Research Institute, Inuvik, NWT.

This and other NWT renewable energy reports can be found at http://www.nwtresearch.com

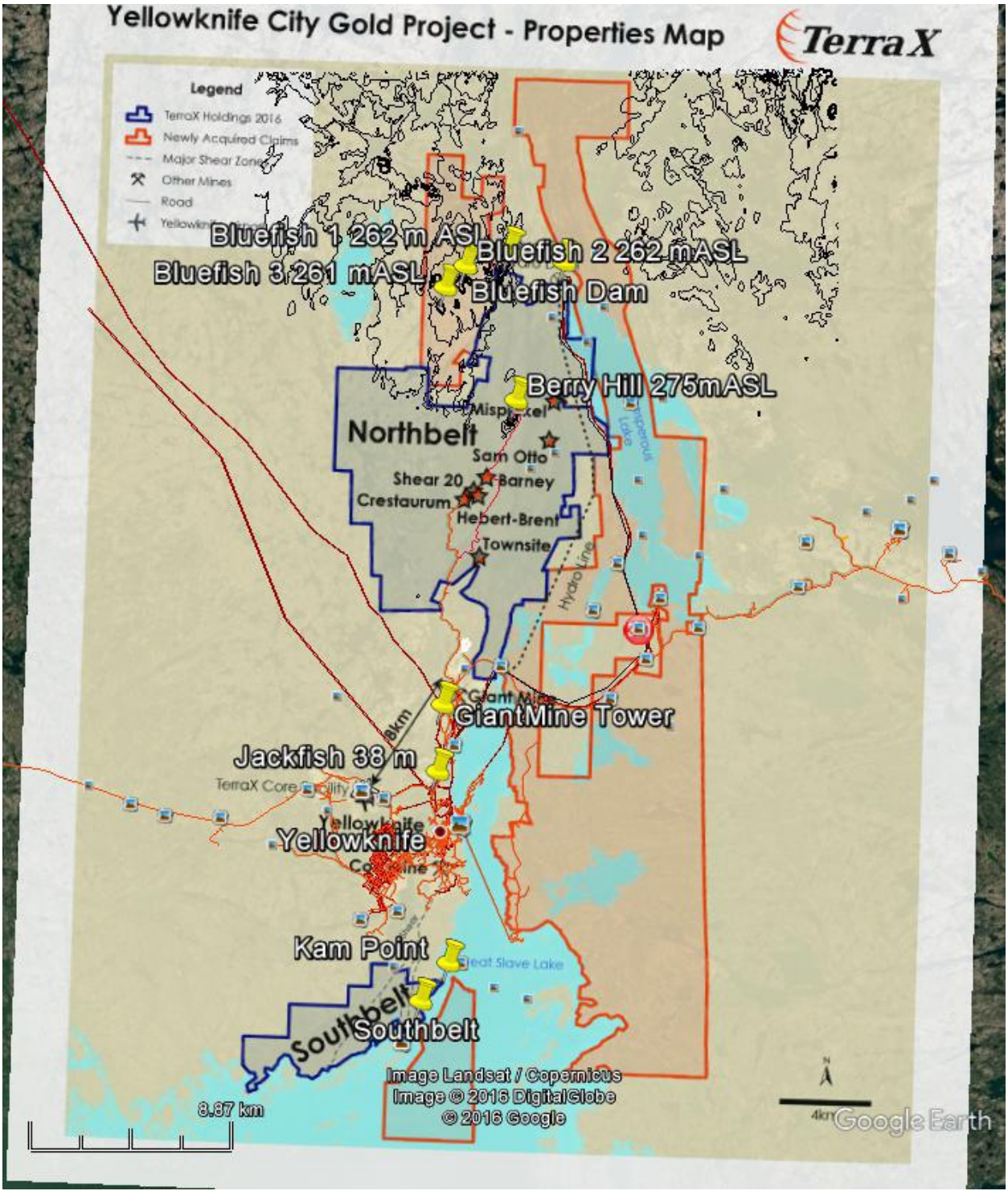


Figure 1: Google Earth area map of Yellowknife with overlay of a map of the TerraX properties.

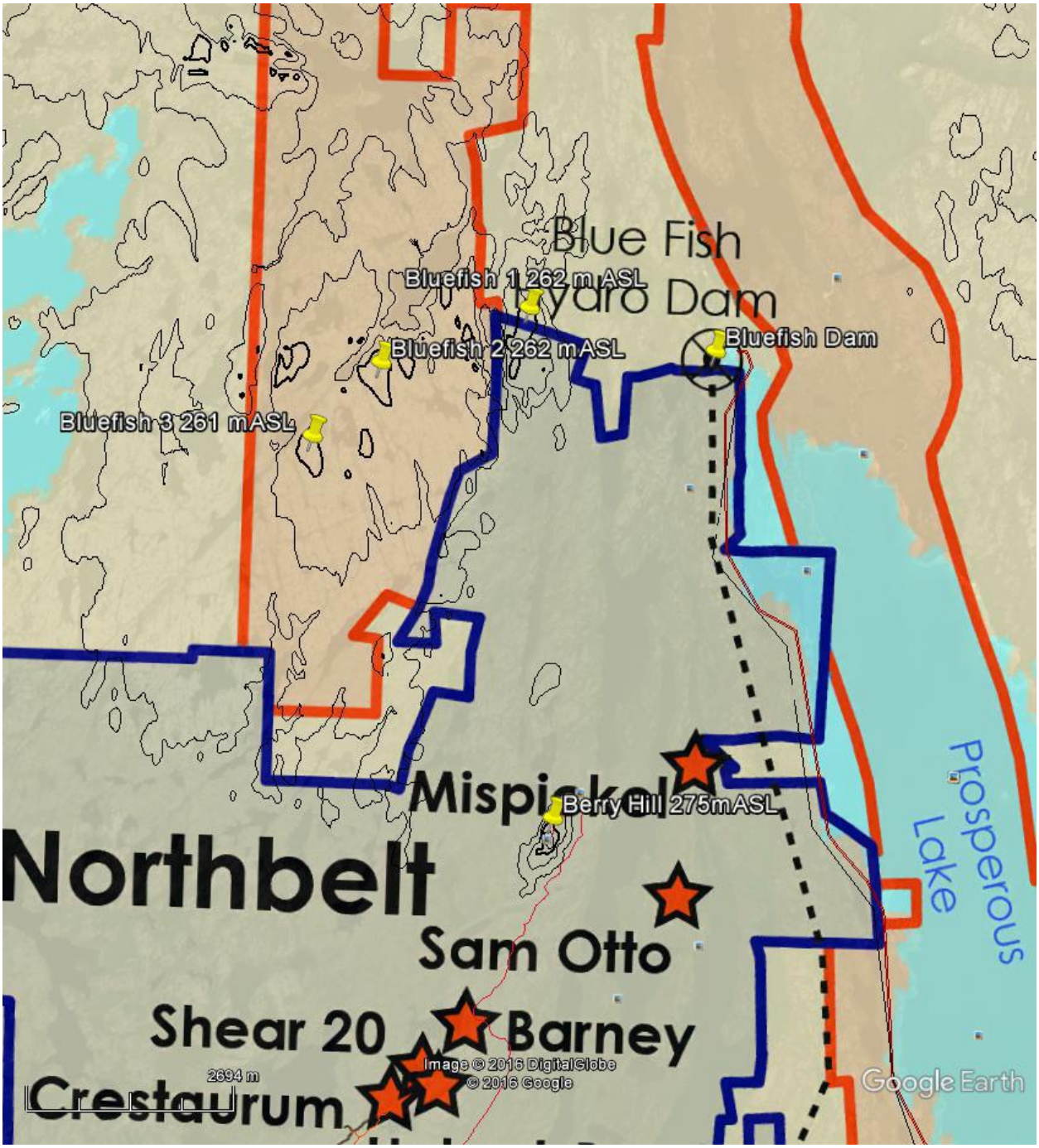


Figure 2: Area map of the Bluefish hills showing the area above 260 m ASL (thick black line) compared to the Berry Hill site, which is at 275 m ASL. The thick black lines are the 260 m ASL contours and the contour interval is 10 m, the thinner black lines are at 240 and 250 m ASL.

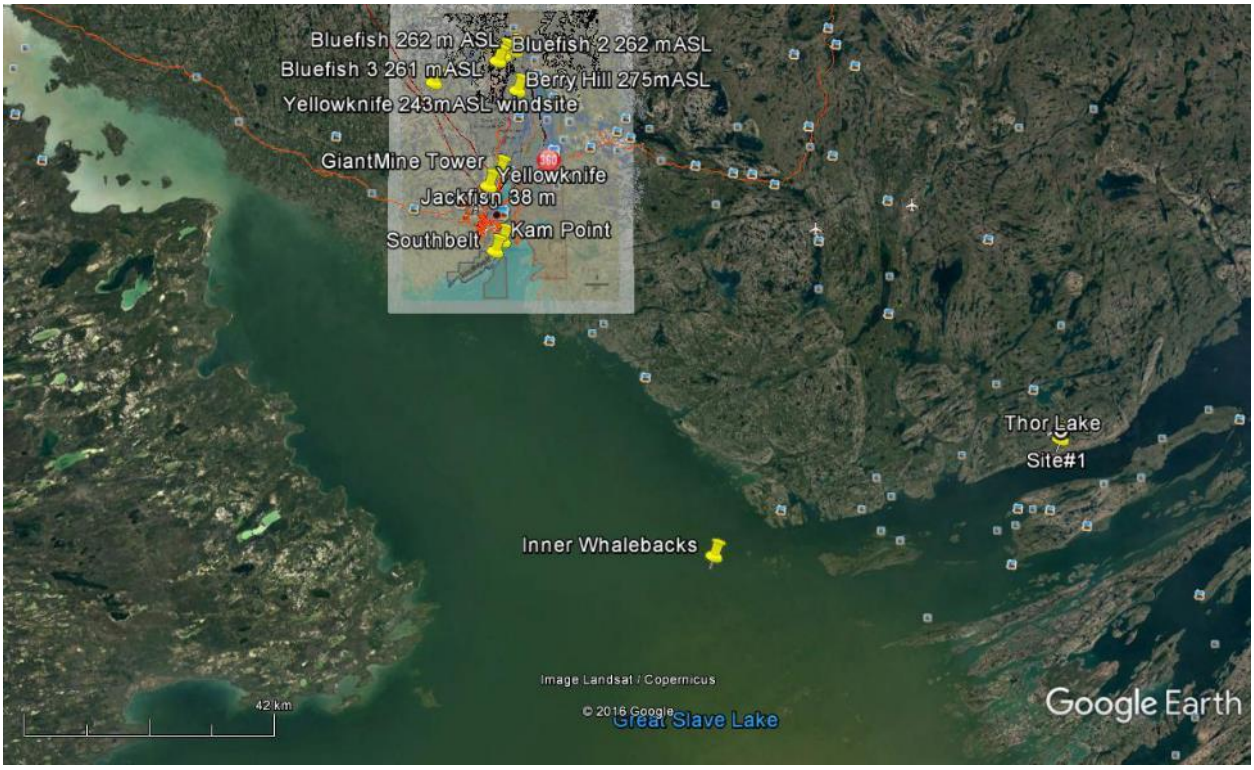


Figure 3: Area map showing the Inner Whalebacks weather station, operated by Environment Canada, and the proposed Southbelt meteorological wind monitoring tower location.

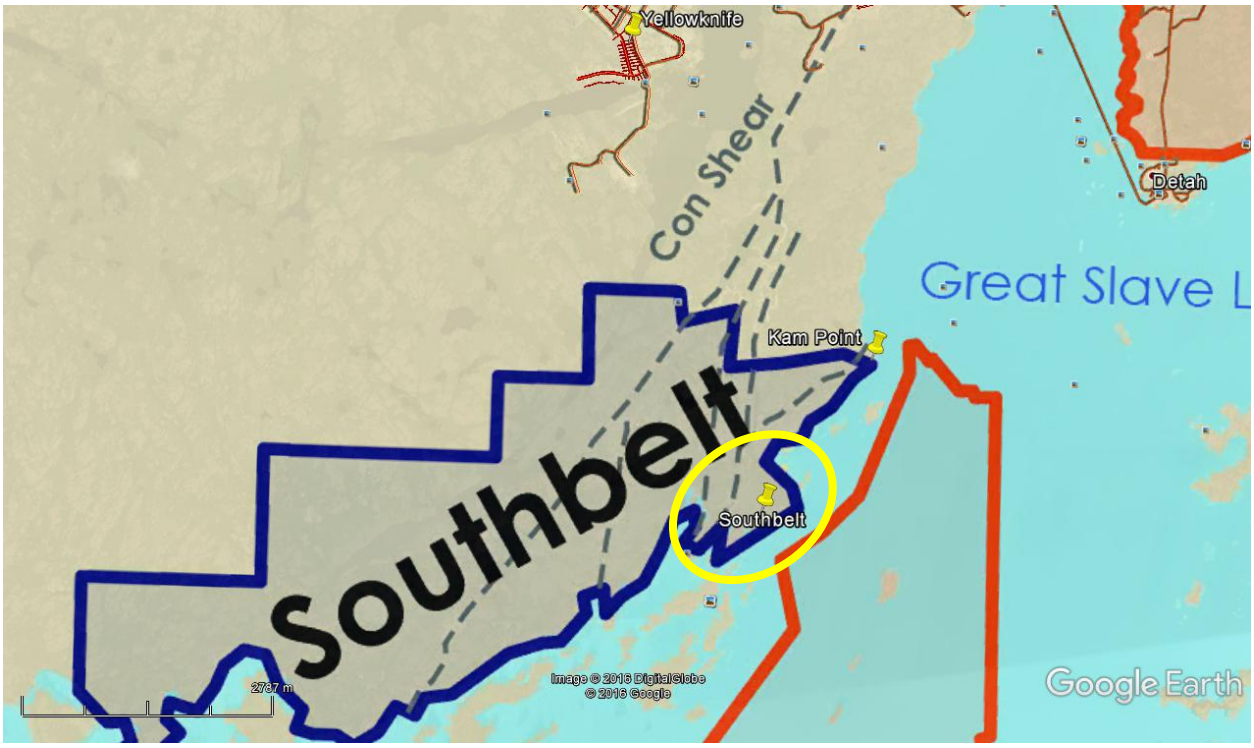
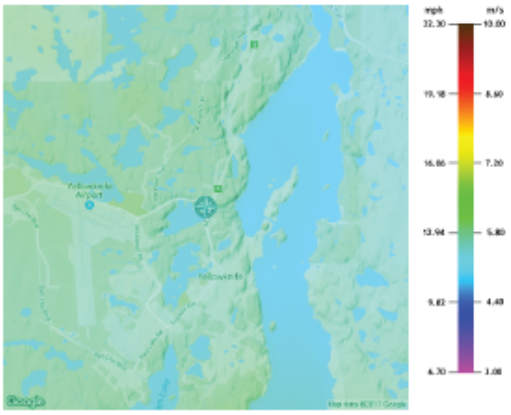


Figure 4: Area showing the Southbelt property and the location, circled in yellow, where the highest wind speeds were modelled for the area.

Appendix A – Jackfish Wind Speed Modelling Results

Compass Print-Out Report

Site Characteristics



Mean annual wind speed map at 50 m hub height for Jackfish.

Latitude: 62.47037 Longitude: -114.37895

Wind Speed (50.0 m): 5.42 m/s

Roughness: 0.5000 m Elevation: 183.1 m (600.7 ft)

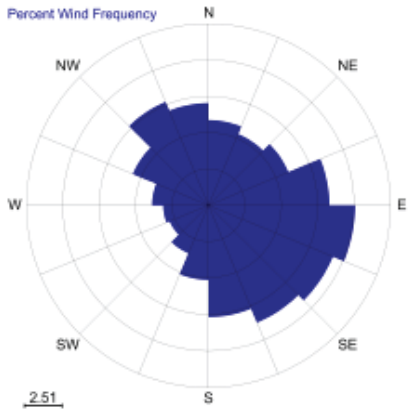
Air Density: 1.253 kg/m3

Mean Power Density: 176 W/m^2

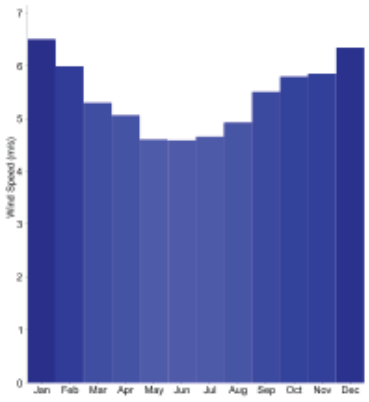
Uncertainty Value: 0.35 +/- m/s

Weibull A: 6.11 Weibull k: 2.16

200m Graphs



Wind Rose



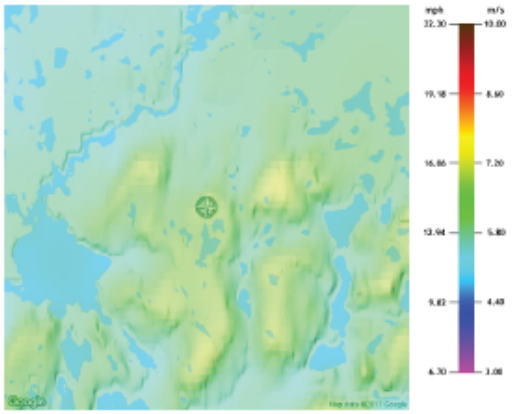
Monthly Distribution

AWS Truepower

Appendix B - Snare Wind Speed Modelling Results

Compass Print-Out Report

Site Characteristics



Mean annual wind speed map at 50 m hub height for Snare.

Latitude: 63.40362 Longitude: -116.17879

Wind Speed (50.0 m): 6.76 m/s

Roughness: 0.1000 m Elevation: 357.6 m (1,173.2 ft)

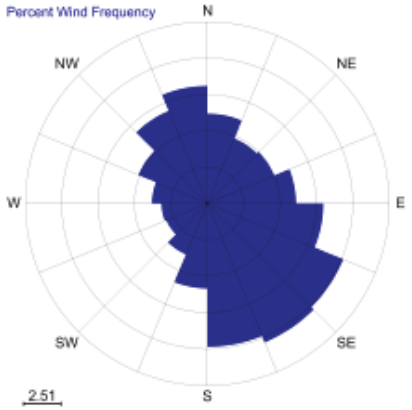
Air Density: 1.239 kg/m3

Mean Power Density: 328 W/m^2

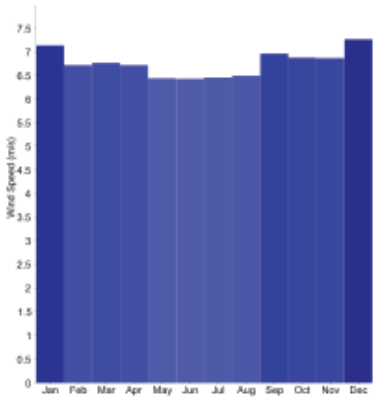
Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.62 Weibull k: 2.23

200m Graphs



Wind Rose



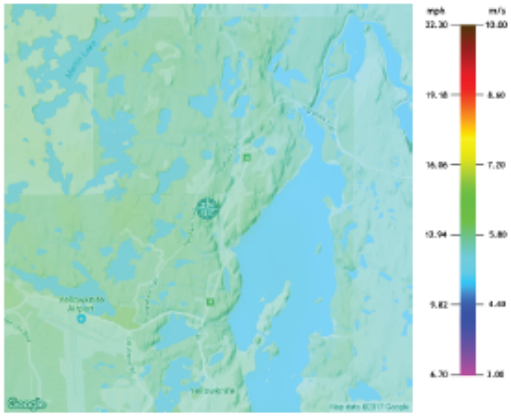
Monthly Distribution

AWS Truepower

Appendix C – Giant Mine Wind Speed Modelling Results

Compass Print-Out Report

Site Characteristics



Latitude: 62.49654 Longitude: -114.3742

Wind Speed (50.0 m): 5.58 m/s

Roughness: 0.0100 m Elevation: 183.3 m (601.4 ft)

Air Density: 1.255 kg/m3

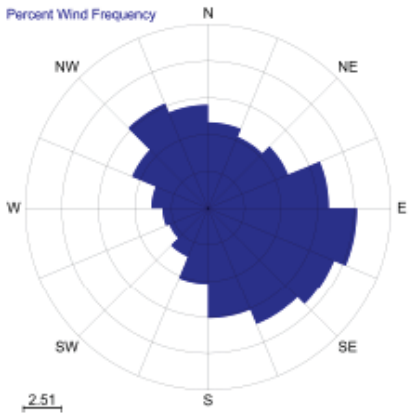
Mean Power Density: 192 W/m^2

Uncertainty Value: 0.35 +/- m/s

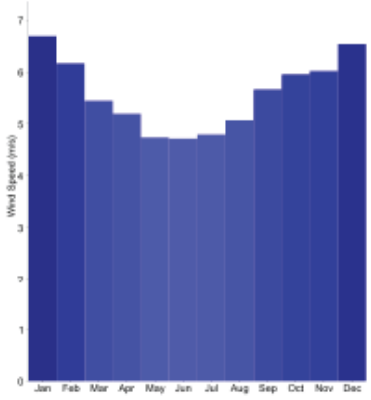
Weibull A: 6.29 Weibull k: 2.17

Mean annual wind speed map at50 m hub height for Giant Mine.

200m Graphs



Wind Rose

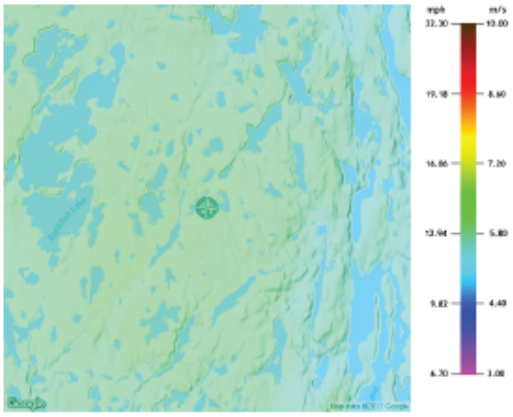


Monthly Distribution

AWS Truepower

Appendix D - Bluefish Wind Speed Modelling Results

Site Characteristics



Mean annual wind speed map at 50 m hub height for Bluefish 3.

Latitude: 62.66194 Longitude: -114.36922

Wind Speed (50.0 m): 5.88 m/s

Roughness: 0.0100 m Elevation: 244.0 m (800.5 ft)

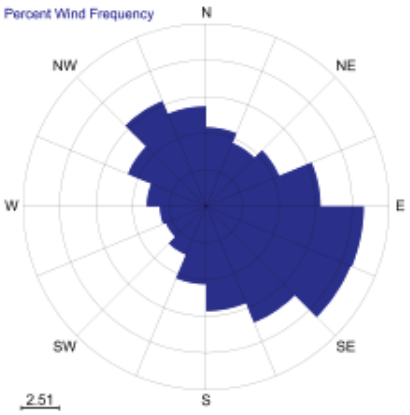
Air Density: 1.248 kg/m3

Mean Power Density: 223 W/m^2

Uncertainty Value: 0.35 +/- m/s

Weibull A: 6.63 Weibull k: 2.18

200m Graphs



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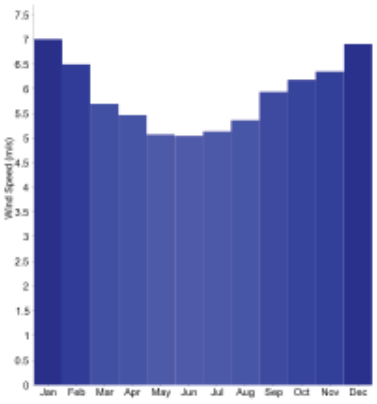
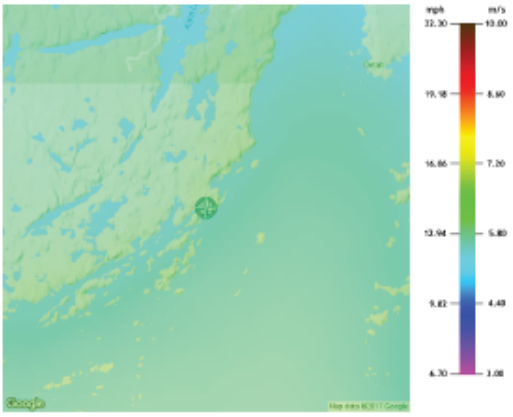


Monthly Distribution

Appendix E - Southbelt Wind Speed Modelling Results

Site Characteristics



Mean annual wind speed map at 50m hub height for Southbelt.

Latitude: 62.37935 Longitude: -114.39448

Wind Speed (50.0 m): 6.25 m/s

Roughness: 0.0100 m Elevation: 167.9 m (550.9 ft)

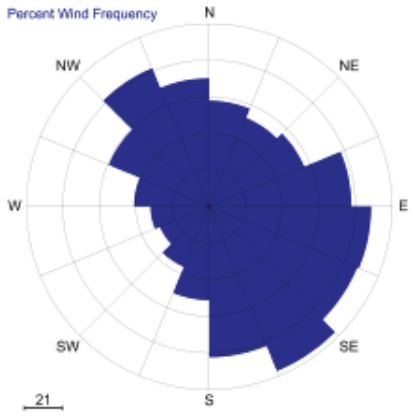
Air Density: 1.259 kg/m3

Mean Power Density: 304 W/m^2

Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.03 Weibull k: 1.92

200m Graphs



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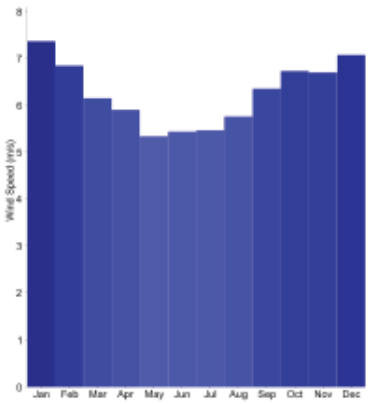

Monthly Distribution