Appendix 4-4

Shadow Flicker Report

SEVEN STARS ENERGY PROJECT

Shadow Flicker Analysis Report

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EXECUTIVE SUMMARY

Seven Stars Energy Limited Partnership (the “Proponent”) retained DNV Canada Ltd. (“DNV”) to conduct an analysis to predict the duration of shadow flicker expected to be experienced at dwellings near the Seven Stars Energy Project (the “Project”) located approximately 5 km southeast of Weyburn, Saskatchewan.

The Project layout consists of a total of 50 Vestas V163-4.5MW wind turbine generators (WTGs) at a hub height of 98 m, 4 of which are alternate locations.

151 dwelling locations have been identified in the vicinity of the Project, of which 26 are located within the shadow flicker impact radius of 10 tip heights of a proposed WTG and were therefore included in the shadow flicker analysis.

While there are no regulatory limits for shadow flicker in Saskatchewan, the limits prescribed in AUC Rule 007 in Alberta have been applied. These limits correspond to 30 hours per year (expected case) and 30 minutes per day (worst case).

Dwelling H008 is predicted to experience the most hours of shadow flicker in one year. The predicted duration of shadow flicker at this dwelling is 14 hours per year when taking into account average monthly cloud cover and wind rose. All dwellings are below the 30 hour annual limit.

The maximum daily duration of shadow flicker, in minutes, also occurs at H008, with a total of 33 minutes per day, predicted to occur on January 19. It is noted that this dwelling, as well as dwellings H040 and H088, which also exceed the recommended limit of 30 daily minutes of shadow flicker, are all Project participants, with active setback waivers.

1 INTRODUCTION

The name of the project is Seven Stars Energy Project (hereafter referred to as “the Project”) and Seven Stars Energy Limited Partnership is the Project Proponent.

The Project Proponent retained DNV Canada Ltd. (“DNV”) to perform a shadow flicker assessment for the Seven Stars Energy Project (the “Project”) located approximately 5 km southeast of Weyburn, Saskatchewan.

The Project layout considered for the analysis includes 50 Vestas V163 4.5 MW wind turbine generators (WTGs) with a hub height of 98 m.

50 turbines have been included, of which 46 will be built because 4 are alternate locations; therefore the results presented are conservative in areas where turbines will not be constructed. The preliminary turbine layout was provided by the Proponent [1].

The V163 4.5 MW has a maximum blade tip height of 179.5 m, a hub height of 98 m, and a rotor diameter of 163 m.

The purpose of this shadow flicker assessment is to calculate the predicted annual shadow flicker duration for the proposed Project at nearby dwelling locations. This report includes a brief presentation of the Project site, a description of the shadow flicker assessment methodology, results of the analysis including a map illustrating areas prone to shadow flicker and concluding comments. This report presents the results of DNV’s analysis.

1.1 Shadow flicker definition

Shadow flicker is defined as the modulation of light levels resulting from the periodic passage of a rotating wind turbine blade between the sun and a viewer. The duration of shadow flicker experienced at a specific location can be determined using a purely geometric analysis which takes into account the relative positions of the sun throughout the year, the wind turbines at the site, and the viewer. This method has been used to determine the shadow flicker duration at dwelling locations in the vicinity of the Project.

It should be noted, as described in Section 3, that there are certain simplifications and conservative assumptions inherent within the model that may result in an overestimation of shadow flicker duration.

2 DESCRIPTION OF THE WIND FARM SITE

2.1 Site description

The Project is situated in relatively simple terrain, consisting of flat farmland, with WTG base elevations ranging from approximately 572 to 610 meters above sea level. The ground cover on and near the site is primarily composed of farmland or open fields. Dwellings are interspersed throughout the Project site. The Project is located approximately 5 km southeast of Weyburn, Saskatchewan.

The Seven Stars Energy Project area, defined as the combination of all land parcels under a development agreement with the Proponent, comprises approximately 24,000 acres of land within the Rural Municipalities of Griffin No. 66 and Weyburn No. 67 being considered for development.

2.2 Wind farm layout and turbine model

The current Project layout consists of 50 Vestas V163 4.5 MW WTGs for modeling purposes, 4 of which are alternate locations; therefore the results presented in this report will be lower at dwellings located near turbines that will eventually be removed. The turbine layout was provided by the Proponent [1].

The V163 4.5 MW has a maximum blade tip height of 179.5 m, a hub height of 98 m, and a rotor diameter of 163 m.

The coordinates of the Project equipment included in the assessment are presented in Appendix A.

2.3 Neighboring wind farms

There are no neighboring wind farms in the vicinity of the Project.

2.4 Dwelling locations

A list of dwellings was provided by the Proponent [3], most of which were dispersed throughout the Project. All dwellings assessed for this Project are private residences and are identified as numbers (i.e. H-##) to protect residence's privacy.

Results for 26 dwellings, representing inhabited residences are reported within 1,795 m of a proposed turbine. Coordinates of each dwelling are presented in Appendix B.

2.5 Applicable regulations

No applicable shadow flicker regulations were identified at the provincial and local level. In the absence of any regulations, the current analysis considers the Alberta Utilities Commission (AUC) Rule 007 [4] as a reasonable reference guideline to assess shadow flicker.

Rule 007, 4.3.2, Shadow Flicker Assessment, WP20 indicates:

> *"Provide a table comparing predicted shadow flicker durations to 30 hours per year for the adjusted-case scenario and 30 minutes per day for the worst-case scenario."*

Therefore, for the purposes of this report, a limit of 30 hours per year (expected case) and 30 minutes per day (worst case) has been considered the effective limit for shadow flicker.

DNV notes that the term "expected case" in this report refers to "adjusted case" in the AUC's regulatory wording above.

3 SHADOW FLICKER ASSESSMENT

3.1 Overview

Shadow flicker may occur under certain combinations of circumstances with regard to the sun's position and wind direction; when the sun passes behind the rotating blades of a wind turbine, a moving shadow is cast in front of or behind the turbine. When viewed from a stationary position, the moving shadows cause periodic flickering of the sunlight, otherwise known as the "shadow flicker" phenomenon.

The effect is most noticeable inside buildings, where the flicker appears through a window opening. The likelihood and duration of the effect depends on a number of variables, namely:

- Orientation of the building and windows relative to the turbine;
- Wind direction: The shape and intensity of the shadow are determined by the position of the sun relative to the blades (the turbine rotor continuously yaws to face the wind so the rotor plane will always be perpendicular to the wind direction);
- Distance from turbine: The farther the observer from the turbine, the less pronounced the effect;
- Turbine height and rotor diameter: A larger turbine rotor diameter will cast a larger shadow, meaning a larger area will be prone to incidences of shadow flicker;
- Time of year and day: Position of sun relative to the horizon;
- Weather conditions: Cloud cover reduces the occurrence of shadow flicker;
- Vegetation and other obstacles that help to mask shadows;
- Operational status of turbines.
- Frequency of the presence of a person in a particular room of a dwelling where flicker events may occur through a given window.

3.2 Assessment methodology

The number of hours of shadow flicker experienced annually at a given location can be calculated using a geometrical model which takes into account the sun's position, topography of the wind farm site, and wind turbine specifications such as rotor diameter and hub height.

Shadow flicker has been calculated at the subject dwellings at a height of 6.5 feet (2 m) to represent ground floor windows. Rather than facing a particular direction, shadow flicker dwellings (windows) are simulated as horizontal planes, meaning they experience shadow flicker over 360°, often referenced as the "greenhouse" scenario; this assumption therefore represents a worst-case scenario. Simulations with WindFarmer Analyst software have been carried out with a resolution of 1 minute; if shadow flicker occurs in any 1-minute period, the model registers this as 1 minute of shadow flicker.

It is generally accepted that shadow flicker from wind turbines does not occur beyond a distance, D, from a given wind turbine. The UK wind industry considers this distance to be equivalent to 10 rotor diameters [2]. DNV has adopted a conservative approach and has assumed the length, D, that a shadow can be cast to be defined as follows:

D = 10 x (hub height + rotor radius)

Beyond this distance, a viewer does not perceive the turbine blade to be chopping the light, but rather as an object passing in front of the sun [2].

The annual hours of shadow flicker at dwellings have been calculated in two steps:

1) A “worst case” or astronomical worst-case, which represents the number of hours of annual shadow flicker that does not take into account attenuating factors, such as cloud cover or the site-specific wind frequency distribution.

2) An “expected case” that considers cloud cover and the site-specific wind frequency distribution in order to get a more realistic estimate, as described below. It is noted that additional attenuation factors are still not considered (see Section 3.4).

In the case of this Project, 10 x (hub height + rotor radius) is equal to 1,795 m.

The annual hours of shadow flicker at dwellings have been calculated using an “expected case” approach.

The daily maximum minutes have been calculated using the “worst case” approach, without any attenuation due to cloud cover or wind direction. This is a more probable situation that could realistically occur at least once during the life of the Project.

3.3 Attenuations

Annual shadow flicker duration calculations can be adjusted using average annual cloud coverage, which is based on historical meteorological data and statistics. According to data gathered from the Regina International Airport Environment Canada (EC) station, monthly sunshine can be estimated and conversely applied as a percentage decrease in flicker duration. The sunshine percentages used in the model are shown in Table 3-1.

Table 3-1 Sunshine percentage (%)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Percentage	44.5	45.1	44.3	52.4	49.2	51.9	65.7	64.4	57.3	50.9	42.2	43.6

The annual site-specific wind direction distribution was used in order to consider the probability of the turbines being oriented in a given direction. This produces a more accurate estimate of shadow flicker duration at dwellings. The directional wind frequency that was measured on site [5] is shown in Table 3-2.

Table 3-2 Site specific directional frequencies (%) (Mast ID: 1168_Weyburn_1915)

Sector (°)	0	30	60	90	120	150	180	210	240	270	300	330
Percentage	5.0	4.1	3.7	5.6	12.1	9.6	7.1	6.2	7.3	10.9	19.1	9.4

Note: The sectors are defined as 30° sectors centered at the given value.

No attempt has been made to account for vegetation or other shielding effects around each dwelling in the calculations of shadow flicker duration. Similarly, turbine operational shut-down has not been considered in this analysis. Consideration of these factors could lead to a reduction of the realized shadow flicker relative to the values predicted in this report.

3.4 Simplifications and assumptions

Shadow flicker duration calculated in the manner described above has several limitations and/or may over-estimate the annual number of hours of shadow flicker experienced at a specified location for a few reasons, namely:

- Turbine blades are of non-uniform thickness with the thickest part of the blade (maximum chord) close to the hub and the thinnest part (minimum chord) at the tip. Diffusion of sunlight, as discussed above, results in a limit to the maximum distance that a shadow can be perceived. This maximum distance will also be dependent on the thickness of the turbine blade and the human threshold for perception of light intensity variation. As such, a shadow cast by the blade tip will be shorter than the shadow cast by the thickest part of the blade [6]. These distinctions are not modeled and shadow cast from any part of the blade is considered a shadow flicker event.
- The orientation of windows on a given residence has not been taken into account, i.e. the model assumes that a window is always facing the turbine(s).
- Aerosols (moisture, dust, smoke, etc.) in the atmosphere have the ability to influence shadows cast by a wind turbine. The length of the shadow cast by a wind turbine is dependent on the degree that direct sunlight is diffused, which in turn is dependent on the amount of dispersants (humidity, smoke and other aerosols) in the path between the light source (sun) and the receiver [6]. The model does not consider any such factors.
- The presence of vegetation or other physical barriers around a dwelling may shield the view of the wind turbine, and therefore reduce the incidence of shadow flicker. No physical barriers have been modeled.
- Periods where Project wind turbines are not in operation due to low winds, high winds, or for operational and maintenance reasons will also reduce shadow flicker occurrence but are not considered herein.

4 RESULTS AND CONCLUSION

The results of the shadow flicker assessment (in terms of expected total hours per year and maximum daily minutes) are presented in tabular format in Appendix B for all dwelling locations in the study area.

The astronomical worst case for annual hours of shadow flicker duration represents a theoretical, extreme situation in which no cloud cover occurs at any point during the year. Furthermore, it assumes that all turbine rotors are always perpendicular to any given dwelling, which is unfeasible.

As a result, the astronomical worst case annual total duration can be assumed to be an extreme, theoretical example which is extremely unlikely to occur, and can be considered informative.

Results for the “expected case”, in terms of annual hours, take into account the average monthly cloud cover from the Regina Internation Airport Environment Canada Station. The annual site specific wind directional frequencies were gathered from one of the meteorological evaluation towers deployed on site, which was most centrally located within the Project area [5].

A detailed map illustrating predicted “expected case” annual shadow flicker duration at dwellings is presented in Figure 4-1. The map takes into account average monthly cloud cover and annual wind direction distribution. Shadow flicker is shown in isopleths of 30 hours per year or more.

Conversely, the daily maximum duration, in minutes, does not take into account any attenuations related to rotor orientation or cloud coverage. Those results consider the realistically probable case of maximum shadow flicker exposure on a given day that is fully sunny and where the rotor is facing the dwelling.

While there are no local or provincial regulations for shadow flicker applicable to this Project, the results for all applicable dwellings are below the recommended annual limits set forth by the AUC Rule 007 of shadow flicker of 30 hours per year. (See Section 2.5). Participating dwellings H-008, H-040 and H-088 slightly exceed the maximum 30 minutes per day threshold, with a worst day totals of 33, 31 and 32 minutes respectively (see Appendix B).

It is noted that only 46 of the 50 modeled turbines are expected to be constructed. The four turbine locations that will eventually be removed from the layout will not cause any shadow flicker after the Project is constructed.

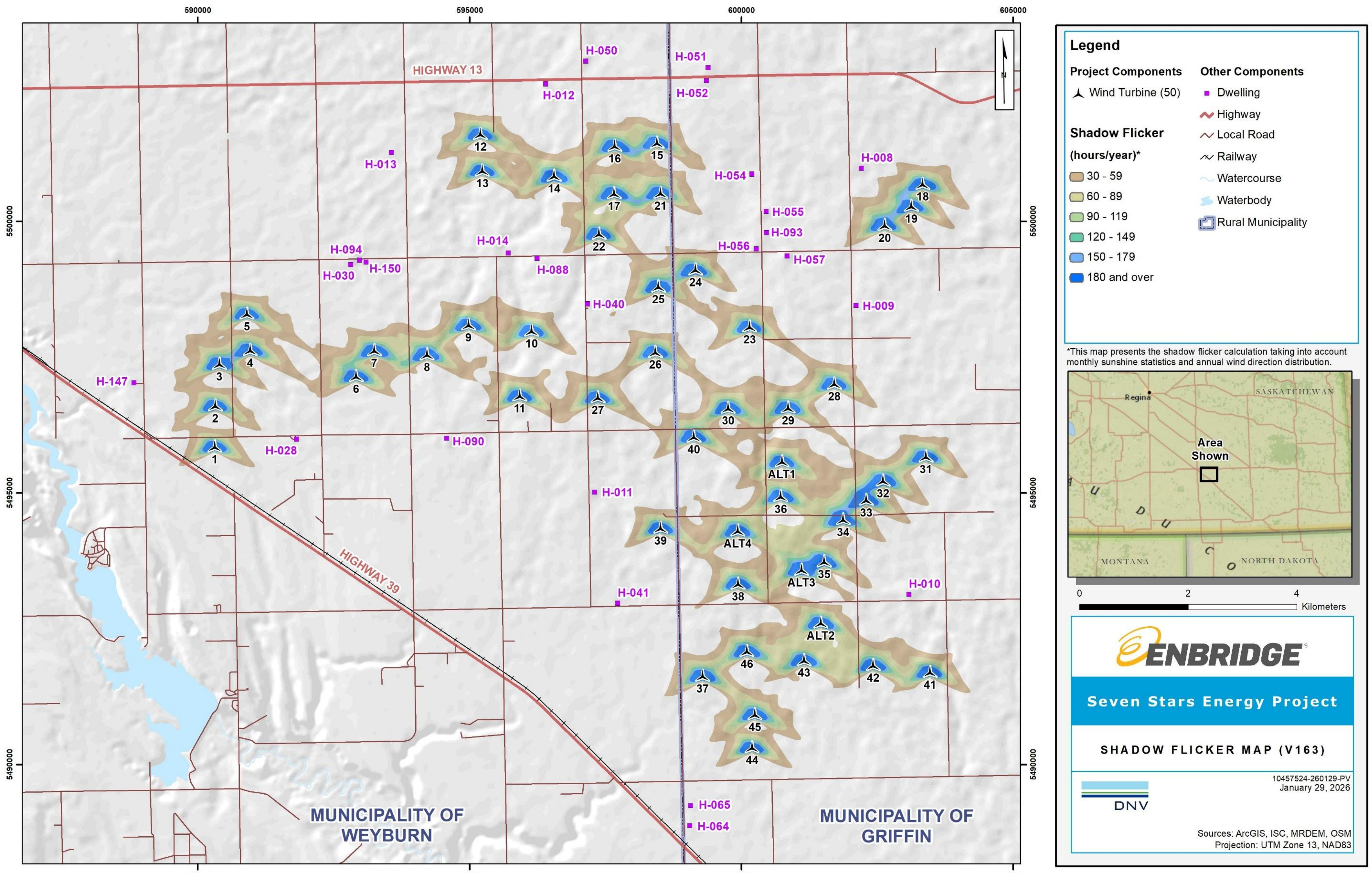

Figure 4-1 Modeled annual hours of shadow flicker (Expected Case)

5 REFERENCES

[1] Turbine and substation locations sent by email from NRSI to DNV on 26 November 2025, "*SevenStars_50xV163_4d5_20251104_V7*"

[2] Department for Business Enterprise & Regulatory Reform, UK, "Onshore Wind: Shadow Flicker", http://webarchive.nationalarchives.gov.uk/20090609003228/http:/www.berr.gov.uk/whatwedo/energy/sources/renewables/planning/onshore-wind/shadow-flicker/page18736.html.

[3] Dwelling locations sent by email from NRSI to DNV on 10 March 2025, "Receptors_Merged_20250310.shp"

[4] AUC (Alberta Utilities Commission), *Rule 007 Facility Applications.* November 6 2025.

[5] Annual site-specific wind direction distribution sent by email to DNV on 12 September 2025, "Met Tower 1168_Weyburn_1915"

[6] Freud H-D, Kiel F.H., "Influences of the opaqueness of the atmosphere, the extension of the sun and rotor blade profile on the shadow impact of wind turbine", DEWI Magazine No. 20 pp 43-51, February 2002.

APPENDIX A – WIND TURBINE COORDINATES

ID	UTM Zone 13, NAD 83 Datum	
	Easting [m]	Northing [m]
T01	590311	5495782
T02	590323	5496538
T03	590398	5497305
T04	590965	5497557
T05	590907	5498226
T06	592913	5497079
T07	593248	5497552
T08	594217	5497478
T09	594982	5498023
T10	596142	5497914
T11	595924	5496718
T12	595197	5501535
T13	595237	5500862
T14	596554	5500755
T15	598448	5501376
T16	597672	5501316
T17	597659	5500444
T18	603339	5500617
T19	603131	5500209
T20	602638	5499860
T21	598514	5500450
T22	597381	5499700
T23	600152	5497987
T24	599150	5499033
T25	598472	5498729

ID	UTM Zone 13, NAD 83 Datum	
	Easting [m]	Northing [m]
T26	598419	5497525
T27	597363	5496686
T28	601713	5496941
T29	600861	5496494
T30	599762	5496493
T31	603396	5495600
T32	602611	5495154
T33	602299	5494802
T34	601875	5494440
T35	601524	5493666
T36	600724	5494868
T37	599289	5491561
T38	599942	5493259
T39	598516	5494283
T40	599128	5495965
T41	603475	5491633
T42	602428	5491758
T43	601157	5491853
T44	600198	5490246
T45	600248	5490852
T46	600106	5492016
ALT01	600750	5495507
ALT02	601465	5492539
ALT03	601109	5493514
ALT04	599938	5494233

APPENDIX B – DWELLING LOCATIONS & RESULTS

Dwelling ID	UTM Zone 13 Easting [m]	UTM Zone 13 Northing [m]	Minutes on worst Day [mins/day]	Total Hours in Year [hrs/yr]		Closest Turbine	
			No cloud cover and spherical rotor	Astronomical Worst Case	Expected Case with Monthly Cloud Cover and Wind Direction	Distance [m]	Turbine ID
H-008	602207	5500974	33	42	14	1188	18
H-040	597169	5498478	31	36	11	1171	10
H-012	596401	5502528	22	24	7	1560	12
H-088	596243	5499318	32	18	6	1200	22
H-090	594578	5496003	24	16	5	1519	08
H-028	591815	5495991	21	13	5	1518	01
H-147	588823	5497029	20	12	4	1578	02
H-010	603086	5493131	19	10	4	1522	42
H-013	593564	5501265	19	10	4	1655	12
H-056	600274	5499492	29	12	4	1214	24
H-011	597299	5495012	25	10	3	1419	39
H-055	600455	5500177	19	10	2	1736	24
H-014	595712	5499415	19	5	2	1523	13
H-093	600463	5499788	23	8	2	1515	24
H-054	600196	5500869	18	4	1	1733	21
H-057	600844	5499361	17	4	1	1538	23
H-009	602110	5498451	0	0	0	1505	20
H-030	592812	5499202	0	0	0	1707	07
H-041	597727	5492968	0	0	0	1533	39
H-050	597139	5502947	0	0	0	1716	16
H-051	599389	5502825	0	0	0	1728	15
H-052	599359	5502591	0	0	0	1519	15
H-064	599053	5488876	0	0	0	1785	44
H-065	599065	5489243	0	0	0	1513	44
H-094	592974	5499282	0	0	0	1752	07
H-150	593095	5499249	0	0	0	1704	07

The maximum amount of shadow flicker minutes on the worst day is 33, 31 and 32 for H-008, H-040 and H-088 respectively.

This is predicted to occur on January 19, shortly after sunrise, caused by turbine T-19 at H-008, on February 14, shortly before sunset, caused by T10 at H-040 and on August 8, shortly after sunrise, caused by T22 at H-088.

H-008, H-040 and H-088 are Project participants, with active setback waivers.

About DNV

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