Appendix T

Shadow Flicker Report

Shadow Flicker Study
Philip Wind Project
Haakon County, South Dakota

May 23, 2025

Prepared for:

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1.0 INTRODUCTION

Philip Wind Partners LLC ("Philip Wind") is proposing to develop an approximately 300-Megawatt (MW) wind power generation facility in Haakon County, South Dakota. The proposed Philip Wind Project (the "Project") application proposes to construct on 53 to 87 of the 91 possible wind turbine generator ("WTG" or "turbine") locations, depending on the final turbine model selected. The turbine models Philip wind is considering range from 3.8 to 5.9 MW nameplate capacity each, depending on the final turbine model(s) selected. The Project is located north of the city of Philip, South Dakota. Philip Wind retained Stantec Consulting Services Inc. (Stantec) to conduct an analysis of potential shadow flicker from turbines at the 91 proposed locations. Philip Wind will construct and operate a subset of one of the turbine models described in this report.

The shadow flicker analyses completed for the Project considered the following three turbine models:

- GE3.8-154 – General Electric 3.8 MW turbines; 154-meter rotor diameter; 98-meter hub height; 87 of the 91 locations are expected to be utilized.
- V163-4.5 – Vestas 4.5 MW turbines; 163-meter rotor diameter; 98-meter hub height; 74 of the 91 locations are expected to be utilized.
- N163-5.9 – Nordex 5.9 MW turbines; 163-meter rotor diameter; 108-meter hub height; 56 of the 91 locations are expected to be utilized.

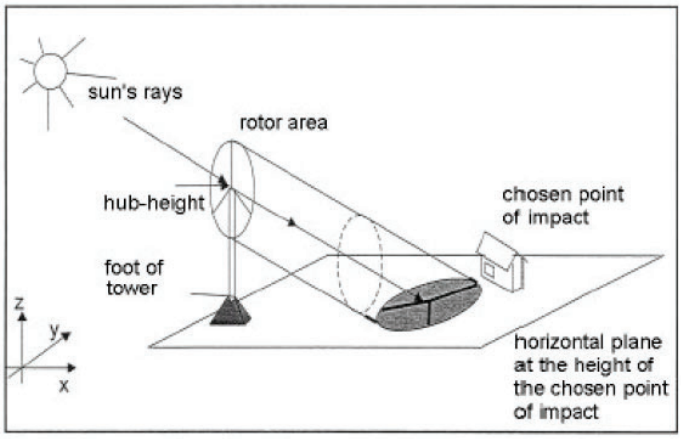
Potential shadow flicker on inhabited dwellings located within the Project boundary or within approximately 1.25 miles of proposed Project turbine sites was assessed and the results are summarized herein.

2.0 SHADOW FLICKER AND REGULATIONS

2.1 DESCRIPTION OF SHADOW FLICKER

Shadow flicker is a term used to describe the intermittent change in the intensity of light cast on an area resulting from the rotation of an operating wind turbine's blades between the sun and a stationary object. The presence and intensity of shadow flicker are dependent on many factors, including but not limited to the position of the sun in relation to the turbine and receptor, distance of receptor from turbine, physical characteristics of the turbine and blades, time of day, season of year, and topography of the Project area. Shadow flicker will only occur during daylight hours, when skies are not overcast or cloudy. Turbines must be operational, as the flicker effect is caused by rotation of the blades as they intercept the sunlight cast on a receptor. When a turbine is not operating it may cast a stationary shadow, similar to other objects such as trees or utility poles.

The amount of shadow flicker received in an area is dependent on the alignment of the rotor blades in relation to the sun and receptor. Maximum shadow flicker is received when the sun is aligned with the turbine and receptor, and the turbine's rotor plane is perpendicular to the receptor. This alignment occurs when the wind is blowing directly from a source turbine towards a receptor. At times when the wind is blowing from other directions, the shadow cast on the target receptor is diminished and the shadow flicker effect passes more quickly.



Shadow flicker also diminishes as the distance between the source turbine and receptor increases. As distance increases from a turbine, the effect of shadow flicker is less pronounced due to its dissipation and the relative ratio of the turbine blade to the sun disk area. It is generally accepted that flicker becomes imperceptible beyond approximately 10 times the rotor diameter of a turbine (1,630 meters [1.01 mile] for the analysis of the V163-4.5 and N163-5.9 turbine models; 1,540 meters [0.96 mile] for the GE3.8-154 turbine model).

2.2 REGULATIONS WITHIN THE PROJECT AREA

No regulations regarding shadow flicker have been identified for Haakon County or the state of South Dakota. However, Philip Wind has designed the Project to limit the amount of shadow flicker that is expected to fall on inhabited dwellings owned by nonparticipants or other community structures considered sensitive (e.g., churches, schools) to 30 hours or less per year. Structures such as barns, agricultural buildings and commercial businesses were not included in the study.

Philip Wind has conducted this study to better understand the shadow flicker that may affect area receptors due to the normal operation of the proposed Project. They have considered shadow flicker in designing the current layout and seek to minimize flicker on sensitive receptors to the extent practicable.

3.0 SHADOW FLICKER ANALYSIS

The potential amount of shadow flicker on inhabited dwellings (also referred to as receptors) within the Project area was modeled using the Shadow module of EMD's WindPRO Version 3.6 software. WindPRO is an industry-accepted modeling program that calculates the number of hours per year that any given receptor may receive shadow flicker from the source turbines. The application considers the attributes and positions of the wind turbines in relation to receptors within the area. Shadow flicker models also consider the sun's position as it passes through the Project area each day in addition to regional climatological information.

Philip Wind requested a shadow flicker analysis on their current Project layout consisting of 91 potential locations of each of the three proposed turbine models. Results of analyses summarized in this report and detailed within the appendices and figures describe expected shadow flicker due to the operation of turbines at the 91 proposed sites.

3.1 SHADOW FLICKER ANALYSIS METHODS

A modeling analysis was completed to assess the expected shadow levels at receptors based on a series of assumptions. The WindPRO model calculates both a “potential” and “expected” scenario. The “potential” scenario provides the periods when shadow flicker *may* occur on a receptor; however, it is not representative of the shadow flicker that is expected to occur. The “potential” scenario assumes no cloud cover, the sun is always shining during daylight hours, and turbines are always operating and rotated to cast maximum shadow on a receptor. The “expected” amount of annual shadow flicker considers the percentage of sunshine based on local regional sunshine statistics; the alignment of the blades in relation to the receptor due to wind direction; and the amount of time that the blades would not be rotating due to wind speeds outside of the turbine’s operating parameters. The “potential” scenario, as described, could not realistically occur; however, is useful as an indicator of the potential times within which shadow flicker may occur. The shadow flicker analysis uses a conservative 90% operational time for purposes of calculating the annual hours of expected shadow flicker.

The results provided in this report include the expected amount of shadow flicker annually on each receptor, given the climatological conditions of the area as previously described and assuming turbines were built at all 91 of the proposed turbine locations for each turbine model. Climatological information was acquired from the National Climatic Data Center (NCDC) and regional meteorological stations. The percentage of sunshine probability was estimated from an analysis of average sunshine statistics for the Project region.

The climatologically based expected hours of sunshine for the Project area are presented in Table 1. The frequency of wind (hours per year) expected in 16 compass directions is summarized in Table 2. The total number of hours that turbines are able to cause shadow flicker takes into account non-operational time due to low or high wind speeds. The turbine types that Philip Wind proposes to use will generally operate when hub-height wind speeds are between 3 meters per second (m/s) and 26 m/s.

Table 1 Sunshine Probability (sun hours/possible sun hours)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.57	0.62	0.63	0.60	0.63	0.69	0.74	0.73	0.68	0.60	0.54	0.55

Table 2 Turbine Operation Time per Sector (hours per year)

0	22.5	45.0	95.5	90.0	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5	315.0	337.5
473	237	158	158	237	394	552	473	355	355	315	315	473	1,104	1,418	867
TOTAL		7,884													

The effect of shadow flicker is also dependent on the physical characteristics of the turbine model and the distance between the source turbine and shadow receptor. The individual locations of the wind turbines are based on the current layout of the Project. The proposed potential turbine locations are the same for each of the three turbine models under consideration, although each will require only a subset of the total proposed sites for the final Project design.

- GE3.8-154 turbines (154-meter rotor diameter, 98-meter hub height); 87 final sites expected
- V163-4.5 turbines (163-meter rotor diameter, 98-meter hub height); 74 final sites expected
- N163-5.9 turbines (163-meter rotor diameter, 108-meter hub height); 56 final sites expected

A total of 17 potential receptors within 1.25 miles of the proposed turbine locations or within the Project boundary were identified by Philip Wind and Stantec utilizing aerial imagery and on-site reconnaissance. Inhabited residences, schools, hospitals, churches, and cemeteries were considered; however, only inhabited residences and cemeteries were identified with the area described. Twelve (12) receptors were within 1.25 miles of the proposed turbine locations. Five (5) receptors were outside of 1.25 miles of the proposed turbine locations but within the Project boundary. Seven (7) of the 17 receptors are owned by participants in the Project. Elevations for turbines and receptors were calculated using data digitally acquired from the U.S. Geological Survey National Elevation Dataset, or similar source. The coordinates (UTM Zone 14) of turbine and receptor locations are included in Appendix A and Appendix B, respectively.

The model utilizes a “greenhouse” approach which defines each receptor as a one-meter glass cube, representing a window able to receive shadow from all directions. Vegetation surrounding receptors may block or diminish the effect of shadow flicker.

Shadow flicker from the turbine types considered is widely considered imperceptible at a distance greater than approximately one mile; however, Stantec conservatively analyzed the impact at all distances when more than 20 percent of the sun would be covered by a turbine blade. Shadow flicker does not occur when the sun-angle is less than three degrees above the horizon, due to atmospheric diffusion.

3.2 SHADOW FLICKER ANALYSIS RESULTS

The amount of shadow flicker on receptors within the Project area was calculated based on the climatological history of wind speed, wind direction and percentage of sunshine for the turbine models described in Section 3.1. Potential blocking of shadow flicker due to vegetation adjacent to a dwelling was not considered in this analysis.

Results of the analyses indicate that the majority of the 17 potential receptors assessed are expected to receive 10 hours or less of shadow flicker each year. All of the assessed receptors are expected to receive no greater than 30 annual hours of shadow flicker, with the following exception:

> The Nordex turbine model results indicate that one receptor, owned by a Project participant, may receive greater than 30 annual hours of shadow flicker, prior to consideration of vegetative blocking. The shadow flicker analysis includes all 91 turbine locations, of which only 53 turbines would be constructed, resulting in a lower potential shadow flicker.

A detailed table of receptor locations and expected annual shadow flicker results is included in Appendix B. A summary of the annual shadow flicker for each turbine model can be found in Table 3.

Table 3 Shadow Flicker Analysis Summary by Turbine Model (91 Turbine Locations)

Expected Annual Shadow Flicker Hours [1]	Existing Residences (GE3.8-154)	Existing Residences (V163-4.5)	Existing Residences (N163-5.9)
Less than 10	12	12	13
10 – 20	3	3	2
20 – 30	2	2	1
Greater than 30	0	0	1[2]

[1] Final Project design will result in lower total shadow flicker impact.
[2] Residence is owned by a participant in the Project

Detailed tabular results of the shadow flicker analyses for each of the turbine models are provided in Appendix B and include the following information.

- Receptor identification number
- Coordinates of receptor location (UTM-Zone 14)
- Participation status in the Project
- The expected annual hours of shadow flicker at receptor

Figures for each turbine model (Figures 1 through 3) are provided with iso-lines of expected shadow flicker hours per year. Expected shadow flicker results assume that turbines within each model would be constructed and operational at each of the 91 potential turbine locations proposed, although, as previously described, only a subset of each turbine model is required to achieve the desired Project capacity.

3.3 SHADOW FLICKER MITIGATION METHODS

As stated previously, multiple turbine models are under consideration for the Project. Shadow flicker analyses were completed for three turbine models currently under consideration. Philip Wind will construct and operate a subset of the turbine locations within each model; therefore, expected annual shadow flicker hours will be less than the results of the analyses summarized herein.

Additionally, the blocking effects of existing vegetation, structures, and other physical barriers between the turbines and receptors were not considered in this analysis. For these reasons, the results overestimate the total shadow flicker impacts that would be anticipated for the final Project design and the actual shadow flicker impact on many receptors will be less than the modeled result given.

Philip Wind is committed to limiting shadow flicker to 30 hours per year or less at existing non-participating residences. Turbines are located at angles and distances from residences, so that the majority of residences in the Project area will experience little to no shadow flicker from the Project. Philip Wind will identify, manage, and mitigate shadow flicker overages, if needed, using commercially reasonable

mitigation measures. Mitigation measures that may be utilized include planting trees and/or vegetative buffers and turbine curtailment.

4.0 CONCLUSION

Potential shadow flicker from the Philip Wind Energy Project on inhabited residences and other sensitive receptors within the Project boundary or within approximately 1.25 miles of potential turbine locations was assessed using WindPRO shadow flicker modelling software. Analyses were completed for a total of 91 turbines on 17 sensitive receptors (inhabited residences and a cemetery).

Results of the shadow flicker analysis demonstrate that the Project can be operated in compliance with Invenergy's standards regarding the shadow flicker on sensitive receptors identified in relation to the Project.

FIGURES

FIGURE 1

SHADOW FLICKER EXPECTED ANNUAL HOURS – GE3.8-154 TURBINE LAYOUT

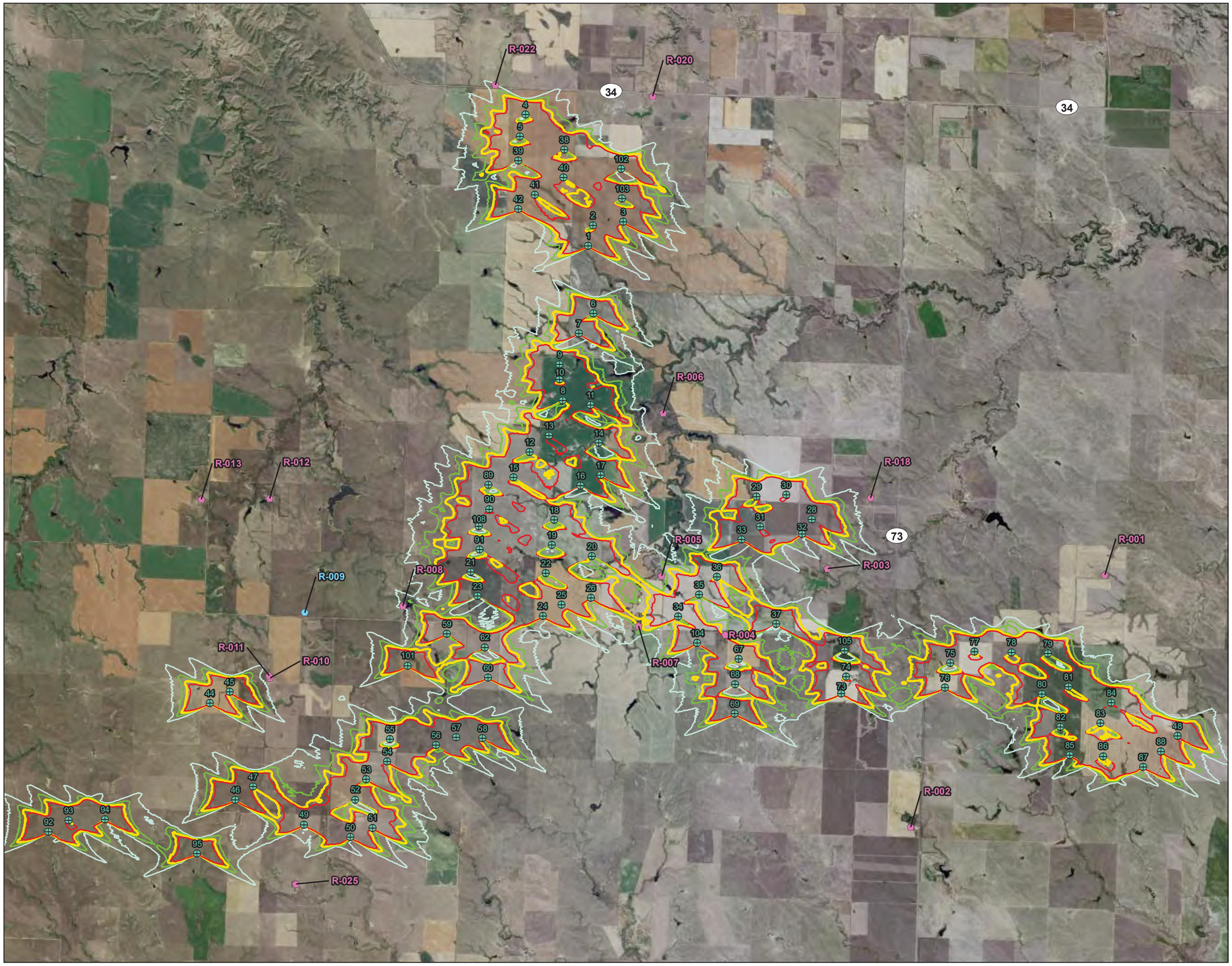


Figure No.
1

Title
Shadow Flicker Modeling Results
Expected Annual Hours - GE 3.8-154

Client/Project
193709483
Invenergy, LLC
Philip Wind Project
Shadow Analysis

Project Location
Haakon Co., SD

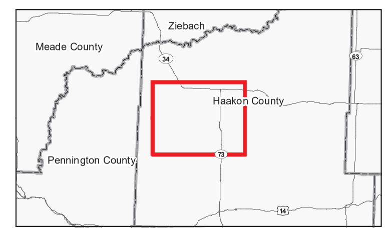
Prepared by JM on 2023-04-13
TR by AS on 2023-04-13
IR by JB on 2025-01-13

N

0 4,000 8,000 Feet
(At original document size of 11x17)
1:96,000

Legend
- Wind Turbine Location
- Sensitive Receptor - Cemetery
- Sensitive Receptor - Residence

Shadow Results
Expected Annual Hours
- 10
- 20
- 30
- 40



Notes
1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Stantec, Invenergy, USGS, NADS
3. Background: 2022 NAIP

Stantec

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FIGURE 2

SHADOW FLICKER EXPECTED ANNUAL HOURS – V163-4.5 TURBINE LAYOUT

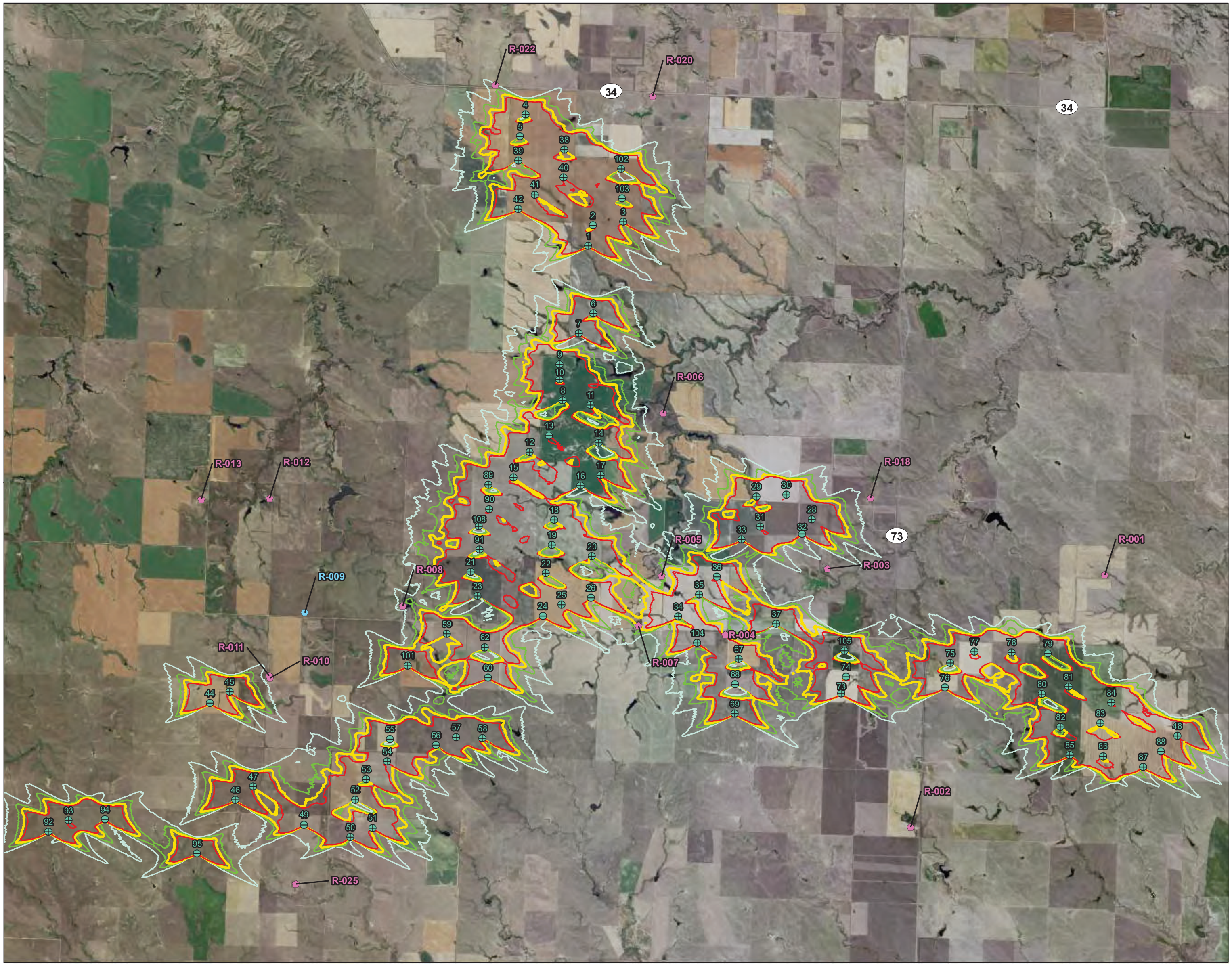


Figure No.

2

Title

Shadow Flicker Modeling Results
Expected Annual Hours - V163-4.5

Client/Project 193709483

Invenergy, LLC
Philip Wind Project
Shadow Analysis

Project Location
Haakon Co., SD

Prepared by JM on 2023-04-13
TR by AS on 2023-04-13
IR by JB on 2025-01-13

N

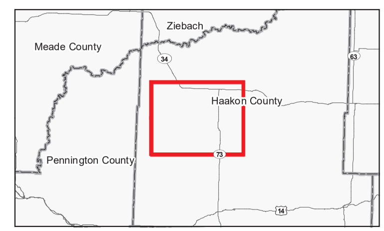
0 4,000 8,000 Feet
(At original document size of 11x17)
1:96,000

Legend

- Wind Turbine Location
- Sensitive Receptor - Cemetery
- Sensitive Receptor - Residence

Shadow Results
Expected Annual Hours

- 10
- 20
- 30
- 40



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3. Background: 2022 NAIP

Stantec

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FIGURE 3

SHADOW FLICKER EXPECTED ANNUAL HOURS – N163-5.9 TURBINE LAYOUT

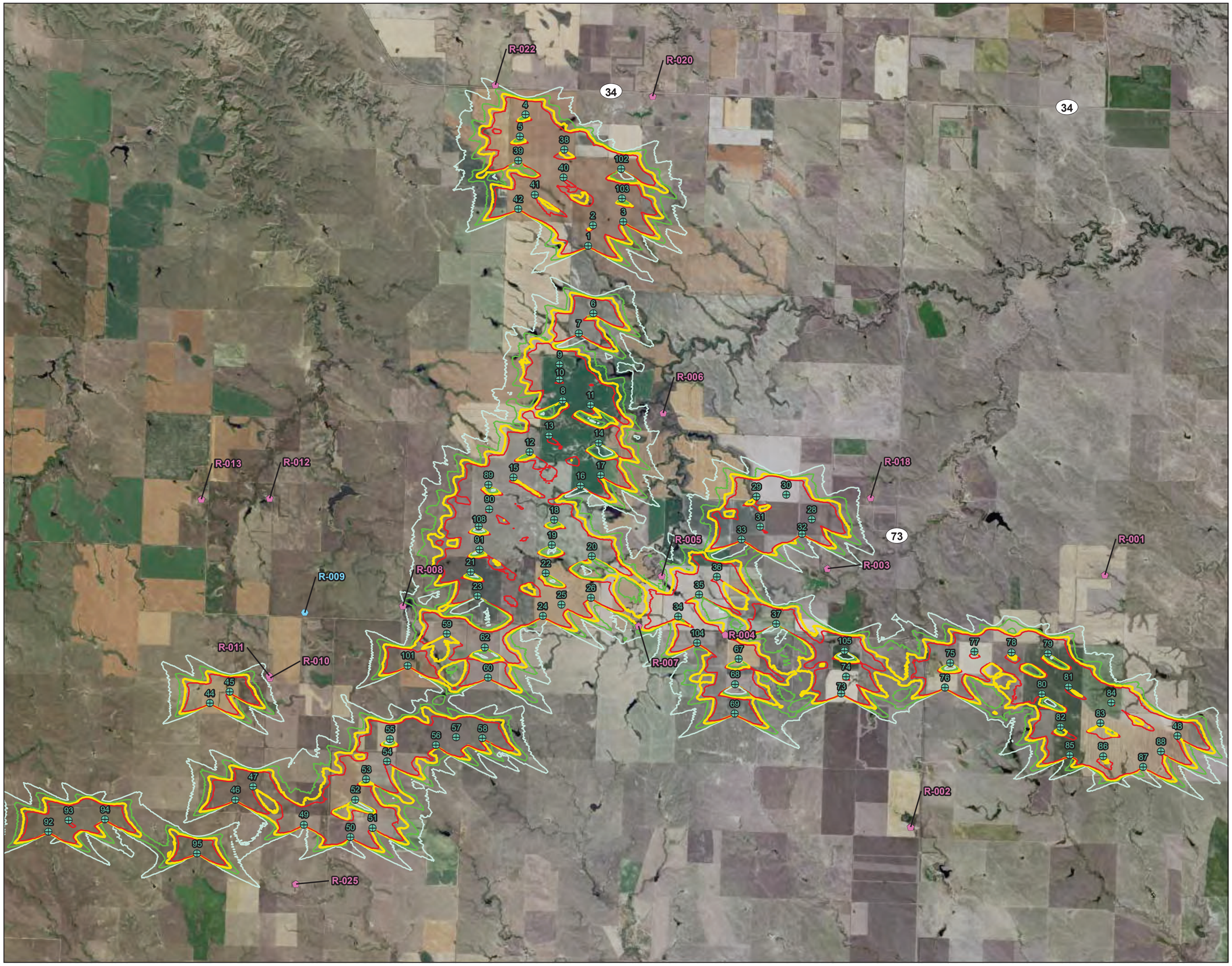


Figure No.

3

Title

Shadow Flicker Modeling Results Expected Annual Hours - N163-5.9

Client/Project 193709483

Invenergy, LLC
Philip Wind Project
Shadow Analysis

Project Location
Haakon Co., SD

Prepared by JM on 2023-04-13
TR by AS on 2023-04-13
IR by JB on 2025-01-13

N

0 4,000 8,000 Feet

(At original document size of 11x17)
1:96,000

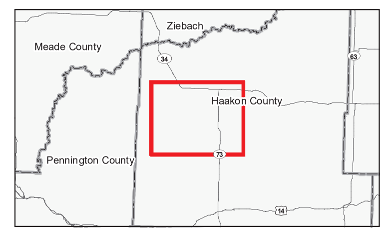
Legend

- Wind Turbine Location
- Sensitive Receptor - Cemetery
- Sensitive Receptor - Residence

Shadow Results

Expected Annual Hours

- 10
- 20
- 30
- 40



Notes
1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Stantec, Invenergy, USGS, NADS
3. Background: 2022 NAIP

Stantec

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APPENDICES

APPENDIX A

TURBINE COORDINATES

Appendix A - Philip Wind Project Turbine Coordinates

Turbine Identification	X (UTM 14)	Y (UTM 14)
T-001	278,953	4,916,432
T-002	279,062	4,916,934
T-003	279,806	4,917,015
T-004	277,421	4,919,621
T-005	277,290	4,919,088
T-006	279,071	4,914,793
T-007	278,716	4,914,301
T-008	278,331	4,912,680
T-009	278,253	4,913,553
T-010	278,250	4,913,184
T-011	279,004	4,912,568
T-012	277,525	4,911,421
T-013	277,997	4,911,819
T-014	279,201	4,911,643
T-015	277,134	4,910,804
T-016	278,760	4,910,602
T-017	279,250	4,910,861
T-018	278,115	4,909,768
T-019	278,059	4,909,162
T-020	279,042	4,908,888
T-021	276,094	4,908,511
T-022	277,918	4,908,477
T-023	276,260	4,907,923
T-024	277,845	4,907,428
T-025	278,299	4,907,713
T-026	279,018	4,907,880
T-028	284,382	4,909,786
T-029	283,041	4,910,336
T-030	283,755	4,910,384
T-031	283,131	4,909,606
T-032	284,151	4,909,433
T-033	282,670	4,909,298
T-034	281,137	4,907,425
T-035	281,644	4,907,959
T-036	282,072	4,908,388
T-037	283,512	4,907,241
T-038	278,366	4,918,774
T-039	277,238	4,918,508
T-040	278,351	4,918,093
T-041	277,653	4,917,679
T-042	277,247	4,917,334
T-044	269,753	4,905,319
T-045	270,225	4,905,590
T-046	270,368	4,902,963
T-047	270,808	4,903,283
T-048	293,274	4,904,520

Turbine Identification	X (UTM 14)	Y (UTM 14)
T-049	272,029	4,902,362
T-050	273,166	4,902,059
T-051	273,707	4,902,284
T-052	273,283	4,902,971
T-053	273,552	4,903,466
T-054	274,060	4,903,900
T-055	274,131	4,904,440
T-056	275,247	4,904,294
T-057	275,737	4,904,481
T-058	276,377	4,904,464
T-059	275,510	4,907,004
T-060	276,515	4,905,940
T-062	276,439	4,906,674
T-067	282,606	4,906,387
T-068	282,523	4,905,775
T-069	282,505	4,905,065
T-073	285,096	4,905,551
T-074	285,208	4,905,962
T-075	287,753	4,906,292
T-076	287,612	4,905,696
T-077	288,335	4,906,565
T-078	289,234	4,906,552
T-079	290,127	4,906,526
T-080	289,977	4,905,534
T-081	290,625	4,905,716
T-082	290,437	4,904,735
T-083	291,392	4,904,824
T-084	291,667	4,905,328
T-085	290,655	4,904,053
T-086	291,462	4,904,025
T-087	292,436	4,903,762
T-088	292,871	4,904,139
T-089	276,518	4,910,626
T-090	276,550	4,910,031
T-091	276,301	4,909,051
T-092	265,824	4,902,186
T-093	266,313	4,902,468
T-094	267,202	4,902,485
T-095	269,437	4,901,663
T-101	274,566	4,906,230
T-102	279,743	4,918,305
T-103	279,765	4,917,586
T-104	281,602	4,906,780
T-105	285,176	4,906,595
T-108	276,288	4,909,618

APPENDIX B

RECEPTOR COORDINATES AND EXPECTED ANNUAL SHADOW FLICKER HOURS

Appendix B - Philip Wind Project
Receptor Coordinates and Expected Annual Shadow Flicker (by Turbine Configuration)

Receptor ID ("-P Denotes Participant)	X (UTM 14)	Y (UTM 14)	Expected Shadow (Annual Hours) GE Configuration	Expected Shadow (Annual Hours) Vestas Configuration	Expected Shadow (Annual Hours) Nordex Configuration
R-001	291,513	4,908,427	0:00	0:00	0:00
R-002-P	286,783	4,902,299	0:00	0:00	0:00
R-003-P	284,773	4,908,590	2:55	3:08	0:00
R-004-P	282,282	4,906,983	24:26	27:40	33:35
R-005	280,732	4,908,410	16:39	18:17	17:56
R-006-P	280,770	4,912,366	3:48	4:10	4:39
R-007	280,174	4,907,189	26:23	28:43	28:27
R-008-P	274,443	4,907,683	12:32	13:39	7:25
R-009[1]	272,059	4,907,512	0:00	0:00	0:00
R-010-P	271,215	4,905,925	6:17	6:48	7:27
R-011-P	271,192	4,905,980	6:01	6:32	7:07
R-012	271,202	4,910,293	0:00	0:00	0:00
R-013	269,543	4,910,269	0:00	0:00	0:00
R-018	285,816	4,910,304	3:31	3:55	2:44
R-020	280,511	4,920,073	0:00	0:00	0:00
R-022	276,691	4,920,341	11:19	12:30	13:46
R-025	271,848	4,900,917	0:00	0:00	0:00

[1] Cemetery