APPENDIX N: ICE THROW RISK STUDY

MEMO

TO: Steffen Schwalfenberg

FROM: Alex Medd, E.I.T., Errol Halberg, P.Eng, Nicolas Simon, Ing., P.Eng.

SUBJECT: **Pokeshaw Wind Farm Ice Throw Risk**

DATE: **August 27, 2018**

WSP has investigated the risk of ice throw at the Pokeshaw Wind Power project. The developer has proposed a 300 m setback from the Pokeshaw Ridge Road. WSP has determined that the public safety risk due to ice throw is low and that a 300 m setback is reasonable.

BACKGROUND

MECHANISM OF ICING

Two predominant icing mechanisms have been identified by current research: in-cloud icing which occurs due to super-cooled droplets in low level clouds and freezing precipitation icing which is a result of rain drops in below zero temperatures[1]. Freezing precipitation and in-cloud icing result in the formation of rime or glaze ice. The temperature and size of the droplets as well as the rate at which they strike a surface governs the form of the ice. Glaze icing is predominantly the result of freezing precipitation. Rime icing occurs when structures are exposed to cold fogs or clouds[2].

Icing losses near the site have been evaluated by WSP and the percentage of time in a year where the conditions are favorable for icing. Icing was calculated using the Canadian Weather Energy and Engineering Data Set (CWEEDS) for the Charlo and Miramachi sites between 1967 to 1990 and 1953 to 2005 respectively[3]. The CWEEDS data was used to calculate the frequency of rime and clear icing, corrected for the difference in elevation at the reference station and hub height. The total icing loss based on CWEEDS was then compared to the icing frequency detected at Met Mast 1030 from the quality control process to confirm the seasonal profile. Based on an empirical fit of icing frequency to production loss[4], the production loss due to icing was calculated to be 3.2% of total production. This assumption neglects the use of blade heating. Thus, it is a conservative expectation that the turbine has the potential to throw ice for 3.2% of the year. This is a very low number as there are jurisdictions in Canada with icing rates over 30%. The low icing rates are due to the moderate temperatures associated with proximity to open water and low elevation.

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[1] Marjaniemi, M., Laakso, T., Makkonen, L., Wright, J., 2001. Results of Pori Wind Farm Measurements. (VTT Energy Reports 42/2001). Finland: VTT Energy, Energy Systems.

[2] Koleychuk, R., Silis, A., 1987. Preliminary Investigation of the Potential Effects of Icing on Wind Energy System Performance. (DSS File No. 54SZ-23216-6-6119) Ottawa: Energy, Mines and Resources Canada.

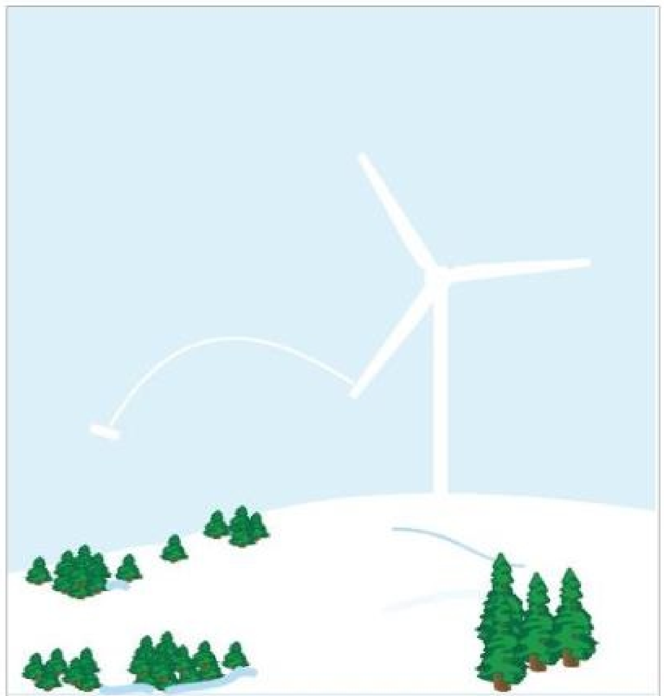
[3] Environment Canada, 'http://climate.weather.gc.ca/prods_servs/engineering_e.html

[4] Barry Turner, Jean-Marie Heurtebize, "Linking Icing Estimates to Operational Losses" CanWEA 2013

MECHANISM OF ICE THROW

When turbines have accumulated ice, the ice may be thrown if the turbine is in operation or fall if the turbine is stopped. Ice fall can travel some distance beyond the turbine in high winds. Ice will release from the wind turbine once it has sufficient mass or during a melt event. Large sheets of ice weighing several kilograms can be released from the turbine with enough energy to cause serious harm or property damage.

Figure 1: Schematic representation of Ice Throw



Two approaches are common in analyzing the potential for ice throw. The first is an empirical representation of throw distances based upon simplified approximation of worst case. The second is a ballistics model that considered frequency of various scenarios to represent the overall probability of risk.

Empirical Formula

A commonly used empirical model found in literature provides an estimation for the worst-case limit of ice throw distance according to Equation 1[5]:

Equation 1 - Generalized Turbine Setback

$$Setback = k * (Hub\ Height + Rotor\ Diameter)$$

Where:

- k=1.5.
- Hub Height = 135 m or 116 m
- Rotor Diameter = 126 m

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5 'Risk Analysis of Ice Throw from Wind Turbines' Seifert et al, 2003

Based upon turbine specifications proposed for the Pokeshaw project (Enercon E126), the throw distance for a 135 m hub height is 390 m. The throw distance for a hub height of 116 m hub height is 363 m.

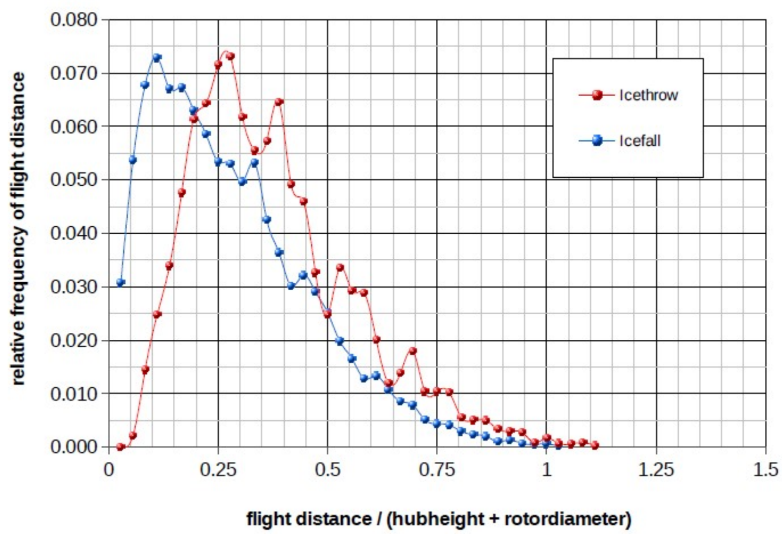
The author suggests that this should be interpreted only as a 'rough guess' and represents a conservative case. In addition, large or long ice fragments that are likely to pose a health or property risk have more aerodynamic drag and will hit the ground in a closer radius around the turbine compared to smaller pieces.

Probabilistic Models

A more sophisticated model considers the probability of risk superimposing scenarios where ice throw is likely to result in risk to the public.

Analytical ballistics models have shown that in simple terrain, ice throw and ice fall rarely exceeds k=1.0 per Figure 2[6]. The Pokeshaw site is orographically simple and ice throw distances exceeding k=1.0 or 260 m are expected to be uncommon. This model demonstrates that k=1.5 is a conservative assumption.

Figure 2 - Generalized Ice Throw Distance in Simple Terrain



A field study in Sweden[7] of 532 ice throw events found a maximum throw distance of k=0.86 which corresponds to 225 m for the E126 at a 135 m hub height. The turbines investigated did not have icing mitigation measures installed.

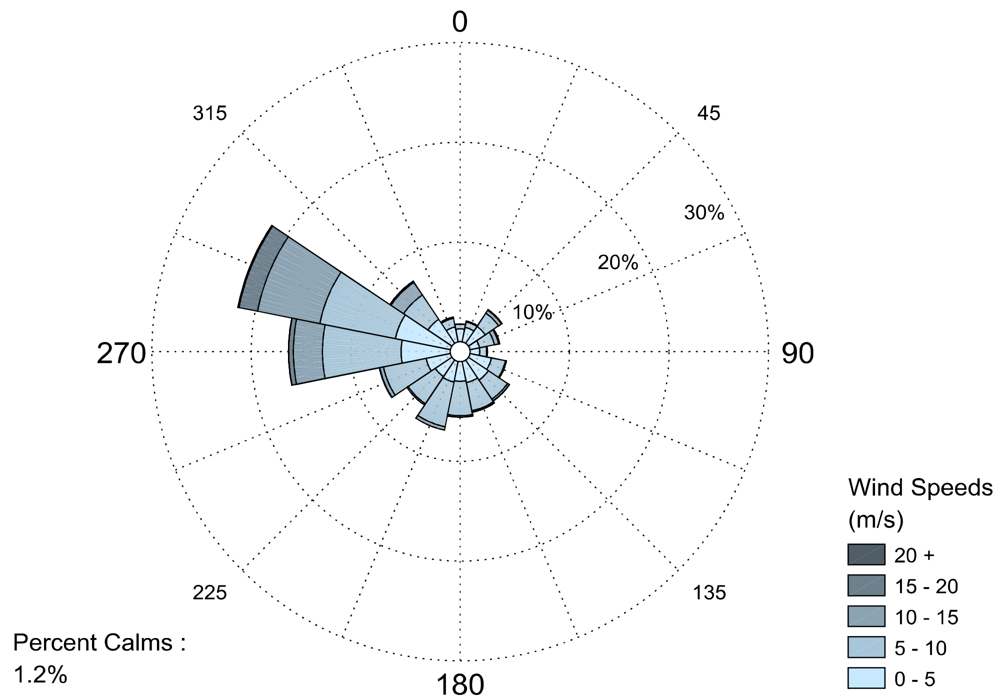
A field study[8] performed by ENERCON showed a maximum measured ice throw distance of 170 m for a turbine with a rotor diameter of 82 m and hub height of 78 m (k=1.06). This is equivalent to 277 m for the E126 at a hub height of 135 m.

A field study in Switzerland[9] has also found that ice fragments are mostly found downwind of the turbine locations.

[6] 'Ice Throw Hazard – Experiences and Recent Developments in Germany' Hahm, Stoffels, 2016
[7] 'Icethrower Mapping and Tool for Risk Analysis' Lunden, 2017
[8] ENERCON, 8_03_1_07_Barup_Making_ice_fall_and_throw_predictions_for_wind_turbines_mo....pdf
[9] 'Ice Throw Studies, Gutsch and St. Brais' Cattin, 2012

The wind direction distribution at the site is shown in Figure 3 where the predominant wind direction is from the west northwest. The respective positions of the road and wind turbine are shown in Figure 4. The wind blows directly away from the road most of the time, especially during high wind events, mitigating the risk of ice throw towards the road.

Figure 3 – Measured Wind Direction Distribution



QUALITATIVE ANALYSIS OF RISK

The following factors directly affect the risk of ice striking a vehicle or person at this site:

- The turbine must be iced to throw or drop ice. The turbine will be under meteorological icing conditions 3.2% of the time which is infrequent.
- Prior field studies indicate that it is reasonable to assume a maximum throw distance of 277 m.
- Due to the prevailing wind directions, most ice throw will have a trajectory away from the road, from the turbine towards the southeast.
- As shown in site photos in Figure 5, the road is closely bordered by trees in most locations. The trees may act as a barrier to ice throw in many locations further reducing the probability of risk.
- The turbine will be equipped with an ice detection and blade heating system:
  - The turbine will be shut down in severe icing conditions reducing the probability of ice throw. Specifications state that the turbine "is usually stopped within 30 minutes, i.e. before the thickness of the ice layer becomes a hazard to the surrounding area".[10]
  - The rotor will be equipped with heated blades, melting and shedding ice build-up before significant ice accretion.

[10] ENERCON, 5_Annex 03-14 ENERCON Ice Detection System.pdf

- The traffic on the road is expected to be infrequent which mitigates risk potential. The road is unmaintained and infrequently traveled as demonstrated by the poor road quality in Figure 5. The traffic may include uncovered snowmobile traffic; however, a New Brunswick Federation of Snowmobile Clubs Trail parallels the Ridge Road to the north and could divert traffic away from the wind turbines.[11]

All factors discussed indicate that the concomitance between road traffic and an ice throw event is improbable thus mitigating the risk to the public.

CONCLUSIONS AND RECOMMENDATIONS

WSP supports the setback of 300 m from the unmaintained road because the risk of ice throw reaching the road is low.

Additionally, other jurisdictions in Canada require significantly lower setbacks from roads than the 300 m proposed. Ontario requires a setback of blade length plus 10 m[12], or 73 m in this case.

Finally, CanWEA has provided best practice guidelines[13] for public safety in cold climate wind farms that can be implemented at the site to reduce risk to the public including the following:

- Danger signs must be visible and placed strategically. In this case, at all entrances to the road.
- Inform the public of danger including newspaper ads, snowmobile clubs and websites.
- Consider turbine shutdown during icing events to reduce the risk of ice throw.

Other mitigating strategies may include a control system to engage blinking lights when icing conditions are present.

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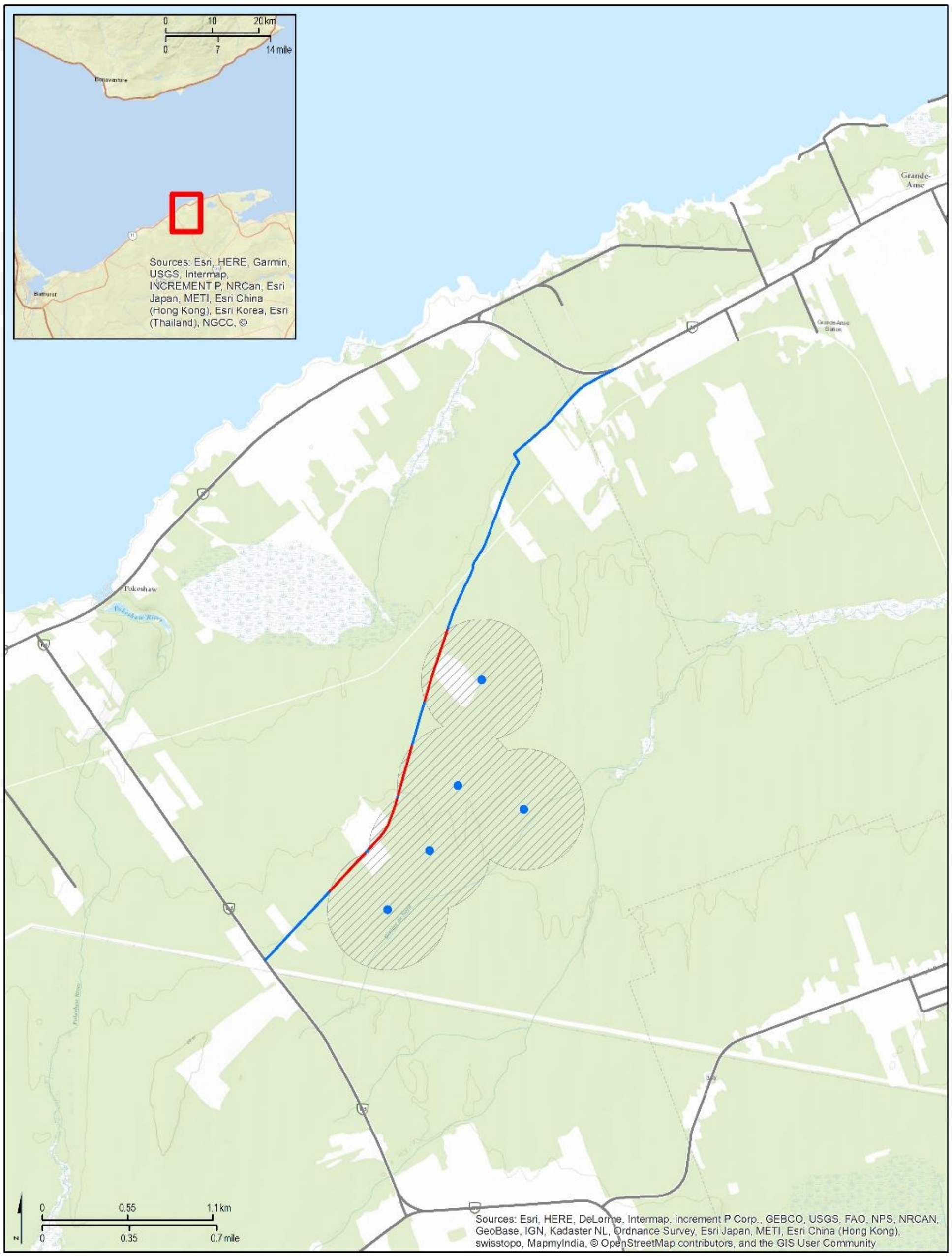
[11] https://www.nbfsc.com/index.php/maps, New Brunswick Federation of Snowmobile Clubs, 2018
[12] 'Technical Guide to Renewable Energy Approvals – Chapter 3' Government of Ontario, 2018
[13] 'Best Practices for Wind Farm Icing and Cold Climate Health and Safety' CanWEA, 2017

Figure 4: Project Map



Pokeshaw Wind Power Project

Ice Throw Area Map

Legend

- Turbine Locations
- Potential Conflict Area
- Pokeshaw Ridge Road
- Road
- k=1.5 Buffer - 391 m

Date: 2018-08-23
Version: 1
Datum: NAD 83
Projection: UTM Zone 20
Scale: 1:24,000

Prepared by: WSP
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In the preparation of this map, WSP has relied upon certain information provided by the client. While WSP has taken reasonable measures to present accurate information in the map, WSP does not warrant the reliability, accuracy, quality, currency, validity, or completeness of information found in the map. The locations shown are for informational purposes only and are not suitable for legal, surveying, or engineering purposes.

Figure 5: Photos of Unmaintained Road