South Branch Wind Farm

ICE THROW REPORT

Revision 2

For

Prowind CANADA

By

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2012 January 23

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1 BACKGROUND

1.1 Purpose

This report provides estimates of the distance and quantity of prospective ice throw from operating turbines in the South Branch Wind Farm. Based on a series of assumptions with respect to ice throw from the turbines, the results are presented in terms of probabilities for ice to land at any specific location surrounding each of the turbines, including the cumulative effect around multiple turbines.

1.2 Revision 0

Revision 0 of this report used Zephyr North's ice throw trajectory model for specified wind turbine characteristics, plus ice fragment estimates comparable to those in a similar report (Leblanc, 2007) written for Ontario wind and freezing precipitation conditions. These are coupled with site specific wind and freezing rain data for a nearby location, and are used as a basis for predicting and mapping potential ice throw from the turbines planned for deployment in the South Branch Wind Farm.

1.3 Revision 1

Revision 1 included an additional section with cumulative estimates of ice fragment strikes for two specific areas – Byker Road and Property D.

1.4 Revision 2

This revision (Revision 2) includes additional discussion with respect to the probability of an ice particle striking a travelling vehicle on Byker Road. It also includes a number of minor formatting changes, minor corrections and a discussion of computations of ice fall from a stationary turbine.

1.5 Theory and Modelling

Safety risks associated with icing on wind turbine blades have long been recognized as a cause for concern in cold climates. Reports such as those by Morgan *et al.* (1998) and Seifert *et al.* (2003) review the problem, and describe ice fragment trajectory models. The report prepared by Garrad Hassan & Partners (Leblanc,

2007) for the Canadian Wind Energy Association (hereinafter referred to as GHP) presents specific recommendations for risk assessment in Ontario.

In this report, Zephyr North's ice throw trajectory model uses the same basic trajectory equations as the model used in the GHP report but allows wind speed to vary more realistically with height according to the usual logarithmic profile. It is based on work described in Biswas *et al.* (2011). This latter paper explores a wide range of particle, wind, and turbine parameters and also presents some sample computations with lift as well as drag forces on the ice fragments.

While the authors are not aware of any reports of personal injury or significant property damage caused by ice falling or thrown from wind turbines in Ontario, there have been reports of ice falling from turbines as documented for example in the GHP report. The biggest problem in assessing the risk of ice throw and its dependence on position relative to a turbine is the serious lack of quantitative data related to these rare occurrences.

1.6 Application and Recommendation

It is important to appreciate that in almost all icing situations, these conditions will be predicted or detected and turbine operation will be terminated — automatically, or by the operator. Ice falling from the tower and blades would remain a problem but would be limited to the immediate vicinity of the turbine, and appropriate safety procedures can be implemented.

It should be emphasized that a prudent wind farm operator would shut down turbines in icing conditions for both safety considerations and to avoid potential damage to the turbine. The initial estimates of risk do not take this into account but in Section 6.4 computations of ice fall from a stationary turbine are discussed. With sufficiently strong winds (30 ms^{-1}) the model predicts that ice fragments falling from the tip of a vertically upward pointing blade could be blown about 180 m downwind but with hub height winds < 20 ms^{-1} no fragments traveled more than 100 m downwind.

2 ICING CONDITIONS OBSERVATIONS IN ONTARIO

Both freezing rain/drizzle or extensive hoar frost deposition due to ice fog or cloud can lead to a buildup of ice on turbine blades but in southern Ontario the occasional occurrence of freezing rain is probably the only cause of significant icing. A climatology of the frequency of occurrence of icing conditions is required in order to determine the number of occasions on which there is potential for ice build-up. Fortunately, in Ontario such climatologies exist. (See, for example, http://ontario.hazards.ca/maps/intro5-e.html.)

However, details of the likely size and number of falling or thrown ice fragments must be determined from other sources. Unfortunately, there are very few of these other sources.

The Environment Canada web site http://ontario.hazards.ca/maps/intro5-e.html provides maps of the number of days and number of hours with freezing precipitation in Ontario. See http://ontario.hazards.ca/docs/Klaassen_et_al,_2003-e.pdf for more detail from Klaassen *et al.* (2003).

The closest location to the South Branch Wind Farm reporting icing data appears to be the Meteorological Service of Canada Ottawa International Airport observing station at an elevation of 114 m above sea level (a.s.l.). This station has an average of 9.7 days with freezing rain per year (between November and April). This is the highest frequency of those sites in south central Ontario and bordering U.S. locations reported in the Klaassen *et al.* report. Freezing rain duration was reported, on average, for 36.6 hours during the 9.7 days. The maximum duration for the study period 1953/1954 to 2000/2001 appears to be near 25 days, and the standard deviation appears to be about 3 days. These values have been taken from the plot presented in the report. There was no significant trend.

Based on the Klaassen *et al.* report, and noting that Ottawa Airport has the highest frequency in the region and is at a slightly higher elevation than South Branch (at 76 m a.s.l.), it is estimated that nine days of icing per year are possible for the South Branch Wind Farm area. These are days when freezing precipitation occurs. The GHP report for Ontario focuses on conditions with 5 icing days per year.

3 ICE THROW TRAJECTORY MODELS

3.1 Garrad-Hassan Report

The GHP report uses a trajectory model for a generic wind turbine with an 80 m hub height and 80 m rotor diameter. For that analysis, the rotor speed was set to 15 rpm. For each ice fragment, the mass (M) was taken to be 1 kg and assumed to have a frontal area (A) of 0.01 m^2. This would correspond to an ice fragment of dimensions 0.1 m x 0.1 m x 0.111 m with an ice density of 900 kgm^{-3}. The drag coefficient (C_D) was 1.0, aerodynamic lift was not included, and the assumed wind speed distribution was independent of height and had a mean value of 8 ms^{-1}. The basic calculation made in the ice throw model described in the GHP report to the Canadian Wind Energy Association is of the number of ice strikes per square metre of area (on the ground) per fragment release, ISPR(r), as a function of r, the radial distance from the base of the turbine. This value is then multiplied by the estimated number of ice fragments released per ice day and by the number of ice days per year to obtain ISPY(r), the number of ice strikes per square metre per year (strikes/m^2/year). In GHP, these are reported as averages for circles surrounding the turbine and do not take into account the preferred wind directions during periods when ice may be present, and shed from the turbine. Figure 1 is copied from the GHP report and shows the radial variation of probability of ice strike per square metre per release of an ice fragment, ISPR(r), based on its assumed distributions of release position and wind speed. Trajectories were computed by GHP for randomized release points in a Monte Carlo numerical simulation involving 100,000 ice fragments.

At 100 m distance the probability is about 6 x 10^{-6} per m^2 per fragment release and at 200 m it drops to 5 x 10^{-7} per m^2. One assumption made by GHP is that the probability of ice detachment at the blade tip is three times greater than at the hub, with linear interpolation used for other radial positions. Blades are however broader near the hub and it can be argued that this offsets the increased relative airspeed and centrifugal effects near the tip. In the calculations to be presented with the Zephyr North model, the probability of fragment release is assumed to be independent of radial position.

Leblanc (2007) does not specify the number of releases per ice day assumed, but based on ratios extracted from that paper's Figures 3.2 and 3.4 for 50, 100 and 200 m, it is between 110 and 240. It is not clear why these values differ but it is assumed that the 110-120 values derived from 50 and 100 m ratios are more reliable.

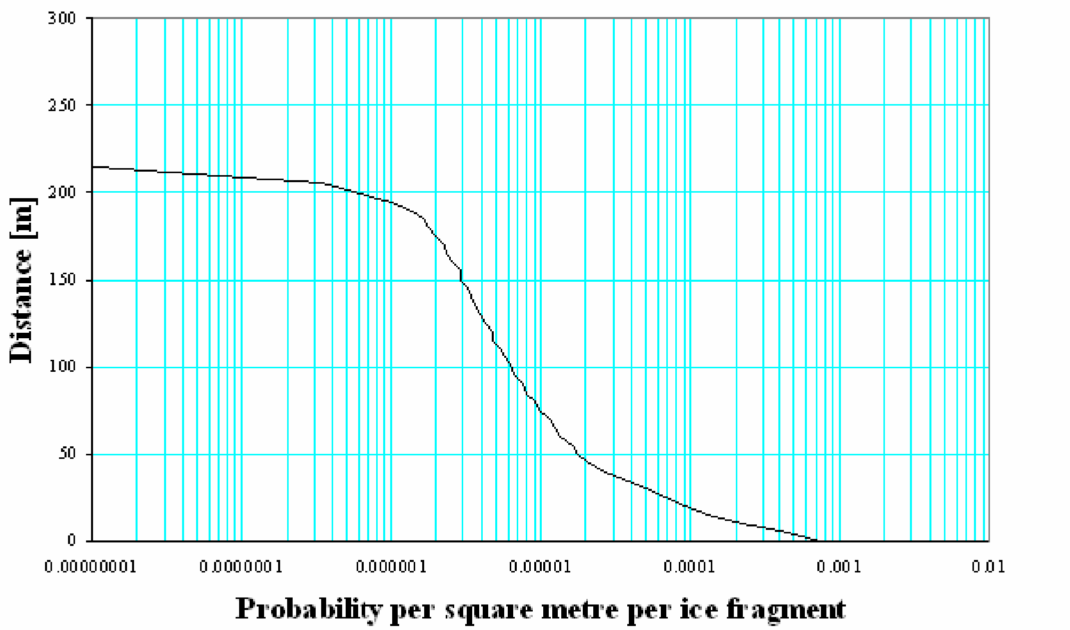

Figure 1: Distances corresponding to relative probability of ice fragment strikes for a single ice fragment release for a representative case for Ontario (from Leblanc 2007).

3.2 The Zephyr North Ice Throw Model

The Zephyr North ice throw model is based on the trajectory model described in the paper by Biswas *et al.* (2011). For the present study, it was applied with specified turbine characteristics and run for a range of wind speeds. Releases are for 100 points along the blade and for 360 angular blade positions. Twenty-five wind speeds (0.5 to 24.5 ms^{-1}) are used for a total of 900,000 different trajectory calculations. Ice fragments have mass of 1 kg, frontal area of 0.02 m^2, and a drag coefficient of 1.0. Sensitivity to these parameters is discussed in Biswas *et al.*

In these calculations, it is assumed that the terrain is flat with no variation in terrain elevation between the turbine and landing locations. Adjustments can be made for more complex terrain but were not considered necessary in this application.

The resulting fragment landing positions for all wind speeds, and with appropriate angular rotations, are coupled with a joint wind speed and direction distribution to produce a plot of the frequency of impacts per ice fragment release per unit area for the specified turbine and wind regime.

4 APPLICATION TO THE SOUTH BRANCH WIND FARM

4.1 Prospective Project Turbine Models

Several wind turbine types are under consideration for this project. Test ice throw trajectory computations were made with each of the prospective turbines' characteristics — hub height, rotor diameter, and rotation speed. Maximum ice throw distances were computed for a typical case — 1 kg ice fragment, $0.02m^2$ fragment frontal area, and 10 ms^{-1} hub height wind speed). All were similar and ranged from 175 to 195 m. The calculations to follow have been carried out for the REpower 3.2M114 since the maximum throw distance occurred for this turbine model. The hub height was set at 128 m, blade length at 57 m and rotation rate at 14.6 rpm, rotating clockwise when viewed from upwind of the turbine.

4.2 Single Turbine Modelling Results

Figure 2 shows results for a single turbine with the November-April wind speed and direction distribution computed from data supplied for the South Branch Wind Project. The joint frequency table is shown in Table 1. Landing frequency results are checked to ensure that the total integrates to 1.0. Because of interpolations between polar coordinate and Cartesian coordinate representations there are slight errors amounting to no more than 2%.

As revealed by the project's site climatology, the predominant moderate to strong winds are from the southwest which explains the slightly higher concentrations of impacts northeast of the turbine in Figure 2, while the higher values to the northwest are caused in part by fragments thrown laterally at lower wind speeds. Near the base of the turbine values are up to 1.2×10^{-4} per square metre but drop to below 10^{-5} per square metre within 100 m of the turbine base. Only 3.1% of the fragments travel beyond 100 m and 0.02% beyond 200 m.

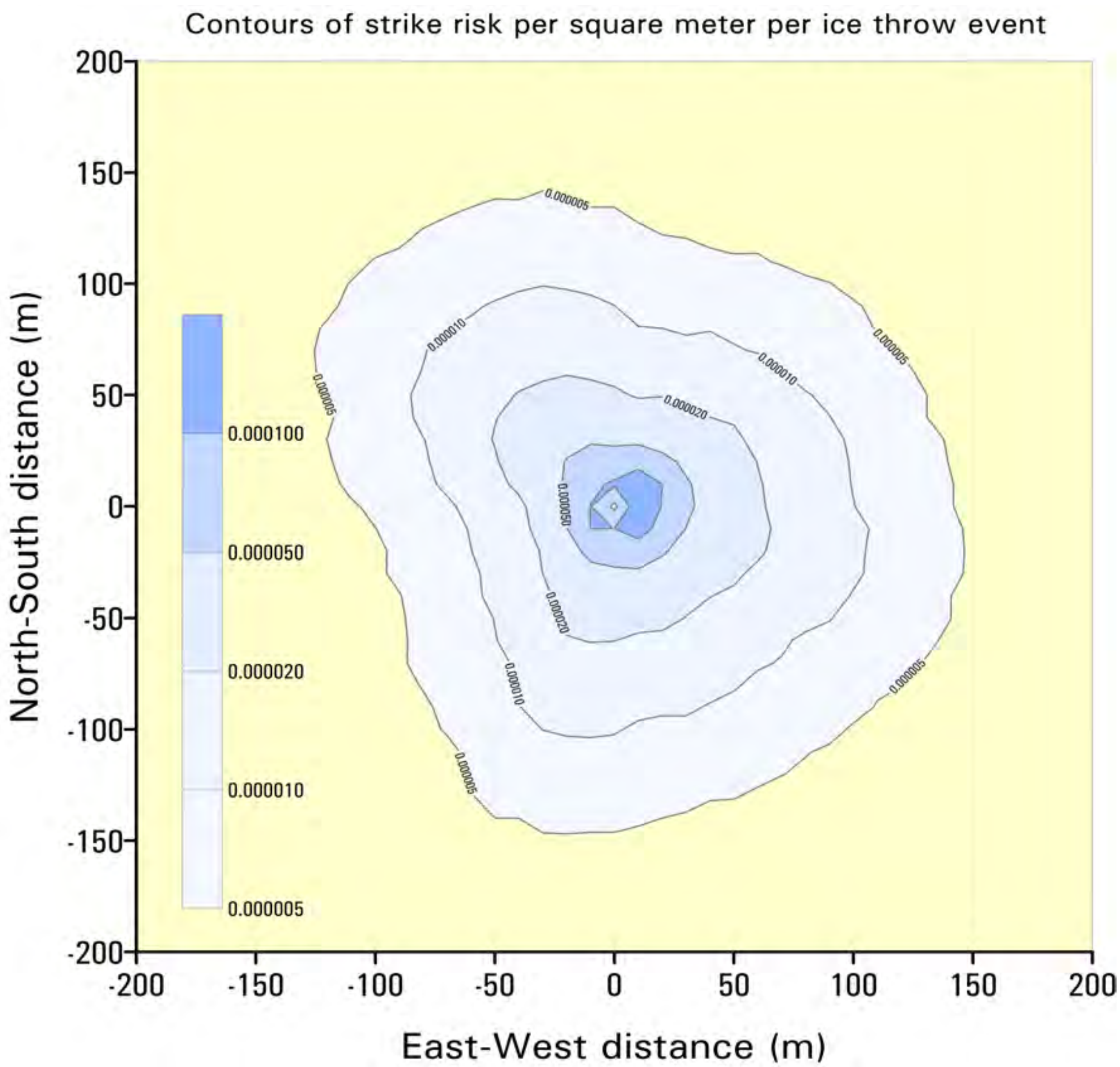

Figure 2: Ice strikes per square metre per release for a single turbine in the South Branch Wind Project. Meteorological data as in Table 1.

Table 1: Joint wind speed and direction frequency (%) table for South Branch Wind Project. Hub height winds, November to April inclusive.

Joint Frequency Table, South Branch Wind Project: Hub Height Winds, November-April inclusive															
Wind Speed Bins (M/s)			Direction Sectors												
	Lower	Upper	345° - 15°	15° - 45°	45° - 75°	75° - 105°	105° - 135°	135° - 165°	165° - 195°	195° - 225°	225° - 255°	255° - 285°	285° - 315°	315° - 345°	All Directions
1.0	0.0	1.0	0.2040	0.2283	0.2747	0.1737	0.1825	0.2252	0.1430	0.1407	0.1825	0.1410	0.1567	0.1830	2.2352
2.0	1.0	2.0	0.5055	0.6272	0.7060	0.4013	0.3282	0.3565	0.3252	0.3090	0.2495	0.2077	0.2783	0.3047	4.5990
3.0	2.0	3.0	0.7813	1.0693	1.1365	0.9255	0.6363	0.3897	0.5463	0.5370	0.4257	0.4415	0.5698	0.5737	8.0327
4.0	3.0	4.0	0.8087	1.1893	1.3062	1.3663	0.9257	0.5955	0.6738	1.0388	0.8745	0.9463	1.1285	0.9315	11.7852
5.0	4.0	5.0	0.8960	0.9948	1.2320	1.5720	0.9038	0.6348	1.0428	2.0090	1.5598	1.5928	1.7988	1.2632	15.5000
6.0	5.0	6.0	0.8150	1.0068	1.1843	1.4402	0.5487	0.4710	1.3255	2.7188	1.8908	1.7340	2.3320	1.4152	16.8823
7.0	6.0	7.0	0.7313	0.6315	0.7673	1.2402	0.4270	0.2507	1.1093	2.6302	2.0193	1.4148	2.3012	1.2903	14.8132
8.0	7.0	8.0	0.4087	0.3050	0.4858	0.8633	0.2192	0.1500	0.7218	1.9713	1.3368	0.9115	1.4400	0.9578	9.7713
9.0	8.0	9.0	0.1547	0.1470	0.4008	0.5423	0.0563	0.1210	0.6500	1.1825	0.9960	0.6690	1.1338	0.5593	6.6128
10.0	9.0	10.0	0.0807	0.0627	0.2988	0.2267	0.0102	0.0390	0.5227	0.7000	0.6670	0.4593	0.6708	0.2557	3.9935
11.0	10.0	11.0	0.0438	0.0270	0.1473	0.0792	0.0010	0.0213	0.2908	0.4957	0.3920	0.2553	0.4517	0.1443	2.3495
12.0	11.0	12.0	0.0065	0.0152	0.0783	0.0442	0.0010	0.0288	0.1645	0.3718	0.3462	0.1457	0.2502	0.0627	1.5150
13.0	12.0	13.0	0.0000	0.0097	0.0187	0.0117	0.0000	0.0075	0.0702	0.2023	0.2185	0.1230	0.1535	0.0220	0.8370
14.0	13.0	14.0	0.0000	0.0065	0.0188	0.0022	0.0000	0.0030	0.0200	0.0842	0.1235	0.0712	0.0963	0.0213	0.4470
15.0	14.0	15.0	0.0000	0.0077	0.0193	0.0012	0.0000	0.0068	0.0032	0.0437	0.0852	0.0388	0.0383	0.0133	0.2575
16.0	15.0	16.0	0.0000	0.0000	0.0150	0.0000	0.0000	0.0030	0.0042	0.0170	0.0535	0.0268	0.0117	0.0055	0.1367
17.0	16.0	17.0	0.0000	0.0012	0.0037	0.0000	0.0000	0.0048	0.0048	0.0075	0.0435	0.0193	0.0080	0.0010	0.0938
18.0	17.0	18.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0058	0.0170	0.0302	0.0055	0.0022	0.0000	0.0637
19.0	18.0	19.0	0.0000	0.0000	0.0043	0.0000	0.0000	0.0010	0.0020	0.0032	0.0240	0.0033	0.0010	0.0000	0.0388
20.0	19.0	20.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0020	0.0022	0.0123	0.0022	0.0000	0.0000	0.0197
21.0	20.0	21.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0033	0.0022	0.0012	0.0000	0.0000	0.0087
22.0	21.0	22.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0043	0.0000	0.0000	0.0000	0.0055
23.0	22.0	23.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0012	0.0000	0.0000	0.0000	0.0022
24.0	23.0	24.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010
25.0	24.0	25.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0010

4.3 Cumulative Results

The results for single turbines can be combined by adding the impact probabilities for a number of turbines after specifying turbine locations. For the South Branch layout, however, the turbines are sufficiently well separated that there is minimal overlap between impacts from different turbines. There is also a considerable distance between turbine groups T1-to-T4 and T5-to-T15 so maps for each group are presented separately in Figure 3 and Figure 4 respectively. These show plots of the number of strikes per release, with one release per turbine. Values along Byker Road are less than 0.000005 per square metre. Ice thrown from turbines other than T2 is highly unlikely to reach Byker Road according to these model calculations.

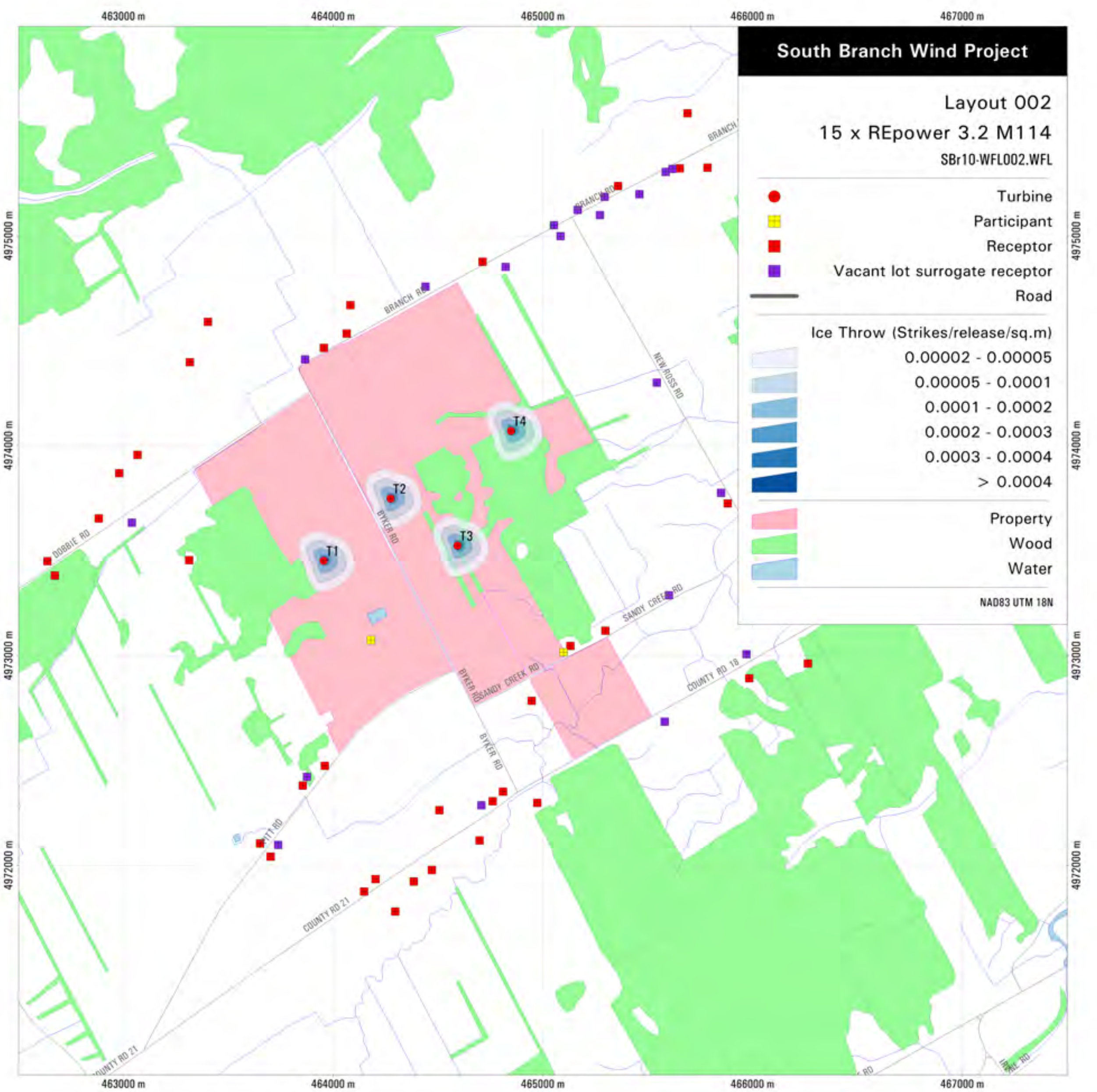

Figure 3: Ice throw landing probabilities for turbines T1 to T4. Contoured values of strikes per ice fragment release, one release per turbine.

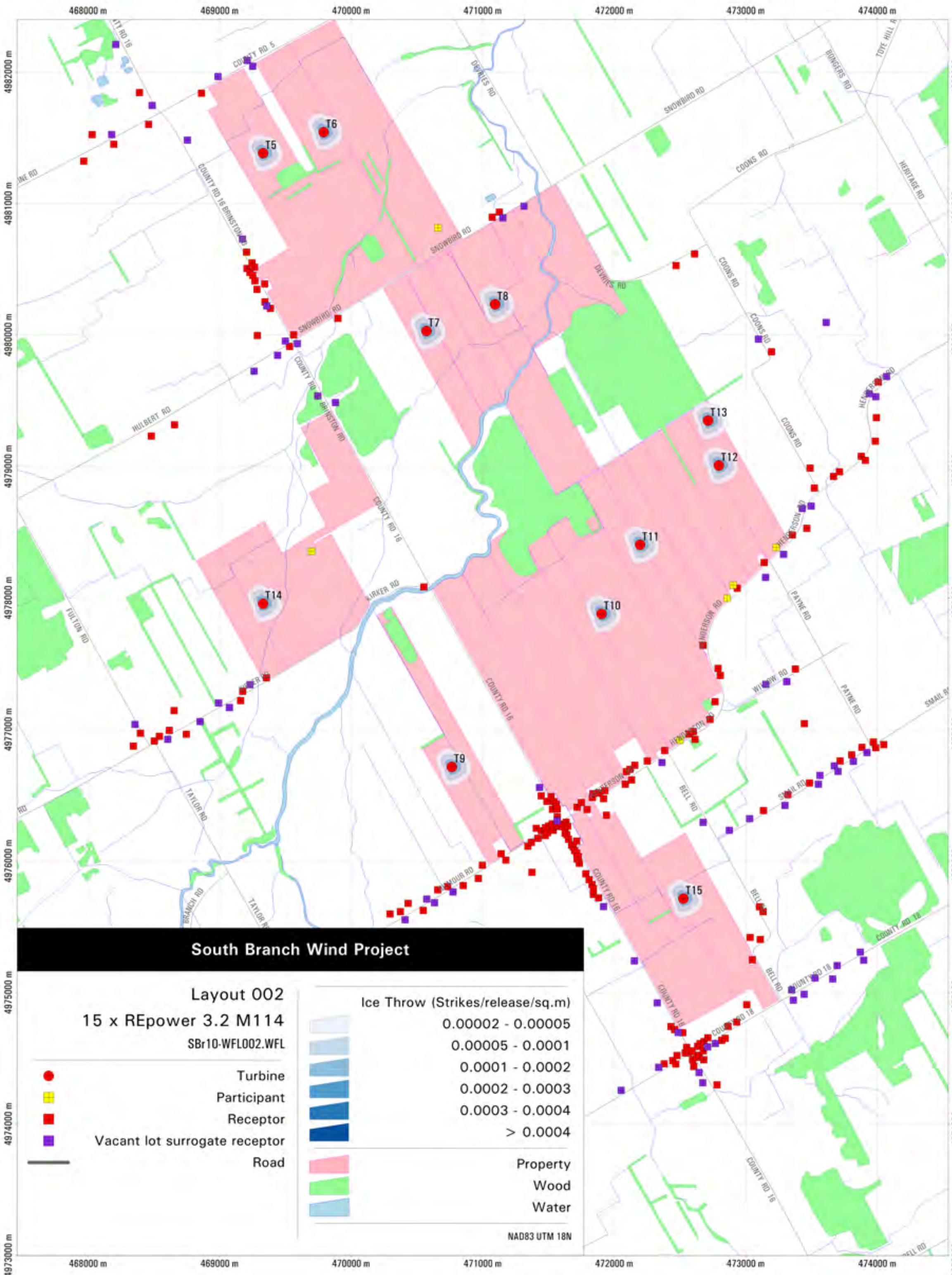

Figure 4: Ice throw landing probabilities for turbines T5 to T15. Contoured values of strikes per ice fragment release, one release per turbine.

4.4 Ice Days And Fragment Releases Per Year

There is considerable uncertainty regarding the amount of ice that could fall from the wind turbine blades. The inferred GHP assumption (Leblanc, 2007) of approximately 110 to 120 1-kg fragments of ice released per icing day is a plausible estimate but operating field experience and anecdotal evidence suggests that this estimate should be regarded as very conservatively high, possibly by a factor of ten. It would be very helpful if some quantitative certainty through field research were brought to bear on this factor.

Again, it is important to bear in mind that under normal operational protocol the turbines would generally have stopped operating in icing conditions, and ice fragments would simply fall, rather than be thrown, from the blades, and would land much closer to the turbine.

Based on 110 fragments per turbine per event and nine events per year the values in Figure 3 and Figure 4 should be multiplied by 1000 in order to estimate possible strikes per year. On this basis, the values at the outer edge of the pale blue regions around each turbine would correspond to one strike per square metre every 200 years.

4.5 Summary

Based on the calculations described above, the chance of an ice strike (per square metre) beyond about 150 m from an operating turbine with accumulated ice is less than 0.000005 per release, and with 1000 releases per year this is less than one strike in 200 years. Near the turbine, the possibility increases, but there is no reason for members of the public to be near a turbine (operating or not) when there is ice accretion on the blades.

5 BYKER ROAD AND PROPERTY D

Two areas of special interest are the section of Byker Road between turbines T1 and T2 and the property to the east of turbines T12 and T13 (Property D). For these sites, the risks per square meter shown in Figure 3 and Figure 4 can be integrated over the areas involved to estimate the total numbers of ice fragments that could potentially fall on Byker Road or on Property D.

5.1 Byker Road

5.1.1 Annual Impacts

Byker Road is relatively narrow, but to provide a conservative (*i.e.*, high) estimate, a total road width of 8 m is assumed. The segment of road potentially affected by ice fragments thrown from turbine T2 is about 200 m long. There is also a very remote possibility of impacts from turbines T1 and T3.

Integration of the impact frequencies over the Byker Road strip shown in Figure 5 gives 0.022 impacts if one fragment is released from each of turbines T1 to T4. With 1000 releases per year this could lead to 22 impacts by 1-kg fragments, but it must again be noted that this is very conservative. As a reference, note that 1 cm of freezing rain would deposit approximately 16,000 kg of ice directly on the 200 m section of Byker Road on each occasion.

5.1.2 Vehicle Impact

Although these ice throw and ice fall computations indicate the possibility of a number of ice fragments falling on the road each year, the likelihood of impacts on vehicles is much lower. No traffic information is available but for a relatively remote, unpaved, rural road such as Byker it is unlikely to exceed 100 vehicles per day in winter. Assuming that the road area potentially impacted by ice is 300 x 8 m then the area and exposure duration per day is 2,400 m^2 x 86,400 s. If vehicles travel at 15 ms^{-1} (54 km/hr) they will be within the 300 m road length for 20 s and occupy about 6 m^2. With 100 vehicles per day, the likelihood of impact by an ice fragment falling on that section of road is then 6 x 20 x 100/(2,400 x 86,400) = 5.8 x 10^{-5} and with 22 ice fragments impacting the roadway, the annual likelihood of an ice-vehicle impact is 0.0013, *i.e.*, one impact every 785 years.

In a similar manner, the annual likelihood of vehicle impact with the turbine *stationary* during any icing events reduces to 0.0010, or one impact every 985 years.

5.2 Property D

5.2.1 Annual Impacts

Property D is shown in Figure 6. An integration analogous to that for the Byker Road case leads to 0.094 impacts when one fragment is released from all turbines, resulting in 94 per year if there were 1000 releases. Again this is a conservative estimate over a large area. Note that the fragments would not travel far enough to reach the southern portion of this property.

Figure 4 and Figure 6 show dwellings or “receptors” and a vacant lot surrogate receptor in Property D. The closest of these is 700 m from the nearest turbine and in model computations with the turbine rotating in a wind speed of 30 m/s, no ice fragments traveled beyond 335 m from the turbine. The maximum distance for a stationary turbine is 170 m.

Other receptors lie to the north-east of T13 at a distance of about 700 m. Again this is well beyond the computed ice throw range.

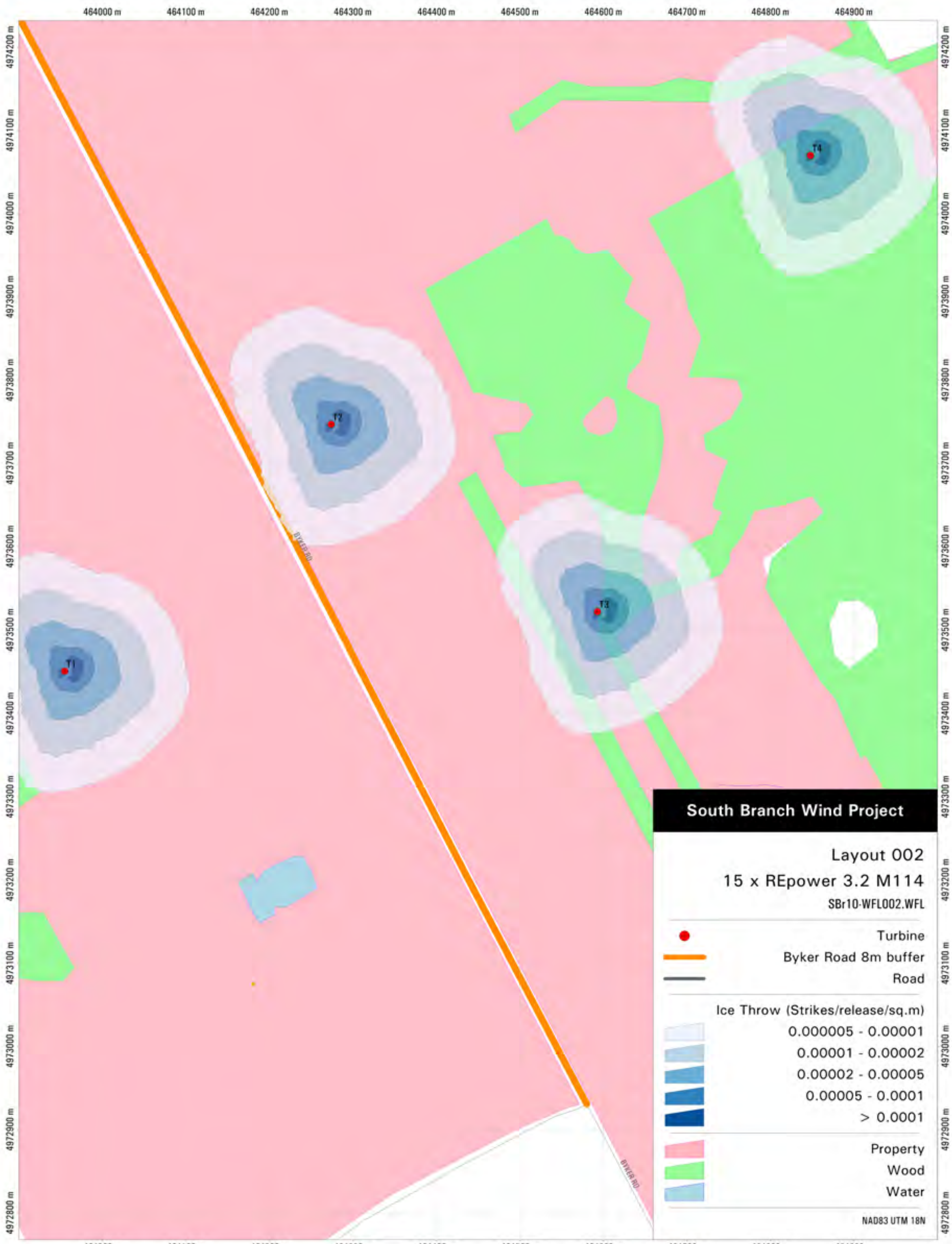

Figure 5: Location of Byker Road and turbines T1 to T4.

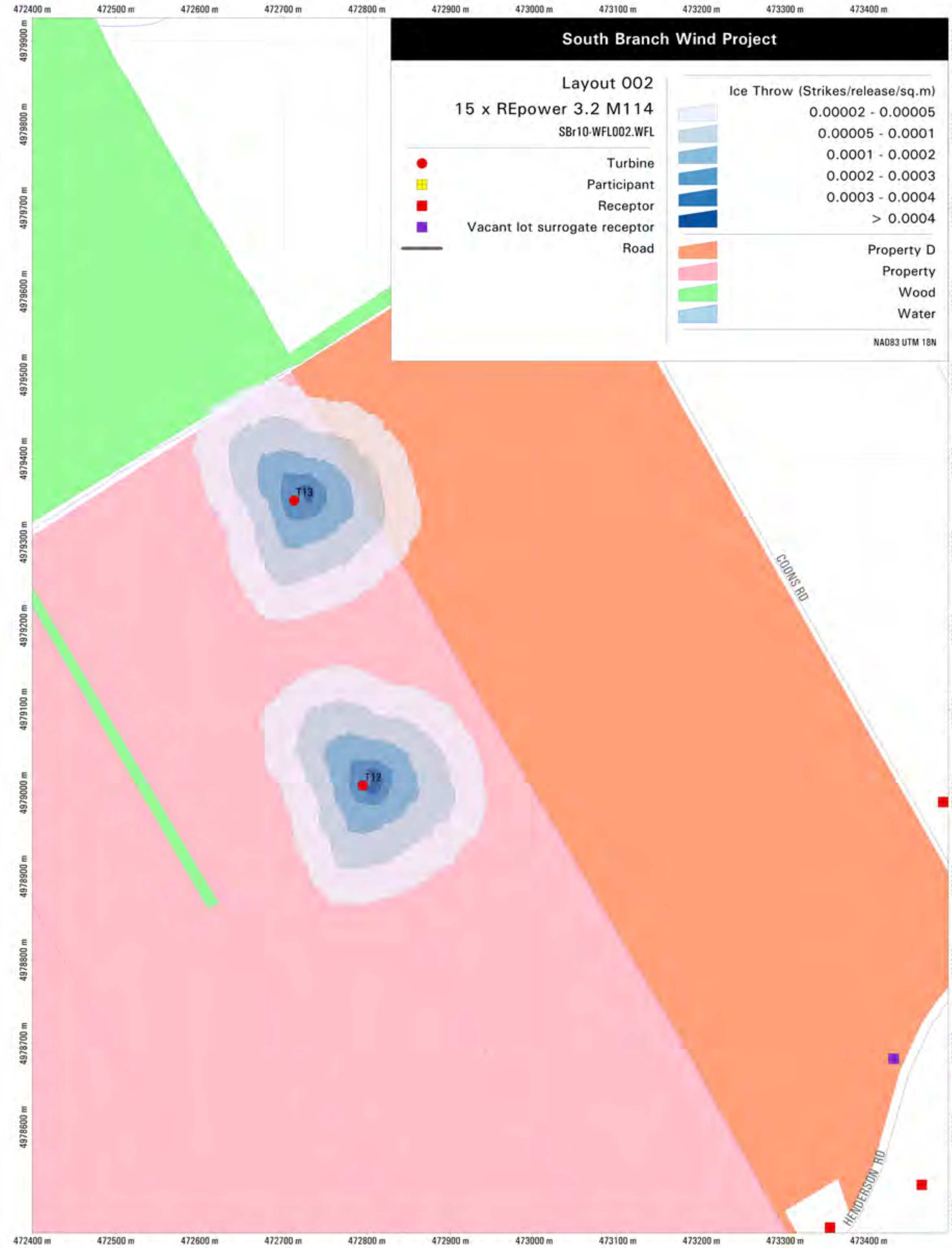

Figure 6: Location of Property D and turbines T12 and T13.

6 MITIGATION MEASURES

As described previously, the probability of an ice fragment thrown from an operating turbine striking a specific location is exceedingly small and decreases rapidly with distance from the turbine. Nevertheless, a number of ice throw mitigation measures can reasonably be applied in all circumstances. These will be described in the following sections.

It is important to note, though, that the primary ice-throw mitigation measure should be to cease operation of the turbines when there is a build-up of ice on the blades.

6.1 Operating Protocol

6.1.1 Ice Detection

The control system in a modern turbine can automatically shut down the turbine should it detect conditions resulting from icing of the blades.

While each manufacturer has its own protocol for detecting and responding to ice buildup, most use the correlation between power and wind speed. That is, if the measured power output is not equal to the expected power output based on the measured wind speed, the control system concludes that there is ice present, and shuts down the turbine. It should be noted that virtually all turbines designed for temperate climates use heated wind sensors to ensure that the correct wind speed is, indeed, being measured, even if an icing event is occurring. Once a specific turbine is chosen for the South Branch Wind Project, details of the icing protocol for that turbine can be provided.

The detection of vibrations (by a shaft vibration sensor) caused by rotor imbalance due to asymmetrical ice formation on the blades is another approach.

External freezing rain detectors are also available for deployment.

6.1.2 Ice Forecasting

Freezing rain generally occurs during winter warm frontal passages when surfaces are cold and water droplets, especially super-cooled water droplets, impact the surfaces and freeze. During such events, freezing rain forecasts are issued by the

Meteorological Service of Environment Canada. Wind farm operators should be trained to pay particular attention to these forecasts, and should then be prepared to effect a shut-down of the turbines once freezing precipitation is detected at the site.

6.1.3 Ice Prevention

Some turbine manufacturers (Enercon, as an example) offer blade heating devices that prevent ice accumulation in the first place. Obviously, this is a solution that renders the issue of ice throw moot.

6.2 Training

Once there has been a build-up of ice on the turbine blades and/or tower and the turbine has ceased operation, the risk of falling ice will be limited to the immediate vicinity of the turbine and slightly downwind. Clearly these areas should be avoided until the ice has melted, fallen or sublimated unless access to the turbine is absolutely essential.

There is very little, if any, reason to require a visit to an iced-up turbine, and avoiding any turbine in this condition should be a priority.

In the unlikely event that an individual is required to visit a turbine with ice, he or she should receive training to the effect that the turbine should only be approached from upwind and appropriate caution should be exercised, noting that ice can fall from any part of the turbine — blades, nacelle, tower. In addition, training should emphasize that the turbine should be shut down remotely (if not stopped already); the rotor should be yawed (if safe to do so) to the side of the tower away from the access door; and the turbine should be restarted remotely after personnel have vacated the site. As always, appropriate safety gear (hard hats, safety glasses, steel-toed boots, *etc.*) should be worn. If possible, approach should be made in a sturdy vehicle with protection for the roof. Alternatively, the vehicle should be parked at least 100 m from the turbine.

The same considerations that would apply to bridges, power lines or other elevated structures subject to icing are relevant to the case of wind turbines.

While it is highly unlikely during the winter/icing season, there is a possibility that the landowner (or employees, or sub-lessees) will require access to the property in the vicinity of the wind turbine. These individuals should be offered training in ice safety with respect to approaching any stopped or operating turbine with accumulated ice.

6.3 Signage

While the recommended operating protocol described above is to avoid turbine operation under any conditions that could result in the accumulation of ice on the turbine blades, there is a very small possibility that small pieces of ice could be blown onto a nearby roadway as noted above. As with rock falls on highways, the chance of being struck by falling ice is remote but there could be a potential hazard from vehicles encountering ice fragments blown from the turbines in addition to the freezing precipitation that has already fallen on the road during the icing event. In this case it is proposed that drivers be warned of this (remote) possibility with signage along any affected roads bearing messages such as "Beware of Fallen Ice during Icing Conditions". Any stretch of road within 200 m of a turbine should be posted. This signage is analogous to the signs warning of fallen rock in areas subject to that hazard.

In addition to roadside signage, it is proposed that similar signage (*e.g.*, "Beware of Falling Ice from Wind Turbine during Icing Conditions") be posted along any possible driving or walking approach to a turbine. Signage would be posted at 200 m from the turbine and at blade-length+10m from the turbine. This latter distance corresponds to a safe perimeter around the turbine to avoid any ice fragments that drop off the turbine while it is stopped.

Again, it is emphasized here that there is virtually no reason why it would be necessary to approach a stopped (or operating) turbine with iced surfaces.

6.4 Ice Fall from Stationary turbines

Although ceasing turbine operation in icing conditions is highly recommended it will not eliminate the possibility of ice falling from the blades, nacelle or tower and being carried some distance by the wind. For hub height wind speeds less than 18 ms^{-1} calculations show that, for the standard ice fragment size and conditions (as above), no fragments will travel more than 100m from the turbine base. At 30 ms^{-1} the maximum range is 180 m implying that only ice from T2 could reach Byker Road since the maximum wind reported for this site was 25 ms^{-1}. The wind speed and direction distribution for the South Branch wind farm does however show that wind speeds exceed 17 ms^{-1} for 0.23% of the time but that these winds come from the north to southeast sector (about 345 through 0 165° true) only 0.02% of the time. On these rare occasions ice fragments from T2 could reach Byker Road.

For this report revision, the ice throw model used for the initial set of computations has been re-run with the turbine rotation rate set equal to zero. Using the wind speed and direction distribution from Table 1, distributions analogous to those shown in Figure 6 show impact likelihood values of about 10^{-5} per fragment release per square metre on Byker Road at the closest points to T2. With 1000 fragment releases per year and assuming a potentially affected road area of about 8 x 200 m, this leads to 16 impacts per year. Detailed computations integrating impact likelihood values over an extended section of the road lead to 16.9 impacts per year.

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