Environment

Jericho Wind, Inc.

Jericho Wind Energy Centre
Shadow Flicker Assessment Report

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1. Introduction

AECOM was retained by Jericho Wind Inc., a wholly owned subsidiary of NextEra Energy Canada, ULC (NextEra) to prepare a Shadow Flicker Assessment Report for the proposed Jericho Wind Energy Centre. Shadow flicker is a temporary condition resulting from the sun casting intermittent shadows from the rotating blades of a wind turbine onto a sensitive receptor such as a window in a building. The flicker is due to alternating light intensity between the direct beam of sunlight and the shadow from the turbine blades. For shadow flicker to occur, the following criteria must be met:

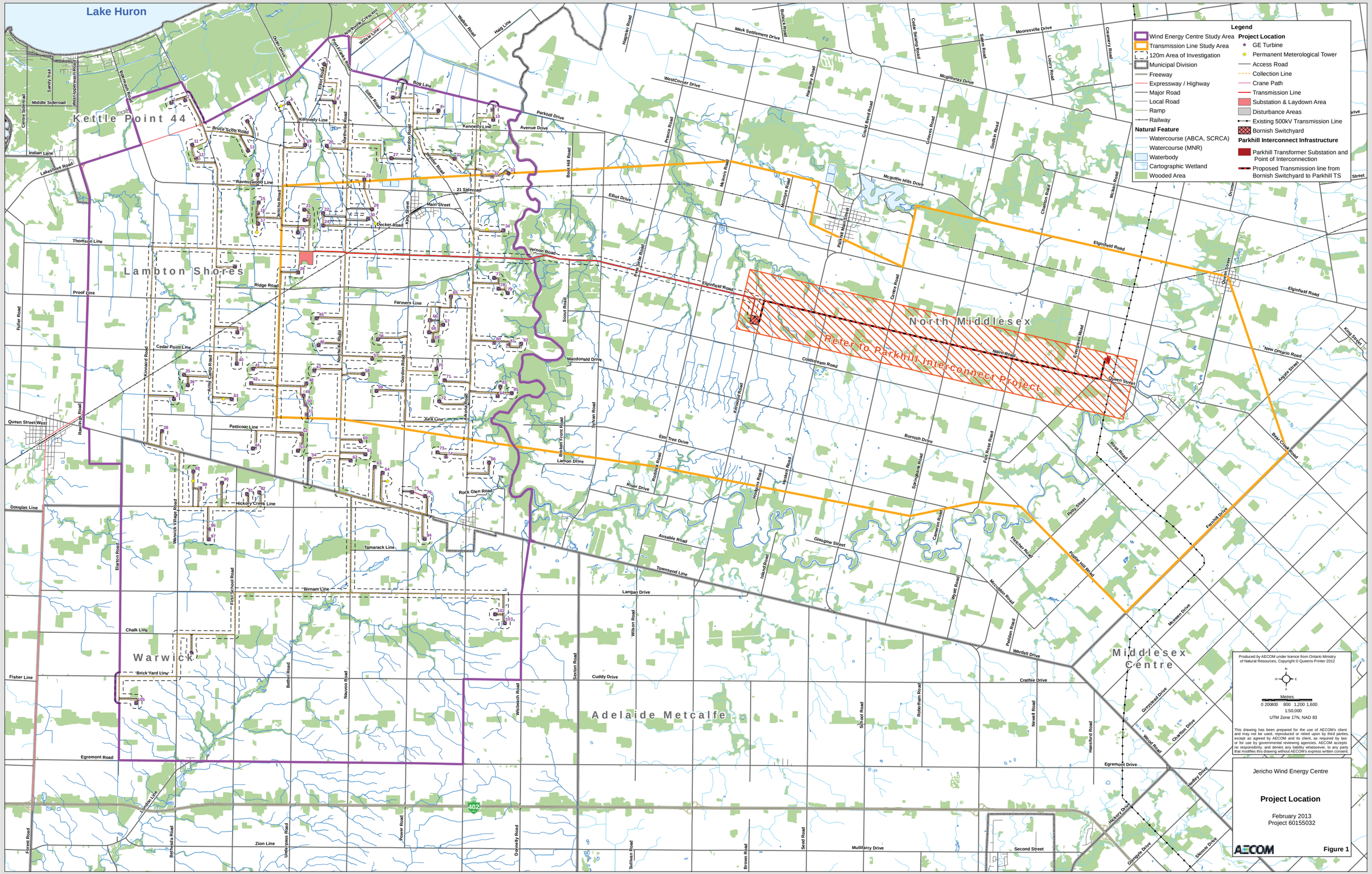
1. The sun must be shining and not obscured by any cloud cover.
2. The wind turbine must be between the sun and the shadow receptor.
3. The wind turbine must be facing directly towards (or away from) the sun such that the rotational plane of the blades is perpendicular to the azimuth of incident sun rays. For this to occur, the wind direction would have to perpetually be parallel to the azimuth of the incident sun rays throughout the day.
4. The line of sight between the turbine and the shadow receptor must be clear. Light impermeable obstacles, such as trees, buildings or other structures, will prevent or reduce shadow flicker from occurring at the receptor.
5. The receptor has to be close enough to the turbine to be in the shadow.
6. The turbine is operational and not stationary due to a lack of wind or maintenance activities.

2. Project Location and Study Area

Approval is being sought for up to 97 GE 1.6-100 Wind Turbine generator locations and pad mounted step-up transformers.

The proposed Project is located in the Municipality of Lambton Shores and the Township of Warwick, in Lambton County, Ontario and in the Municipality of North Middlesex, in Middlesex County, Ontario. The Project Study Area consists of the areas being studied for the wind energy component (Wind Energy Centre Study Area), as well as for the interconnection route (i.e., the area being studied for transmission lines to connect the Project to the electrical grid) (Transmission Line Study Area). The Wind Energy Centre Study Area is generally bounded by Lakeshore Road/Bog Line to the north, Egremont Road to the south, the Lambton Shores/North Middlesex municipal boundary to the east and Rawlings Road/Elarton Road to the west, in Lambton County. The Transmission Line Study Area is generally bounded by Kennedy Line, Parkhill Drive and Elginfield Road to the north, Jura Line, Elm Tree Drive and Poplar Hill Road to the south, Fernhill Drive to the east, and the Jericho Road to the west, in Lambton and Middlesex Counties.

The location of the Project Study Area was defined early in the planning process for the proposed wind energy facility, based on the availability of wind resources, approximate area required for the proposed project, and availability of existing infrastructure for connection to the electrical grid. The Project Study Area was used to facilitate information collection. The Project Location is provided in Figure 1.



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3. Shadow Flicker Sources

The wind turbine technology proposed for this Project is the GE 1.6-100 Wind Turbine. The turbines are 3-bladed, upwind, horizontal-axis wind turbines that are state of the art technology. The turbines have a 100 m rotor diameter with a swept area of 7,854 m^2; each blade is connected to the main shaft via the hub. The turbine model has a hub height of 80 m. The GE 1.6-100 Wind Turbine is designed to operate between 9.75 and 15.33 revolutions per minute (rpm). The turbine has a cut-in speed of 3 m/s and a cut-out speed of 13 m/s. The coordinates for the proposed turbines are listed in Table 1.

Table 1. Wind Turbine Locations

Identifier	UTM Coordinates	
	X	Y
1	422624	4782877
2	423076	4782967
3	425072	4782306
4	426390	4782888
5	427541	4784137
6	427880	4782909
7	429752	4783065
8	431218	4782647
9	432948	4782666
10	432980	4782332
11	423300	4781450
12	423455	4781100
13	425096	4781354
14	425407	4780588
15	425432	4779689
16	425427	4779324
17	425438	4779000
18	424671	4777622
19	426927	4781538
20	427625	4781512
21	426904	4779457
22	427490	4779351
23	426912	4779123
24	427496	4778951
25	426702	4778723
26	426705	4777447
27	429702	4781114
28	428834	4780429
29	429082	4779472
30	428966	4779176
31	431737	4781108
32	432946	4780524
33	433468	4780620

Identifier	UTM Coordinates	
	X	Y
34	433305	4778809
35	423023	4774153
36	423163	4773804
37	422709	4773370
38	422315	4772336
39	424752	4775510
40	424739	4774511
41	425265	4774348
42	425195	4773894
43	424568	4773358
44	425250	4771778
45	427315	4775969
46	427344	4775093
47	427230	4774277
48	426991	4773869
49	426878	4773491
50	426937	4773188
51	426974	4772870
52	426800	4772226
53	426701	4771707
54	427078	4771459
56	429249	4775281
57	429070	4774660
58	428800	4774175
59	429218	4773628
60	428729	4772001
61	428870	4771602
62	428396	4771388
63	429171	4771190
64	429434	4770999
65	431622	4776681
66	430947	4775902
67	431368	4775755

Identifier	UTM Coordinates	
	X	Y
68	430917	4775519
69	431033	4775239
70	431153	4774338
71	431413	4773975
72	431241	4773292
73	431190	4771673
74	431458	4771501
75	430375	4770394
76	430783	4770250
77	433007	4777262
78	433148	4776918
79	433445	4776777
80	433011	4775171
81	433464	4775119
82	433893	4775152
83	433198	4773791
84	433120	4773447
85	433574	4773553
86	432842	4771321
88	423333	4771025
89	423570	4770500
90	424258	4770677
91	425041	4770310
92	425439	4770368
94	430779	4768868
96	423842	4769183
97	423840	4768848
102	433049	4766446
103	433371	4766165
104	423276	4765200
105	421483	4763587

The exposure time and amount of shadow flicker at each receptor can vary based on several factors. The sun must be shining and not obscured by cloud cover. The turbine must be between the sun and the receptor and be facing directly towards (or away from) the sun such that the rotation of the blades is perpendicular to the sun rays. The shadow from a turbine extends furthest when the sun is low in the sky (sunrise and sunset) such that receptors to the east or west of a turbine will be exposed more than receptors to the north and south of a turbine. Terrain, other buildings and vegetation can also affect the exposure at a receptor such that if there are trees between the turbine and a receptor, shadow flicker will not occur at the receptor. The turbine must also be close enough to the receptor to cause shadow flicker and be operational (not stationary due to lack of wind or maintenance activities).

The orientation of windows at each receptor location will determine what rooms at each receptor would be exposed to shadow flicker. AECOM did not catalogue the number or orientation of windows at each receptor; instead each receptor is assumed to have eight windows (one every 45 degrees) to capture all angles for exposure. The amount of bright sunshine can also affect the frequency and duration of exposure to shadow flicker. Table 2 summarizes the percentage of bright sunshine at London Airport, Ontario, based on monthly climatological data.

Table 2. Percent of Bright Sunshine at London, Ontario Airport

Month	% Bright Sunshine
January	22.6
February	30.9
March	32.4
April	40.4
May	48.6
June	53.0
July	56.3
August	51.4
September	43.3
October	37.4
November	23.8
December	18.6
Annual Average	38.2

4. Points of Reception

The receptors have been classified into four (4) different categories which are outlined in Table 3, below. There are 4,022 receptors in the Jericho Wind Energy Centre Study Area.

Table 3. Receptor Classifications

Class	Number of Points of Reception	Description
NPR	3,070	Non-participating
PR	99	Participating
VNPR	784	Vacant Lot Non-participating
VPR	69	Vacant Lot Participating

Participating receptors are associated with the wind farm development via a legal agreement with the owner of the subject property to allow for the installation and operation of wind turbines or related equipment.

5. Detailed Shadow Flicker Impact Assessment

The shadow flicker analysis for the Jericho Wind Energy Centre was completed using the WindFarm modelling software. WindFarm considers the hourly meteorological data, terrain features, receptor, and turbine locations in the modelling analysis. The wind speed distribution for the 48-meter tower level is shown in Figure 2. It is generally accepted that shadow flicker from wind turbines does not occur beyond a certain distance from a wind turbine. The *Update of UK Shadow Flicker Evidence Base* by Parsons Brinckerhoff on behalf of the Department of Energy and Climate Change considers this distance to be equivalent to 10 rotor diameters. AECOM conservatively calculated using a maximum distance of 1,300 metres (80 metre hub height plus 50 metre blade times 10). WindFarm also assumes the sun is shining during all daytime hours and that the turbines are always operating. This method produces a theoretical worst case astronomical prediction at each receptor. The distance limitation reduced the number of receptors in the analysis to 2,487 as shown in Table 4 and the receptor locations are shown in Figure 3.

Figure 2. Wind Speed Distribution

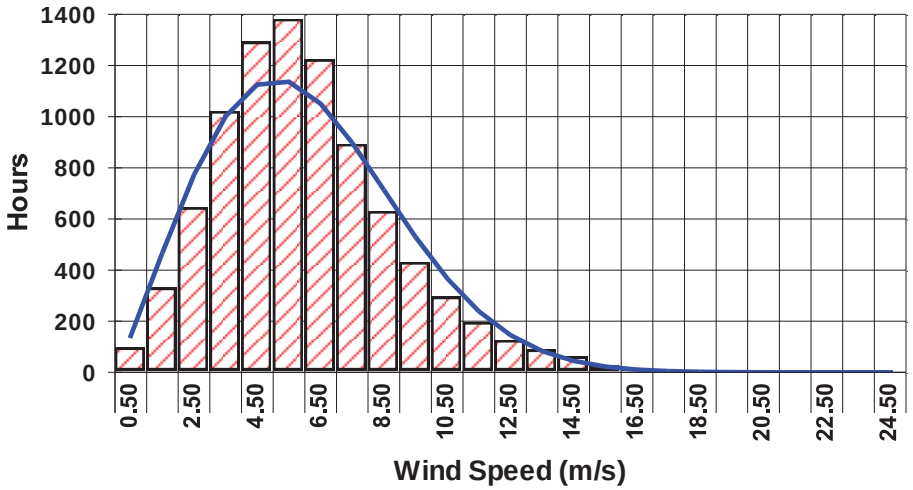

Table 4. Receptors within 1,300 m of Turbine Locations

Class	Number of Receptors	Description
NPR	1,809	Non-participating
PR	77	Participating
VNPR	541	Vacant Lot Non-participating
VPR	60	Vacant Lot Participating

6. Results

Table 5 presents the worst case astronomical results of the shadow flicker modelling and the corrected hours per year based on the annual percentage of sunshine shown in Table 2. Figure 4 shows the contours based on the corrected number of hours per year that shadow flicker occurs in the modelling domain. Appendix A includes shadow time graphs for each receptor location where shadow flicker occurs and Appendix B lists the specific start and end times of each exposure.

The worst case maximum shadow flicker per day is 1.37 hours and the worst case maximum shadow flicker per year is 115.2 hours (corrected to 44.0 hours per year based on annual percentage of sunshine in Table 2). All receptors with zero shadow flicker are not included in Table 5. The analysis accounts for the placement of turbines, receptors and sun angle such that the time when the turbine is in between the sun and the receptor is included in the total minutes per day and hours per year that shadow flicker could occur. However, this is a conservative analysis that does not account for maintenance time, winds less than 3 m/s when the turbines will not operate, light permeable obstacles such as trees and other structures, or that the turbine will rarely be directly facing the sun which will shorten the shadow from the turbine blades. The house number corresponds to the Receptor ID and it was assumed that there are 8 windows (located at 0, 45, 90, 135, 180, 225, 270, and 315 degrees from north) at each house located 2 meters high off the ground.

Potentially affected receptors should be monitored and if excessive shadow flicker occurs, vegetation can be planted, window shutters installed or other mitigation measures can be considered.

Figure 3. Modeled Receptor Locations