Shadow Flicker Impact Analysis for the Oliver III Wind Energy Center

Prepared for

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1.0 OVERVIEW

A wind turbine's moving blades can cast a moving shadow on locations within a certain distance of a turbine. These moving shadows are called shadow flicker, and can be a temporary phenomena experienced by people at nearby residences or public gathering places. The impact area depends on the time of year and day (which determines the sun's azimuth and altitude angles) and the wind turbine's physical characteristics (height, rotor diameter, blade width, and orientation of the rotor blades). Shadow flicker generally occurs during low angle sunlight conditions, typical during sunrise and sunset times of the day. However, when the sun angle gets very low (less than 3 degrees), the light has to pass through more atmosphere and becomes too diffuse to form a coherent shadow. In addition, when the turbine blades mask (cover) less than 20% of the solar disk, relative to the position of the observer, the shadow is too diffuse to form a coherent shadow. Shadow flicker will not occur when the sun is obscured by clouds or fog, at night, or when the source turbine(s) are not operating.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance. Shadow flicker intensity for receptor-to-turbine distances beyond 1,500 meters (4,921 feet) is very low and generally considered imperceptible. Shadow flicker intensity for receptor-to-turbine distances between 1,000 and 1,500 meters (between 3,281 and 4,921 feet) is also low and considered barely noticeable. At this distance shadow flicker intensity would only tend to be noticed under conditions that would enhance the intensity difference, such as observing from a dark room with a single window directly facing the turbine casting the shadow. At distances less than 1,000 meters (3,281 feet), shadow flicker may be more noticeable. In general, the largest number of shadow flicker hours, along with greatest shadow flicker intensity, occurs nearest the wind turbines.

NextEra Energy Resources LLC is proposing to install 30 wind turbines as part of the Oliver III Wind Energy Center (Project) in Morton County, North Dakota (the layout includes 4 alternate locations). Since the Project is using a minimum turbine siting setback requirement of 1,400 feet (to any occupied residence), sensitive receptors (occupied residences) are generally not located in the worst case potential shadow flicker impact zones, which ensures that shadow flicker impacts are minimized.

The wind turbine being considered for the Project, and evaluated for potential shadow flicker impacts, has the following characteristics:

- **GE Wind Energy GE 1.6xle** – 3-blade 100-meter-diameter rotor, with a hub height of 80 meters. The GE 1.6xle has a nominal rotor speed of 18 rpm which translates to a blade pass frequency of 0.9 Hz (less than 1 alternation per second).

Shadow flicker frequency is related to the wind turbine's rotor blade speed and the number of blades on the rotor. From a health standpoint, such low frequencies are harmless. For comparison, strobe lights used in discotheques have frequencies which range from about 3 Hertz (Hz) to 10 Hz (1 Hz = 1 flash per second). As a result, public concerns that flickering light from wind turbines can have negative health effects, such as triggering seizures in people with epilepsy are unfounded. The Epilepsy Action (working name for the British Epilepsy Foundation), states that there is no evidence that wind turbines can cause seizures. However, they recommend that wind turbine flicker frequency be limited to 3 Hz (http://www.epilepsy.org.uk/info/photo_other.html). Since the proposed Project's wind turbine blade pass frequency is approximately 0.9 Hz (less than 1 alternation per second), no negative health effects to individuals with photosensitive epilepsy are anticipated.

Shadow flicker impacts are not regulated in applicable state or federal law, and there is no permitting trigger with regard to hours per year of anticipated impacts to a receptor from a wind energy project. Due to the significant growth of the wind energy industry in recent years, some states have published model bylaws for local governments to adopt or modify at their own discretion which sometimes includes guidance and recommendations for shadow flicker levels and mitigation. However, a general precedent has been established in the industry both abroad and in the United States that fewer than 30 hours per year of shadow flicker impacts is acceptable to receptors in terms of nuisance and well below health hazard thresholds. In German court case for example, a judge found 30 hours of actual shadow flicker per year at a certain neighbor's property to be tolerable (WindPower 2003).

2.0 WINDPRO SHADOW FLICKER ANALYSIS

An analysis of potential shadow flicker impacts from the Project was conducted using the WindPro software package. The turbine array dated September 13, 2012, which includes 30 turbines and 3 alternate locations, was included in the analysis. The WindPro analysis was conducted to determine shadow flicker impacts under realistic impact conditions (actual expected shadow flicker). This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at receptors out to 1,500 meters (4,921.3 feet). The realistic impact condition scenario is based on the following assumptions:

- The elevation and position geometries of the wind turbines and surrounding receptors (houses). Elevations were determined using USGS National Elevation Dataset (NED) information. Positions geometries were determined using GIS and referenced to UTM Zone 14 (NAD83).
- The position of the sun and the incident sunlight relative to the wind turbine and receptors on a minute by minute basis over the course of a year.
- Historical sunshine hours availability (percent of total available). Historical sunshine rates for the area (as listed by the National Weather Service for nearby Bismarck, ND) used in this analysis are as follows:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
53%	53%	58%	58%	61%	64%	73%	72%	65%	58%	43%	47%

- Estimated wind turbine operations and orientation (based on nearly 2.5 years of wind data from 10/23/2008 to 4/30/2011 (wind speed / wind direction frequency distribution) measured at meteorological tower on the proposed project site). The WindPro calculated wind direction frequency distribution for operating hour winds is as follows:

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
7.5%	4.6%	4.0%	4.6%	6.7%	10.9%	10.1%	5.9%	5.4%	9.5%	16.0%	14.8%

- Receptor viewpoints (i.e., house windows) are assumed to always be directly facing turbine to sun line of sight ("greenhouse mode").

WindPro incorporates terrain elevation contour information and the analysis accounts for terrain elevation differences. The sun's path with respect to each turbine location is calculated by the software to determine the cast shadow paths every minute over a full year. Sun angles less than 3 degrees above the horizon, and periods where the rotor masks less than 20% of the solar disk, were excluded, for the reasons identified earlier (in Section 1).

A total of 31 sensitive receptor locations were identified in the vicinity of the Project Area. These receptors are based on the February 11, 2010 Farmstead Report data. These locations correspond to houses or other structures in the Project Area. A receptor in the model is defined as a 1 m^2 area (approximate size of a typical window), 1 meter (3.28 feet) aboveground level. Approximate eye level is set at 1.5 meters (4.94 feet). Figure 1 shows the sensitive receptor locations considered.

3.0 WINDPRO SHADOW FLICKER ANALYSIS RESULTS

WindPro predicts that shadow flicker impacts will primarily occur near the wind turbines. Figure 2 describes the WindPro predicted expected shadow flicker impact areas. A detailed WindPro shadow flicker analysis results summary, for each of the modeling receptor locations, is provided in Attachment A. Table 1 presents the WindPro predicted expected shadow flicker impacts for the top ten worst case impact receptors. Only one of the 31 receptors modeled had expected shadow flicker impacts predicted for more than 30 hours per year.

The maximum predicted shadow flicker impact at any receptor, for the range of potential wind turbine options, is for Receptor # 7002 at 32 hours, 12 minutes per year, which is approximately 0.7 percent of the potential available daylight hours. Receptor # 7002 is an occupied residence of a Project participant.

Table 1. WindPro Predicted Shadow Flicker Impacts for Receptors with Maximum Impacts

Receptor ID	Receptor Description	Shadow Hours per Year (expected) [hh:mm / year]
7002	Occupied	32:12
7007	Occupied	25:34
300008	Unoccupied	19:16
6005	Occupied	10:54
6011	Occupied	9:13
6003	Unoccupied	9:08
6006	Occupied	6:37
7016	Occupied	5:41
7004	Unoccupied	5:01
6004	Occupied	3:41

Eighteen of the receptor locations evaluated would have no shadow flicker impacts; eleven of the receptor locations evaluated would have less than 20 hours per year of predicted shadow flicker impact. The shadow flicker impact prediction statistics are as summarized in Table 2.

Table 2. Statistical Summary of WindPro Predicted Shadow Flicker Impacts at Modeled Sensitive Receptor Locations

Cumulative Shadow Flicker Time (expected)	Number of Receptors
Total	31
= 0 Hours	18
> 0 Hours < 10 hours	9
≥ 10 Hours < 20 hours	2
≥ 20 Hours < 30 hours	1
≥ 30 Hours < 40 hours	1
> 40 Hours	0

4.0 CONCLUSION

The analysis of potential shadow flicker impacts from the Project on nearby houses (receptors) shows that shadow flicker impacts within the area of study are expected to be minor. The analysis assumes that the houses all have a direct in line view of the incoming shadow flicker sunlight and does not account for trees or other obstructions which may block sunlight. In reality, the windows of many houses will not face the sun directly for the key shadow flicker impact times. In addition, potential shadow flicker impacts for wind turbines up to 1,500 meters (4,921 feet) away were determined. In reality, the shadow flicker impacts for turbines beyond 1,000 meters (3,281 feet) will be very low intensity. For these reasons, shadow flicker impacts are expected to be less than estimated with the conservative analysis, and shadow flicker is not expected to be a significant environmental impact.

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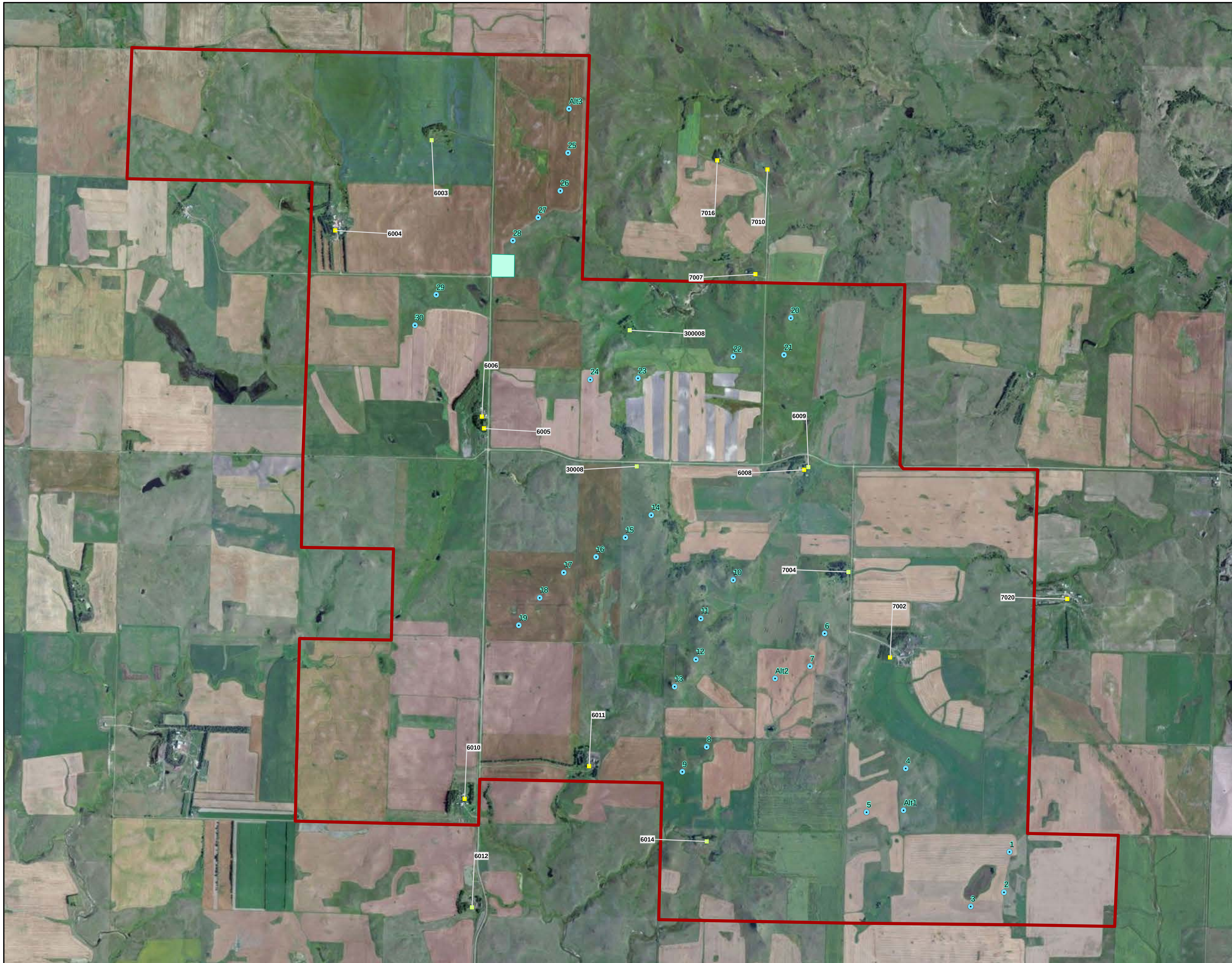
Morton County, North Dakota

FIGURE 1
RESIDENTIAL RECEPTORS MODELED WITH WINDPRO TO PREDICT EXPECTED SHADOW FLICKER IMPACTS

October, 2012



Legend

- Oliver III WTG (9/13/12)
- Receptor - Occupied
- Receptor - Unoccupied
- Substation
- Project Boundary

REFERENCE MAP

Path: P:\GIS\NextEra_OliverIII\GIS\Spatial\MXD\20121105_ShadowFlicker\OliverIII_Shadow_Flicker_Fig1_Receptors.mxd

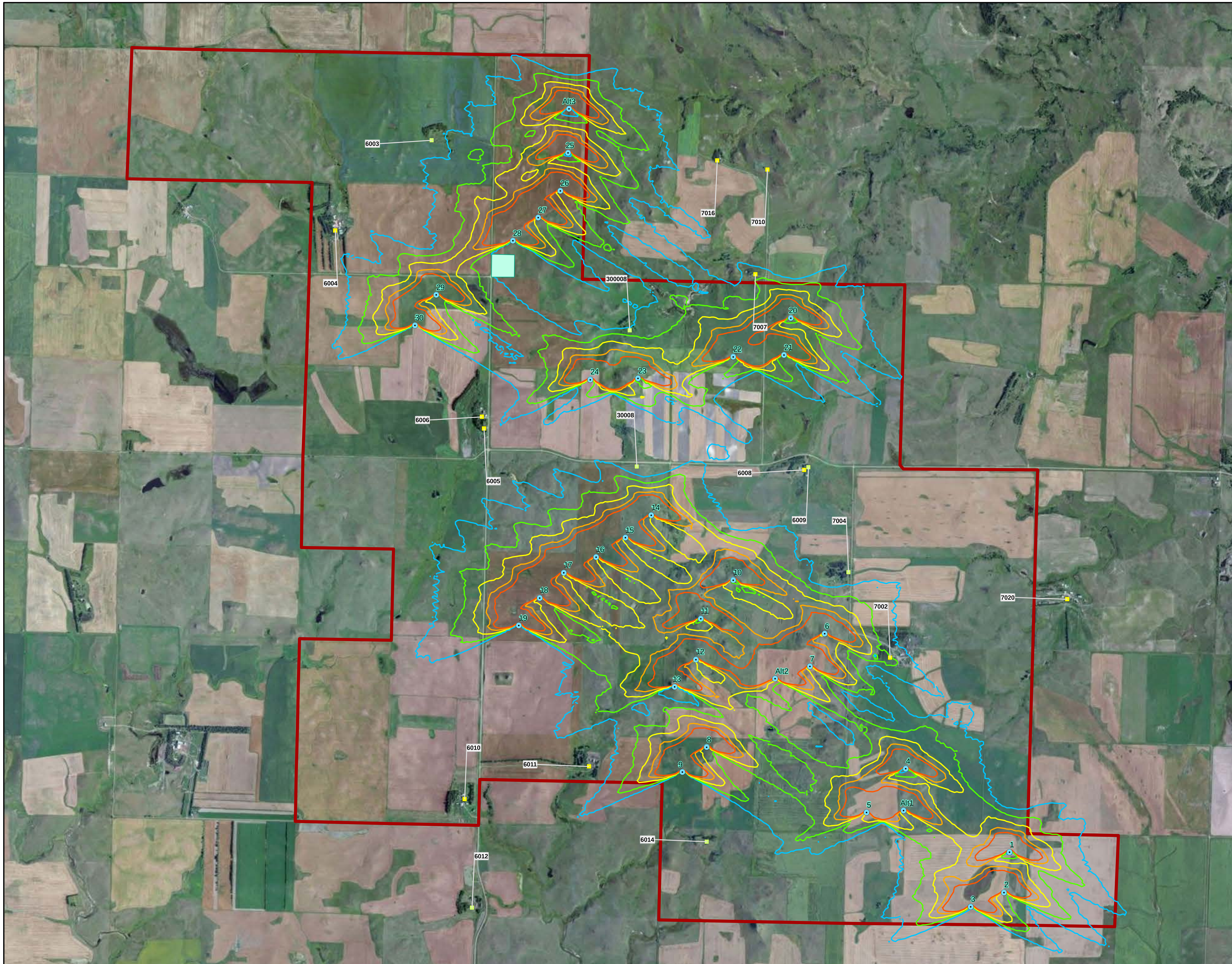


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FIGURE 2
WINDPRO PREDICTED EXPECTED SHADOW FLICKER IMPACT AREAS

October, 2012

Legend

- Oliver III WTG (9/13/12)
- Receptor - Occupied
- Receptor - Unoccupied
- Substation
- Project Boundary

Shadow Flicker Iso Line (hrs/yr)

15 30 50 75 100 200

REFERENCE MAP

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ATTACHMENT A

Detailed Summary of WindPro Shadow Flicker Analysis Results

Oliver III Wind Energy Center
WindPro Shadow Flicker Analysis Results Summary

WindPro Receptor ID	NextEra Oliver III Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted Expected Shadow Flicker (Hours per Year)	Status	Owner
1	6002	335,368	5,206,778	0:00	Unoccupied	Alan Schwalbe
2	6003	335,434	5,204,641	9:08	Unoccupied	Calvin Schmidt
3	6004	334,582	5,203,847	3:41	Occupied	Tom Zander
4	6005	335,894	5,202,102	10:54	Occupied	Chad Olson
5	6006	335,875	5,202,206	6:37	Occupied	Arden Hagerott
6	30008	337,240	5,201,768	0:00	Unoccupied	(Relay Tower)
7	6008	338,714	5,201,739	1:34	Occupied	Audrey Spence Etal
8	6009	338,753	5,201,759	1:29	Unoccupied	Audrey Spence Etal
9	6010	335,722	5,198,836	0:00	Occupied	Marcus Zander
10	6011	336,821	5,199,125	9:13	Occupied	Val Schlosser
11	6012	335,789	5,197,882	0:00	Unoccupied	Zander Family Trust
12	6013	336,785	5,196,966	0:00	Occupied	Bruce Engelhardt
13	6014	337,857	5,198,463	1:28	Unoccupied	Kasper & Caroline
14	7002	339,472	5,200,083	32:12	Occupied	Walter Vogel
15	7004	339,106	5,200,837	5:01	Unoccupied	Nels & Darlene
16	7007	338,286	5,203,461	25:34	Occupied	Ben Kopp
17	7010	338,391	5,204,385	0:00	Occupied	Lawrence & Frances
18	7016	337,949	5,204,464	5:41	Occupied	Lawrence & Frances
19	7020	341,032	5,200,597	0:00	Occupied	Ronald & Virginia
20	7023	342,191	5,197,153	0:00	Occupied	Vernon Bahm Etal
21	7027	342,143	5,197,130	0:00	Occupied	Vernon Bahm Etal
22	7029	341,907	5,197,106	0:00	Occupied	Vernon Bahm Etal
23	300008	337,179	5,202,968	19:16	Unoccupied	Arden Hagerott
24	5015	335,015	5,210,254	0:00	Occupied	Dale & Gail Hilton
25	5016	335,270	5,210,159	0:00	Occupied	Dale & Gail Hilton
26	5017	335,141	5,210,664	0:00	Occupied	Dale Barnhardt
27	5013	331,662	5,210,195	0:00	Occupied	Douglas Doll etal
28	5018	334,958	5,209,903	0:00	Occupied	Delmar Hagerott etal
29	5026	331,919	5,207,710	0:00	Occupied	Mark & Lynette Dagley
30	5021	334,144	5,206,664	0:00	Occupied	Simon Schmidt
31	5020	334,149	5,206,673	0:00	Occupied	Simon Schmidt