Appendix D: Shadow Flicker Analysis

Wisconsin Power and Light Company
Docket No. IP7145/WS-24-349

SHADOW FLICKER IMPACT ASSESSMENT

Bent Tree North Wind Project

Freeborn County, Minnesota

JANUARY 22, 2025

PREPARED FOR:

Wisconsin Power & Light

(Alliant Energy Corporation)

PREPARED BY:

Westwood

Westwood

Shadow Flicker Impact Assessment

Bent Tree North Wind Project

Freeborn County, Minnesota

Prepared For:

Wisconsin Power & Light (Alliant Energy Corporation)
4902 N. Biltmore Lane
Madison, WI 53718

Prepared By:

Westwood Professional Services
12701 Whitewater Drive, Suite 300
Minnetonka, MN 55343
(952) 937-5150

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Table of Contents

Tables

Appendices

Executive Summary

Westwood Professional Services (Westwood) was hired by Wisconsin Power & Light (Alliant Energy Corporation) (Client) to provide estimates of the shadow flicker potential for two proposed wind turbine layouts of the Bent Tree North Wind Project (Project) in Freeborn County, Minnesota.

Geographical information of residential structures within 2 kilometers of any turbine location was obtained from the publicly available US building footprint dataset, converted to points, and verified with aerial imagery.

The proposed wind turbine layouts were designed by Westwood in conjunction with the Client. The turbine technology/type were provided by the Client. A digital windPRO model was built including definitions of elevation data and the turbine layouts information to generate shadow flicker calculations for the site. Based on the shadow flicker calculations, site-wide realistic shadow flicker maps were produced and an evaluation of the shadow flicker at 250 residential structures within 2 kilometers (1.2 miles) of a proposed Project turbine location were performed.

The 250 residential structures were represented in the model by omni-directional shadow receptors that simulate a 1 meter by 1 meter window located 1 meter above ground level (AGL). Reductions based on turbine operational time, turbine operational direction, and sunshine probabilities were used to calculate a realistic number of hours of shadow flicker to be expected at each shadow receptor. No obstacles were used so that shadow flicker reductions due to interference from trees and structures were not included, meaning that the "realistic" estimates are conservative.

Section 26-56 of the Freeborn County Ordinance No. 2015-01, § 8, 12-1-2015 states "A flicker analysis shall include the duration and location of flicker potential for all receptors and road ways within a one-mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any receptor shall not exceed 30 hours per year within the analysis area."

For both layouts, results indicated that there are eight residential structures registering more than 30 hours per year, ranging from 31 hours and 6 minutes to 48 hours and 48 minutes for Layout A, and 31 hours and 17 minutes to 49 hours and 0 minutes for Layout B. The eight residential structures receive shadow flicker mainly from alternate turbines included in the modeling. No exceedance is expected at receptors when only primary turbines are included in the modeling.

1.0 Introduction

Westwood was hired to provide estimates of the shadow flicker potential for two proposed wind turbine layouts of the Bent Tree North Wind Project (Project) in Freeborn County, Minnesota. The proposed Project turbine layouts consist of 38 Vestas V136-4.5 wind turbines; one with a

hub heights of 112 meters (367 feet) and the other with a hub height of 120 meters (394 feet) above ground level. To meet setbacks, some turbine coordinates differ between layouts.

The topography of the project area is generally flat with elevations ranging from 369 – 398 meters (1,211 – 1.306 feet) above mean sea level. The project area is generally cropland with farm steads.

Locations of residential structures within 2 kilometers (1.2 miles) of a proposed Project turbine location were obtained from the publicly available US building footprint dataset, converted to points, and verified with aerial imagery. Field verification of the status of occupancy of residential structures and/or to check for new construction that may not be visible on imagery has not been done as part of this analysis.

Land ownership or project participation status was not considered, rather any residential structure within 2 kilometers (1.2 miles) of a proposed Project turbine was subject to a 30 hour/year shadow flicker limit at the residential structure.

2.0 Background

Shadow flicker from wind turbines occurs when rotating wind turbine blades move between the sun and the observer. Shadow flicker is generally experienced in areas near wind turbines where the distance between the observer and wind turbine blade is short enough that sunlight has not been significantly diffused by the atmosphere. When the blades rotate, this shadow creates a pulsating effect, known as shadow flicker. If the blade's shadow is passing over the window of a building, it will have the effect of increasing and decreasing the light intensity in the room at a low frequency in the range of 0.5 to 1.2 Hz, hence the term "flicker."

This flickering effect can also be experienced outdoors, but the effect is typically less intense, and becomes less intense farther from the wind turbine causing the flicker. The moving shadow of a wind turbine blade on the ground is similar to the effect one experiences when driving on a road when there are shadows cast across the road by an adjacent row of trees.

This flickering effect is most noticeable within approximately 1,000 meters (3,281 feet) of the turbine and becomes more and more diffused as the distance increases. Beyond 1,700 meters (5,577 feet), the shadow flicker effects are indistinguishable. There are no uniform standards defining what distance from the turbine is regarded as an acceptable limit beyond which the shadow flicker is considered insignificant nor the number of hours of flickering that is deemed to be acceptable. The windPRO model considers shadow effects to be indistinguishable when less than 20% of the solar disc is covered by the turbine blade. Dimensions of the blade can be used to determine an acceptable calculation distance.

Shadow flicker is typically greatest in the winter months when the angle of the sun is lower and casts longer shadows. The effect is also more pronounced around sunrise and sunset when the sun is near the horizon and the shadows are longer. A number of factors influence the amount of shadow flicker on the observer.

One consideration is the environment around the observer. Obstacles such as terrain, trees or buildings between the wind turbine and the observer can significantly reduce or eliminate shadow flicker effects. Deciduous trees may block the shadow flickering effect to some degree, depending on the tree density, species present and time of year.

Deciduous trees can lead to a reduction of shadow flicker during the summer when the trees are bearing leaves. However, during the winter months, these trees are without their leaves and their impact on shadow flicker is not as significant. Coniferous trees tend to provide mitigation from shadow flicker year-round. For this study, no credit was taken for any potential shading effects from any type of trees or other obstacles that would reduce the number of shadow flickering hours at the residential structures which will make the shadow flicker prediction more conservative (higher than in reality).

Another consideration is the time of day when shadow flicker occurs. For example, it may be more acceptable for private homes to experience the shadow flickering during daytime hours when family members may be at work or school. Likewise, a commercial property would not be significantly affected if all the shadow flicker impact occurred before or after business hours.

The climate also needs to be considered when assessing shadow flicker. In areas with a significant amount of overcast weather, there would be less shadow flicker, as there are no shadows if the sun is blocked by clouds. Also, if the wind is not blowing, the turbines would not be operational and therefore not creating shadow flickering.

Section 26-56 of the Freeborn County Ordinance No. 2015-01, § 8, 12-1-2015 states “A flicker analysis shall include the duration and location of flicker potential for all receptors and road ways within a one-mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any receptor shall not exceed 30 hours per year within the analysis area.”

For this study, in the interest of being conservative, any presumed occupied residential structure within 2 kilometers (1.2 miles) of proposed Project turbines were included in the analysis. Shadow hours results contours are also mapped and overlaid on aerial imagery.

The nearest existing wind turbine to a project turbine is approximately 1,800 meters (5,906 feet), part of the Bent Tree 1 wind farm. Shadow flicker contributions from the neighbor wind farms were not included in the model. Details of the project turbines included in this model can be seen below in **Table 1**.

Table 1 – Turbines Included in the Shadow Flicker Model

Layout ID	Turbine Quantity	Manufacturer	Model	Hub Height (m)	Rotor Diameter (m)	Cut-in Speed (m/s)	Cut-out Speed (m/s)
A	38	Vestas	V136-4.5	112	136	3	32
B	38	Vestas	V136-4.5	120	136	3	32

3.0 Study Methodology

This shadow flicker analysis was performed utilizing windPRO, which has the ability to calculate detailed shadow flicker maps across an entire area of interest or at site-specific locations using shadow receptors.

Shadow maps which indicate where the shadows will be cast and for how long, are generated using windPRO, calculating the shadow flicker in varying user-defined resolutions. Fine resolution was used for this study and represents shadow flicker being calculated every two minutes of every 3rd day over the period of an entire year over a grid with a resolution of 10 meters by 10 meters (33 feet by 33 feet).

In addition to generating a shadow flicker map, the amount of shadow flicker that may occur at a specific point can be calculated more precisely by placing a shadow receptor at the location of interest and essentially "recording" the shadow flicker that occurs as the relative sunrise to sunset motion of the sun is simulated throughout an entire year.

The point-specific shadow flicker calculation is run at a higher resolution as compared to the shadow flicker map calculation to utilize the highest precision available within windPRO. Shadow flicker at each shadow receptor location is calculated every minute of every day for an entire year. Shadow receptors can be configured to represent an omni-directional window of a specific size at a specific point (greenhouse mode) or a window facing a single direction of a specific size at a specific point (single direction mode). The shadow receptors used in this analysis were configured as greenhouse-mode receptors representing a 1 meter by 1 meter window located 1 meter AGL. This represents more of a "worst-case" scenario and thus will produce more conservative results since it assumes that all windows are always in direct line of sight with the turbines and the sun.

As a part of the calculation method, windPRO must determine whether a turbine will be visible at the receptor locations and not blocked by local topography or obstacles. It does this by performing a preliminary Zones of Visual Influence (ZVI) calculation, utilizing a 10-meter grid spacing. If a particular turbine is not visible within the 10-meter by 10-meter area that the shadow receptor is contained within, then that turbine is not included in the shadow flicker calculation for that receptor.

The inputs for the windPRO shadow flicker calculation include the following:

- Turbine Coordinates
- Turbine Specifications
- Shadow Receptor Coordinates
- Monthly Sunshine Probabilities
- Joint Wind Speed and Direction Frequency Distribution
- USGS Digital Elevation Model (DEM)

Turbine Coordinates: The location of a wind turbine in relation to a shadow receptor is one of the most important factors in determining shadow flicker impacts. A line-of-site is required for shadow flicker to occur. The intensity of the shadow flicker is dependent upon the distance from the wind turbine and weather conditions.

Turbine Specifications: A wind turbine's total height and rotor diameter will be included in the windPRO shadow flicker model. The taller the wind turbine, the more likely shadow flicker could have an impact on local shadow receptors as the ability to clear obstacles (such as hills or trees) is greater, although in this analysis, no credit is taken for any such blockage from trees. The larger the rotor diameter is, the wider the area where shadows will be cast. Also included with the turbine specifications are the cut-in and cut-out wind speeds within which the wind turbine is operational. If the wind speed is below the cut-in threshold or above the cut-out

threshold, the turbine rotor will not be spinning and thus shadow flicker will not occur. Turbine blade dimensions are also important as the amount of the blade surface covering the sun contributes to the perceptiveness of the resulting shadow.

Shadow Receptor Coordinates: As with the wind turbine coordinates, the elevation, distance, and orientation of a shadow receptor in relation to the wind turbines and the sun are the main factors in determining the impact of shadow flicker. Westwood obtained receptors from the publicly available US building footprint dataset, converted to points, and verified with aerial imagery. A total of 250 residential structures were included in the model.

Monthly Sunshine Probabilities: windPRO calculates sunrise and sunset times to determine the total annual hours of daylight for the modeled area. To further refine the shadow flicker calculations, the monthly probability of sunshine is included to account for cloud cover. The greater the probability of cloud cover, the less of an impact from shadow flicker. The monthly sunshine probabilities for many of the larger cities across the United States are available from the National Climatic Data Center (NCDC). For this study, 18 years' worth of monthly sunshine probability data were retrieved for Minneapolis-St. Paul MN, which was the closest, most representative station, to create the long-term representative monthly sunshine probabilities.

The long-term representative monthly average sunshine probabilities are presented in **Table 2** below.

Table 2 – Minneapolis-St. Paul, MN Monthly Sunshine Probability 1965 - 1983

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sunshine %	53	59	57	56	62	67	74	69	62	51	37	38

Retrieved from: http://www1.ncdc.noaa.gov/pub/data/ccd-data/pctpos15.dat

Joint Wind Speed and Direction Frequency Distribution: Approximately two and three quarter years of quality-controlled wind speed and direction data was provided by the client, recorded at a meteorological mast with the highest wind speed measurement at 58 meters (190 ft). Using the provided data and reanalysis data, Westwood predicted a long-term time series of wind speeds and direction using MCP (measure-correlate-predict) methods. This data was extrapolated to a hub height based on estimated wind shear observed from the multiple measurement heights and used to estimate the probable number of operational hours of the wind turbines for each wind directional sector. During operation, the wind turbine rotors will always be assumed to face into the wind and automatically orient themselves as the wind direction changes. Shadow flicker can only occur when the wind turbine rotor is spinning and is in between the sun and the receptor. Shadow flicker is most significant when the rotor is facing the sun.

USGS Digital Elevation Model (DEM): For this study, 1/3 arc-second USGS National Elevation Database (NED) DEM's were used for the windPRO shadow flicker model. The DEM grid information is important to the shadow flicker calculation since it allows the model to place the wind turbines and the shadow receptors at the correct elevations. The elevation model also allows the model to include the topography of the site when calculating the zones of visual influence surrounding the wind turbine and shadow receptor locations.

Shadow Flicker Calculation: The actual calculation of potential shadow flicker at a given shadow receptor is carried out by simulating the environment near the wind turbines and the

shadow receptors. The position of the sun relative to the turbine rotor disk and the resulting shadow is calculated in time steps of one minute throughout an entire year. If the shadow of the rotor disk (which in the calculation is assumed solid) at any time casts a shadow on a receptor, then this step will be registered as one minute of shadow flicker. The calculation also requires that the sun must be at least 3.0° above the horizon in order to register shadow flicker. When the sun angle is less than 3.0°, the shadow quickly becomes too diffuse to be distinguishable since the amount of atmosphere that the light must pass through is 15 times greater than when the sun is directly overhead. When less than 20% of the solar disc is covered by the blade, the shadow effects are considered negligible. For this study, the maximum distance the shadow can reach is 1,802 meters (5,912 feet).

The sun's path with respect to each wind turbine location is calculated by the software to determine the paths of cast shadows for every minute of every day over a full year.

The turbine runtime and direction are calculated from the site's wind speed and direction distribution. Finally, the effects of cloud cover are calculated using long-term reference data (monthly sunshine probability) to arrive at the projected annual flicker time at each receptor.

4.0 Results of Analysis

The term "realistic" as used in this report means that turbine operational hours and direction as well as local sunshine probabilities have been factored in, but no blocking or shading effects due to trees or structures have been accounted for. This means that the realistic estimates are still inherently conservative values. Also, the realistic shadow flicker hours predicted by windPRO assumes an availability factor of 100% which is very unlikely to be the case. Actual availability factors will likely be in the range of 95-98%, however, with a conservative approach to estimating shadow flicker totals, the realistic estimates are not discounted accordingly.

A total of 250 residential structures within the project area vicinity were analyzed. Fine resolution shadow flicker maps were also generated for the turbine arrays. All 250 residential structures were modeled as greenhouse-mode shadow receptors in the shadow flicker calculations.

For Layout A, one hundred and forty-six (146) shadow receptor are not expected to experience shadow flicker. Ninety-six (96) shadow receptors are expected to experience no more than 30 hours of shadow flicker per year. Of the remaining eight (8) shadow receptors registering above 30 hours per year, the maximum expected impact is 48 hours and 38 minutes.

For Layout B, one hundred and forty-seven (147) shadow receptor are not expected to experience shadow flicker. Ninety-five (95) shadow receptors are expected to experience no more than 30 hours of shadow flicker per year. Of the remaining eight (8) shadow receptors registering above 30 hours per year, the maximum expected impact is 49 hours and 0 minutes.

Table 3 below depicts the distribution of shadow flicker hours modeled at the shadow receptors. Please see **Appendix B** for the full shadow flicker analysis results.

Table 3 – Realistic Shadow Flicker Distribution

	Layout A	Layout B
Realistic Shadow Flicker (hrs/year)	# of Receptors	# of Receptors
0	146	147
0 to 5	47	45
5 to 10	18	17
10 to 15	9	10
15 to 20	6	8
20 to 25	8	6
25 to 30	8	9
30 +	8	8

The highest shadow flicker contributors to the exceedance are the alternate turbine T-08ALT, T-10ALT, T-36ALT and T-37ALT.

5.0 Conclusions

The shadow flicker impact assessment for the identified residential structures was calculated with reductions due to turbine operational time, direction, and sunshine probabilities. Based on the proposed layouts, two hundred and forty-two (242) shadow receptors are expected to experience no more than 30 hours of shadow flicker per year. Eight (8) shadow receptors are expected to exceed 30 hours per year of shadow flicker, mainly caused by alternate Project turbines T-08ALT, T-10ALT, T-36ALT and T-37ALT.

No exceedance is expected at receptors when only primary turbines are included in the modeling.

The shadow flicker impact on the shadow receptors was calculated from turbines within 1,802 meters (5,912 feet) with reductions due to turbine operational time, direction and sunshine probabilities included.

This shadow flicker analysis is based on the following assumptions:

- The assessment assumes all Project wind turbines are the V136-4.5 with a hub height of 112 meters (Layout A) and 120 meters (Layout B).
- No credit was taken for blocking effects of trees or structures during the initial shadow flicker model run.
- The shadow receptors were omni-directional rather than modeling specific facades of buildings.
- The assessment assumes 100% turbine availability.

The overall effect of using these conservative assumptions indicate that realistically, the number of hours of shadow flicker that would be observed will be less than those predicted by this study.

Westwood suggests communicating with the occupants of the residential structures that would experience more than or around 30 hours per year of shadow flicker, to inform them about the

shadow flicker impacts, determine the occupational status of the residential structures during the daytime and propose any mitigation measures for any of the residential structures that are occupied at the times the shadow flicker events occur.

Based on the current layout utilizing primary turbine locations , no shadow mitigation is anticipated to be necessary. If an alternate turbine location causing shadow flicker at a receptor greater than 30 hours per year is selected to be used as a primary location, a mitigation plan will be provided for review and approval.

Appendix A

Layout A - Turbine Coordinates

(NAD83 UTM Zone 15)

Turbine ID	Easting [m]	Northing [m]	Elevation [m]	Model	Rotor Diameter [m]	Hub Height [m]
T-01	456,338	4,849,145	380.0	V136-4.5	136	112
T-02	456,988	4,849,245	374.0	V136-4.5	136	112
T-03	457,296	4,849,597	375.5	V136-4.5	136	112
T-04	458,096	4,849,914	374.7	V136-4.5	136	112
T-05	458,857	4,850,587	372.6	V136-4.5	136	112
T-06	456,535	4,850,571	369.4	V136-4.5	136	112
T-07	456,942	4,850,779	370.8	V136-4.5	136	112
T-08ALT	457,229	4,850,936	370.2	V136-4.5	136	112
T-09	457,915	4,850,947	380.3	V136-4.5	136	112
T-10ALT	458,068	4,851,439	380.7	V136-4.5	136	112
T-11	457,800	4,853,131	374.2	V136-4.5	136	112
T-12	458,650	4,853,301	375.2	V136-4.5	136	112
T-13	459,677	4,852,647	371.0	V136-4.5	136	112
T-14	459,990	4,853,091	370.9	V136-4.5	136	112
T-16	459,369	4,854,460	370.2	V136-4.5	136	112
T-17	459,806	4,854,556	375.6	V136-4.5	136	112
T-18	462,175	4,851,406	388.7	V136-4.5	136	112
T-19	462,740	4,851,460	384.0	V136-4.5	136	112
T-20	463,305	4,851,574	390.3	V136-4.5	136	112
T-21	464,120	4,851,741	388.7	V136-4.5	136	112
T-22	464,570	4,851,755	394.6	V136-4.5	136	112
T-23	465,158	4,851,856	397.6	V136-4.5	136	112
T-24	465,638	4,851,869	386.5	V136-4.5	136	112
T-25	466,229	4,851,484	387.1	V136-4.5	136	112
T-26	466,819	4,851,605	394.6	V136-4.5	136	112
T-27	468,407	4,851,609	384.5	V136-4.5	136	112
T-28	465,377	4,853,923	390.3	V136-4.5	136	112
T-29	465,812	4,853,974	392.8	V136-4.5	136	112
T-30	466,442	4,854,184	391.0	V136-4.5	136	112
T-31	465,127	4,854,646	390.8	V136-4.5	136	112
T-32	466,913	4,854,815	386.1	V136-4.5	136	112
T-33	467,409	4,854,803	384.1	V136-4.5	136	112
T-34	467,531	4,853,720	382.6	V136-4.5	136	112
T-35	469,218	4,853,846	388.8	V136-4.5	136	112

Turbine ID	Easting [m]	Northing [m]	Elevation [m]	Model	Rotor Diameter [m]	Hub Height [m]
T-36ALT	469,619	4,853,974	383.1	V136-4.5	136	112
T-37ALT	469,358	4,854,700	382.5	V136-4.5	136	112
T-38	470,495	4,854,628	385.5	V136-4.5	136	112
T-39	471,035	4,854,661	386.4	V136-4.5	136	112

Appendix B
Layout B - Turbine Coordinates

(NAD83 UTM Zone 15)

Turbine ID	Easting [m]	Northing [m]	Elevation [m]	Model	Rotor Diameter [m]	Hub Height [m]
T-01	456,338	4,849,145	380.0	V136-4.5	136	120
T-02	456,988	4,849,245	374.0	V136-4.5	136	120
T-03	457,285	4,849,598	375.1	V136-4.5	136	120
T-04	458,096	4,849,914	374.7	V136-4.5	136	120
T-05	458,857	4,850,587	372.6	V136-4.5	136	120
T-06	456,535	4,850,571	369.4	V136-4.5	136	120
T-07	456,942	4,850,779	370.8	V136-4.5	136	120
T-08ALT	457,229	4,850,936	370.2	V136-4.5	136	120
T-09	457,915	4,850,947	380.3	V136-4.5	136	120
T-10ALT	458,063	4,851,439	380.6	V136-4.5	136	120
T-11	457,800	4,853,131	374.2	V136-4.5	136	120
T-12	458,650	4,853,301	375.2	V136-4.5	136	120
T-13	459,677	4,852,647	371.0	V136-4.5	136	120
T-14	459,990	4,853,091	370.9	V136-4.5	136	120
T-16	459,369	4,854,460	370.2	V136-4.5	136	120
T-17	459,784	4,854,556	375.1	V136-4.5	136	120
T-18	462,175	4,851,406	388.7	V136-4.5	136	120
T-19	462,740	4,851,460	384.0	V136-4.5	136	120
T-20	463,305	4,851,574	390.3	V136-4.5	136	120
T-21	464,124	4,851,745	388.7	V136-4.5	136	120
T-22	464,570	4,851,755	394.6	V136-4.5	136	120
T-23	465,158	4,851,856	397.6	V136-4.5	136	120
T-24	465,638	4,851,869	386.5	V136-4.5	136	120
T-25	466,229	4,851,484	387.1	V136-4.5	136	120
T-26	466,819	4,851,605	394.6	V136-4.5	136	120
T-27	468,407	4,851,609	384.5	V136-4.5	136	120
T-28	465,377	4,853,923	390.3	V136-4.5	136	120
T-29	465,812	4,853,974	392.8	V136-4.5	136	120
T-30	466,442	4,854,184	391.0	V136-4.5	136	120
T-31	465,127	4,854,646	390.8	V136-4.5	136	120
T-32	466,907	4,854,815	386.3	V136-4.5	136	120
T-33	467,409	4,854,813	383.6	V136-4.5	136	120
T-34	467,531	4,853,720	382.6	V136-4.5	136	120
T-35	469,220	4,853,848	388.8	V136-4.5	136	120

Turbine ID	Easting [m]	Northing [m]	Elevation [m]	Model	Rotor Diameter [m]	Hub Height [m]
T-36ALT	469,619	4,853,965	382.8	V136-4.5	136	120
T-37ALT	469,357	4,854,662	381.9	V136-4.5	136	120
T-38	470,495	4,854,628	385.5	V136-4.5	136	120
T-39	471,035	4,854,652	386.6	V136-4.5	136	120

Appendix C
Layout A - Shadow Receptor Coordinates and Realistic Shadow Hours

(NAD83 UTM Zone 15)

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-003-NP	467,274	4,856,654	385.7	0:00	0:00
R-007-NP	470,686	4,856,546	384.2	0:00	0:00
R-008-NP	468,615	4,856,533	383.8	0:00	0:00
R-009-NP	467,261	4,856,529	392.3	0:00	0:00
R-010-NP	459,366	4,856,513	364.0	0:00	0:00
R-012-NP	465,479	4,856,414	383.2	0:00	0:00
R-013-NP	465,801	4,856,409	392.2	0:00	0:00
R-014-NP	464,044	4,856,316	378.7	0:00	0:00
R-015-NP	464,831	4,856,128	384.3	0:00	0:00
R-016-NP	470,382	4,856,046	390.0	0:00	0:00
R-018-NP	458,303	4,856,025	365.9	0:00	0:00
R-021-NP	470,436	4,855,904	389.8	0:00	0:00
R-022-NP	458,136	4,855,890	367.3	0:00	0:00
R-024-NP	459,562	4,855,803	369.2	0:00	0:00
R-026-NP	472,224	4,855,750	396.8	0:00	0:00
R-028-NP	466,119	4,855,651	392.0	2:55	2:55
R-030-NP	458,858	4,855,493	365.6	0:40	0:40
R-031-NP	465,273	4,855,428	389.0	1:26	1:26
R-032-NP	461,210	4,855,170	372.1	1:55	1:55
R-033-NP	463,607	4,855,169	384.4	2:00	2:00
R-034-P	467,901	4,855,164	388.1	26:45	24:47
R-035-P	468,978	4,855,134	387.2	23:38	3:12
R-037-P	470,970	4,855,116	389.8	13:10	11:26
R-038-NP	472,905	4,855,109	399.3	0:00	0:00
R-043-NP	469,792	4,854,953	389.2	35:34	14:23
R-044-P	465,621	4,854,894	390.9	28:37	28:37
R-045-NP	464,648	4,854,805	386.3	28:21	28:21
R-047-NP	461,221	4,854,699	373.1	2:19	2:19
R-048-NP	471,926	4,854,660	400.6	7:00	7:00
R-050-NP	471,932	4,854,594	401.0	7:55	7:55
R-051-NP	468,832	4,854,440	393.5	34:56	5:58

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-052-NP	471,847	4,854,412	396.0	17:20	17:20
R-054-NP	467,437	4,854,383	384.1	5:29	5:29
R-055-P	464,833	4,854,320	392.5	28:28	28:28
R-056-NP	458,131	4,854,313	370.2	3:54	3:54
R-057-NP	456,985	4,854,289	369.5	0:00	0:00
R-058-NP	456,672	4,854,281	366.8	0:00	0:00
R-059-NP	471,921	4,854,255	389.0	22:00	22:00
R-061-P	470,149	4,854,226	390.5	34:57	17:56
R-062-P	470,448	4,854,216	386.4	19:42	2:42
R-063-P	467,432	4,854,167	387.2	7:44	7:44
R-064-NP	458,757	4,854,132	369.2	20:41	20:41
R-066-P	470,022	4,854,132	391.9	36:06	15:35
R-067-P	460,705	4,854,056	371.6	13:32	13:32
R-068-NP	456,154	4,853,961	368.4	0:00	0:00
R-070-P	457,582	4,853,945	370.0	4:46	4:46
R-071-NP	457,476	4,853,936	369.2	3:47	3:47
R-072-NP	459,419	4,853,877	378.6	10:21	10:21
R-073-NP	471,866	4,853,848	387.1	4:21	4:21
R-078-P	468,577	4,853,582	387.8	31:06	29:41
R-081-NP	461,525	4,853,440	380.1	1:19	1:19
R-082-NP	471,958	4,853,383	396.8	0:00	0:00
R-083-NP	456,156	4,853,362	366.5	1:41	1:41
R-085-P	461,339	4,853,316	376.1	3:16	3:16
R-086-NP	461,915	4,853,205	386.5	0:00	0:00
R-087-NP	467,469	4,853,048	393.5	0:00	0:00
R-089-NP	472,047	4,852,992	388.7	0:00	0:00
R-090-NP	463,792	4,852,966	389.7	3:18	3:18
R-093-NP	457,077	4,852,799	368.7	19:34	19:34
R-094-NP	458,827	4,852,757	378.0	22:07	22:07
R-099-NP	466,640	4,852,665	396.1	6:17	6:17
R-100-NP	461,310	4,852,664	378.0	5:25	5:25

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-101-P	460,401	4,852,660	378.5	11:26	11:26
R-102-P	463,440	4,852,660	389.7	5:43	5:43
R-103-P	464,877	4,852,658	395.7	0:49	0:49
R-104-P	469,709	4,852,649	388.7	2:25	2:25
R-105-NP	465,496	4,852,635	396.5	6:31	6:31
R-106-NP	461,571	4,852,634	383.6	1:52	1:52
R-107-NP	466,357	4,852,633	395.8	2:56	2:56
R-108-NP	465,576	4,852,625	394.7	8:16	8:16
R-110-P	467,417	4,852,545	386.8	1:15	1:15
R-111-NP	468,587	4,852,537	388.8	0:00	0:00
R-112-P	465,534	4,852,533	395.6	11:09	11:09
R-113-P	464,671	4,852,529	391.4	9:11	9:11
R-114-P	467,369	4,852,501	387.9	4:56	4:56
R-118-P	463,468	4,852,275	389.2	24:07	24:07
R-121-P	469,132	4,852,136	390.4	10:13	10:13
R-122-NP	461,728	4,852,030	386.3	6:48	6:48
R-123-P	462,539	4,851,924	382.9	21:25	21:25
R-124-NP	458,413	4,851,871	380.5	18:05	0:31
R-125-P	460,414	4,851,838	375.9	0:00	0:00
R-127-NP	455,838	4,851,738	369.5	5:46	3:27
R-128-P	457,770	4,851,719	379.9	48:48	0:00
R-129-P	468,812	4,851,696	389.3	29:14	29:14
R-132-NP	461,655	4,851,552	387.1	26:17	26:17
R-135-P	458,763	4,851,467	377.4	19:48	6:12
R-136-NP	455,158	4,851,466	368.5	2:37	2:37
R-138-NP	469,680	4,851,397	391.1	3:32	3:32
R-139-NP	457,328	4,851,362	368.4	34:52	19:05
R-140-NP	456,794	4,851,323	369.2	35:49	4:23
R-141-NP	460,061	4,851,210	380.9	2:26	2:26
R-142-P	463,872	4,851,131	394.6	10:31	10:31
R-143-P	469,064	4,851,086	399.9	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-144-NP	467,096	4,851,057	394.5	22:38	22:38
R-145-P	467,924	4,851,048	391.0	13:58	13:58
R-146-NP	467,422	4,851,034	393.7	9:39	9:39
R-147-NP	464,005	4,851,034	395.5	4:22	4:22
R-148-NP	470,171	4,851,002	394.6	0:00	0:00
R-149-NP	469,898	4,850,989	389.9	3:31	3:31
R-152-NP	462,328	4,850,948	385.8	0:00	0:00
R-153-P	464,923	4,850,931	393.3	7:28	7:28
R-154-NP	469,239	4,850,862	393.0	0:00	0:00
R-155-P	459,614	4,850,833	381.4	13:30	10:26
R-156-NP	465,542	4,850,820	395.7	0:28	0:28
R-157-NP	460,425	4,850,811	380.8	1:24	1:24
R-158-P	468,022	4,850,804	390.5	0:00	0:00
R-159-P	466,167	4,850,796	396.8	0:00	0:00
R-160-P	468,541	4,850,773	391.2	0:00	0:00
R-161-P	461,395	4,850,748	384.9	5:29	5:29
R-162-P	464,614	4,850,738	395.8	2:43	2:43
R-163-NP	470,092	4,850,723	393.4	0:00	0:00
R-164-NP	458,335	4,850,683	378.2	28:52	23:23
R-165-NP	466,889	4,850,658	390.6	0:00	0:00
R-167-NP	455,863	4,850,559	372.5	23:54	21:57
R-170-NP	457,455	4,850,250	381.1	27:23	27:23
R-173-P	459,306	4,850,090	378.2	4:13	4:13
R-174-NP	467,682	4,850,042	393.3	0:00	0:00
R-175-NP	455,144	4,849,978	370.0	9:05	9:05
R-177-NP	456,729	4,849,881	379.0	19:25	19:25
R-178-NP	460,164	4,849,828	385.2	3:43	3:43
R-179-P	463,116	4,849,825	394.3	0:00	0:00
R-180-P	461,841	4,849,796	392.4	0:00	0:00
R-181-NP	462,563	4,849,723	396.0	0:00	0:00
R-182-NP	468,475	4,849,669	397.1	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-188-NP	458,746	4,849,447	384.2	3:12	3:12
R-196-NP	457,456	4,848,776	378.7	7:03	7:03
R-199-NP	456,062	4,848,677	379.2	1:05	1:05
R-217-NP	456,087	4,847,814	376.5	0:00	0:00
R-253-NP	461,112	4,849,989	382.1	0:00	0:00
R-254-NP	460,873	4,849,909	388.2	0:00	0:00
R-255-NP	460,873	4,849,951	388.3	0:00	0:00
R-256-NP	460,824	4,849,954	387.7	0:00	0:00
R-257-NP	460,717	4,849,948	387.4	0:00	0:00
R-258-NP	460,675	4,849,947	387.1	0:00	0:00
R-259-NP	460,689	4,850,008	386.5	0:00	0:00
R-260-NP	460,724	4,850,007	387.1	0:00	0:00
R-261-NP	460,753	4,850,006	387.3	0:00	0:00
R-262-NP	460,784	4,850,006	387.3	0:00	0:00
R-263-NP	460,807	4,850,006	387.4	0:00	0:00
R-264-NP	460,877	4,850,022	386.6	0:00	0:00
R-265-NP	460,903	4,850,009	386.2	0:00	0:00
R-266-NP	460,937	4,850,015	384.7	0:00	0:00
R-267-NP	460,957	4,850,014	384.2	0:00	0:00
R-268-NP	460,977	4,850,014	383.7	0:00	0:00
R-269-NP	461,012	4,849,997	383.8	0:00	0:00
R-270-NP	460,634	4,850,014	386.7	0:00	0:00
R-271-NP	460,639	4,850,059	384.5	0:00	0:00
R-272-NP	460,552	4,850,058	382.3	1:37	1:37
R-273-NP	460,554	4,850,036	383.2	1:39	1:39
R-274-NP	460,593	4,850,084	381.7	0:00	0:00
R-275-NP	460,594	4,850,059	383.3	0:00	0:00
R-276-NP	460,640	4,850,105	381.9	0:00	0:00
R-277-NP	460,642	4,850,126	381.4	0:00	0:00
R-278-NP	460,553	4,850,112	380.4	1:34	1:34
R-279-NP	460,552	4,850,157	379.6	1:33	1:33

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-280-NP	460,592	4,850,130	380.2	1:26	1:26
R-281-NP	460,592	4,850,166	379.8	1:24	1:24
R-282-NP	460,641	4,850,172	380.8	0:00	0:00
R-283-NP	460,639	4,850,152	381.0	0:00	0:00
R-284-NP	460,684	4,850,177	381.3	0:00	0:00
R-285-NP	460,721	4,850,172	382.2	0:00	0:00
R-286-NP	460,737	4,850,172	382.8	0:00	0:00
R-287-NP	460,782	4,850,112	386.4	0:00	0:00
R-288-NP	460,728	4,850,114	384.8	0:00	0:00
R-289-NP	460,713	4,850,112	384.1	0:00	0:00
R-290-NP	460,697	4,850,112	383.5	0:00	0:00
R-291-NP	460,683	4,850,112	382.9	0:00	0:00
R-292-NP	460,690	4,850,071	384.5	0:00	0:00
R-293-NP	460,723	4,850,073	385.6	0:00	0:00
R-294-NP	460,762	4,850,073	386.4	0:00	0:00
R-295-NP	460,572	4,850,217	378.0	1:28	1:28
R-296-NP	460,606	4,850,217	378.8	1:23	1:23
R-297-NP	460,694	4,850,222	380.6	0:00	0:00
R-298-NP	460,731	4,850,219	381.3	0:00	0:00
R-299-NP	460,758	4,850,218	382.0	0:00	0:00
R-300-NP	460,645	4,850,283	379.8	0:00	0:00
R-301-NP	460,645	4,850,317	380.5	0:00	0:00
R-302-NP	460,693	4,850,312	381.6	0:00	0:00
R-303-NP	460,701	4,850,286	381.5	0:00	0:00
R-304-NP	460,700	4,850,274	381.4	0:00	0:00
R-305-NP	460,646	4,850,349	381.0	0:00	0:00
R-306-NP	460,645	4,850,377	381.3	1:05	1:05
R-307-NP	460,686	4,850,379	381.1	0:00	0:00
R-308-NP	460,692	4,850,342	381.3	0:00	0:00
R-309-NP	460,729	4,850,385	380.2	0:00	0:00
R-310-NP	460,759	4,850,383	379.9	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-311-NP	460,787	4,850,383	379.7	0:00	0:00
R-312-NP	460,638	4,850,440	381.7	1:05	1:05
R-313-NP	460,829	4,850,390	379.6	0:00	0:00
R-314-NP	460,825	4,850,350	379.8	0:00	0:00
R-315-NP	460,823	4,850,330	380.4	0:00	0:00
R-316-NP	460,819	4,850,291	380.8	0:00	0:00
R-317-NP	460,826	4,850,244	382.6	0:00	0:00
R-318-NP	460,873	4,850,216	384.8	0:00	0:00
R-319-NP	460,872	4,850,251	383.5	0:00	0:00
R-320-NP	460,869	4,850,266	382.8	0:00	0:00
R-321-NP	460,865	4,850,278	382.1	0:00	0:00
R-322-NP	460,872	4,850,291	381.3	0:00	0:00
R-323-NP	460,871	4,850,323	380.9	0:00	0:00
R-324-NP	460,872	4,850,348	380.5	0:00	0:00
R-325-NP	460,870	4,850,372	380.3	0:00	0:00
R-326-NP	460,871	4,850,386	380.1	0:00	0:00
R-327-NP	460,822	4,850,430	379.2	0:00	0:00
R-328-NP	460,868	4,850,426	379.8	0:00	0:00
R-329-NP	460,911	4,850,379	380.7	0:00	0:00
R-330-NP	460,936	4,850,386	380.9	0:00	0:00
R-331-NP	460,957	4,850,386	381.2	0:00	0:00
R-332-NP	460,968	4,850,386	381.3	0:00	0:00
R-333-NP	460,886	4,850,428	379.9	0:00	0:00
R-334-NP	460,914	4,850,428	380.2	0:00	0:00
R-335-NP	460,929	4,850,427	380.6	0:00	0:00
R-336-NP	460,950	4,850,430	380.9	0:00	0:00
R-337-NP	461,005	4,850,422	381.6	0:00	0:00
R-338-NP	460,968	4,850,283	381.6	0:00	0:00
R-339-NP	460,969	4,850,254	381.9	0:00	0:00
R-340-NP	460,954	4,850,213	382.7	0:00	0:00
R-341-NP	460,919	4,850,213	384.3	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-342-NP	460,959	4,850,178	382.9	0:00	0:00
R-343-NP	460,945	4,850,171	383.3	0:00	0:00
R-344-NP	460,930	4,850,173	383.9	0:00	0:00
R-345-NP	460,914	4,850,174	384.6	0:00	0:00
R-346-NP	460,692	4,850,528	379.0	1:06	1:06
R-347-NP	460,694	4,850,573	378.4	2:51	2:51
R-348-NP	460,749	4,850,528	378.2	0:06	0:06
R-349-NP	460,788	4,850,579	378.5	1:04	1:04
R-350-NP	460,789	4,850,528	378.4	0:00	0:00
R-351-NP	460,820	4,850,578	378.6	0:20	0:20
R-352-NP	460,820	4,850,529	378.5	0:00	0:00
R-353-NP	460,875	4,850,528	379.3	0:00	0:00
R-354-NP	460,912	4,850,527	379.7	0:00	0:00
R-355-NP	460,942	4,850,574	379.2	0:00	0:00
R-356-NP	460,966	4,850,578	379.5	0:00	0:00
R-357-NP	460,959	4,850,528	379.9	0:00	0:00
R-358-NP	460,922	4,850,477	380.0	0:00	0:00
R-359-NP	460,906	4,850,477	379.9	0:00	0:00
R-360-NP	460,959	4,850,475	380.1	0:00	0:00
R-361-NP	461,080	4,850,367	382.5	0:00	0:00
R-362-NP	461,240	4,850,431	383.7	0:00	0:00
R-363-NP	461,262	4,850,431	382.8	0:00	0:00
R-364-NP	461,218	4,850,378	385.7	0:00	0:00
R-365-NP	461,254	4,850,379	383.9	0:00	0:00
R-366-NP	461,222	4,850,325	384.0	0:00	0:00
R-367-NP	461,172	4,850,336	384.9	0:00	0:00
R-368-NP	461,183	4,850,285	383.0	0:00	0:00
R-369-NP	461,138	4,850,287	382.2	0:00	0:00
R-370-NP	461,153	4,850,163	381.3	0:00	0:00
R-371-NP	461,196	4,850,166	381.6	0:00	0:00
R-372-NP	461,222	4,850,158	381.7	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-373-NP	460,510	4,855,205	377.1	9:25	9:25
R-374-NP	458,120	4,847,906	380.6	0:00	0:00

Appendix D
Layout B - Shadow Receptor Coordinates and Realistic Shadow Hours

(NAD83 UTM Zone 15)

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-003-NP	467,274	4,856,654	385.7	0:00	0:00
R-007-NP	470,686	4,856,546	384.2	0:00	0:00
R-008-NP	468,615	4,856,533	383.8	0:00	0:00
R-009-NP	467,261	4,856,529	392.3	0:00	0:00
R-010-NP	459,366	4,856,513	364.0	0:00	0:00
R-012-NP	465,479	4,856,414	383.2	0:00	0:00
R-013-NP	465,801	4,856,409	392.2	0:00	0:00
R-014-NP	464,044	4,856,316	378.7	0:00	0:00
R-015-NP	464,831	4,856,128	384.3	0:00	0:00
R-016-NP	470,382	4,856,046	390.0	0:00	0:00
R-018-NP	458,303	4,856,025	365.9	0:00	0:00
R-021-NP	470,436	4,855,904	389.8	0:00	0:00
R-022-NP	458,136	4,855,890	367.3	0:00	0:00
R-024-NP	459,562	4,855,803	369.2	0:00	0:00
R-026-NP	472,224	4,855,750	396.8	0:00	0:00
R-028-NP	466,119	4,855,651	392.0	3:06	3:06
R-030-NP	458,858	4,855,493	365.6	0:37	0:37
R-031-NP	465,273	4,855,428	389.0	1:36	1:36
R-032-NP	461,210	4,855,170	372.1	1:59	1:59
R-033-NP	463,607	4,855,169	384.4	2:10	2:10
R-034-P	467,901	4,855,164	388.1	25:36	23:26
R-035-P	468,978	4,855,134	387.2	19:35	3:29
R-037-P	470,970	4,855,116	389.8	14:13	12:17
R-038-NP	472,905	4,855,109	399.3	0:00	0:00
R-043-NP	469,792	4,854,953	389.2	35:11	14:29
R-044-P	465,621	4,854,894	390.9	29:18	29:18
R-045-NP	464,648	4,854,805	386.3	28:22	28:22
R-047-NP	461,221	4,854,699	373.1	2:24	2:24
R-048-NP	471,926	4,854,660	400.6	7:20	7:20
R-050-NP	471,932	4,854,594	401.0	8:08	8:08
R-051-NP	468,832	4,854,440	393.5	43:15	6:39

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-052-NP	471,847	4,854,412	396.0	18:06	18:06
R-054-NP	467,437	4,854,383	384.1	5:46	5:46
R-055-P	464,833	4,854,320	392.5	27:02	27:02
R-056-NP	458,131	4,854,313	370.2	4:18	4:18
R-057-NP	456,985	4,854,289	369.5	0:00	0:00
R-058-NP	456,672	4,854,281	366.8	0:00	0:00
R-059-NP	471,921	4,854,255	389.0	22:56	22:56
R-061-P	470,149	4,854,226	390.5	42:10	18:49
R-062-P	470,448	4,854,216	386.4	17:23	2:54
R-063-P	467,432	4,854,167	387.2	9:02	9:02
R-064-NP	458,757	4,854,132	369.2	19:45	19:45
R-066-P	470,022	4,854,132	391.9	37:26	16:43
R-067-P	460,705	4,854,056	371.6	15:00	15:00
R-068-NP	456,154	4,853,961	368.4	0:00	0:00
R-070-P	457,582	4,853,945	370.0	4:57	4:57
R-071-NP	457,476	4,853,936	369.2	3:58	3:58
R-072-NP	459,419	4,853,877	378.6	10:54	10:54
R-073-NP	471,866	4,853,848	387.1	4:31	4:31
R-078-P	468,577	4,853,582	387.8	31:17	28:53
R-081-NP	461,525	4,853,440	380.1	1:27	1:27
R-082-NP	471,958	4,853,383	396.8	0:00	0:00
R-083-NP	456,156	4,853,362	366.5	1:52	1:52
R-085-P	461,339	4,853,316	376.1	3:35	3:35
R-086-NP	461,915	4,853,205	386.5	0:00	0:00
R-087-NP	467,469	4,853,048	393.5	0:00	0:00
R-089-NP	472,047	4,852,992	388.7	0:00	0:00
R-090-NP	463,792	4,852,966	389.7	3:42	3:42
R-093-NP	457,077	4,852,799	368.7	18:51	18:51
R-094-NP	458,827	4,852,757	378.0	23:32	23:32
R-099-NP	466,640	4,852,665	396.1	6:47	6:47
R-100-NP	461,310	4,852,664	378.0	5:58	5:58

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-101-P	460,401	4,852,660	378.5	11:36	11:36
R-102-P	463,440	4,852,660	389.7	6:08	6:08
R-103-P	464,877	4,852,658	395.7	2:04	2:04
R-104-P	469,709	4,852,649	388.7	2:43	2:43
R-105-NP	465,496	4,852,635	396.5	7:34	7:34
R-106-NP	461,571	4,852,634	383.6	2:09	2:09
R-107-NP	466,357	4,852,633	395.8	3:29	3:29
R-108-NP	465,576	4,852,625	394.7	9:12	9:12
R-110-P	467,417	4,852,545	386.8	2:13	2:13
R-111-NP	468,587	4,852,537	388.8	0:00	0:00
R-112-P	465,534	4,852,533	395.6	11:57	11:57
R-113-P	464,671	4,852,529	391.4	9:36	9:36
R-114-P	467,369	4,852,501	387.9	5:51	5:51
R-118-P	463,468	4,852,275	389.2	24:58	24:58
R-121-P	469,132	4,852,136	390.4	10:33	10:33
R-122-NP	461,728	4,852,030	386.3	8:30	8:30
R-123-P	462,539	4,851,924	382.9	26:10	26:10
R-124-NP	458,413	4,851,871	380.5	19:49	0:27
R-125-P	460,414	4,851,838	375.9	0:00	0:00
R-127-NP	455,838	4,851,738	369.5	6:25	3:55
R-128-P	457,770	4,851,719	379.9	49:00	0:00
R-129-P	468,812	4,851,696	389.3	29:17	29:17
R-132-NP	461,655	4,851,552	387.1	26:31	26:31
R-135-P	458,763	4,851,467	377.4	19:59	6:17
R-136-NP	455,158	4,851,466	368.5	2:49	2:49
R-138-NP	469,680	4,851,397	391.1	3:48	3:48
R-139-NP	457,328	4,851,362	368.4	39:45	20:10
R-140-NP	456,794	4,851,323	369.2	36:22	4:30
R-141-NP	460,061	4,851,210	380.9	2:39	2:39
R-142-P	463,872	4,851,131	394.6	11:13	11:13
R-143-P	469,064	4,851,086	399.9	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-144-NP	467,096	4,851,057	394.5	23:36	23:36
R-145-P	467,924	4,851,048	391.0	14:15	14:15
R-146-NP	467,422	4,851,034	393.7	10:08	10:08
R-147-NP	464,005	4,851,034	395.5	4:49	4:49
R-148-NP	470,171	4,851,002	394.6	0:00	0:00
R-149-NP	469,898	4,850,989	389.9	3:56	3:56
R-152-NP	462,328	4,850,948	385.8	0:00	0:00
R-153-P	464,923	4,850,931	393.3	8:24	8:24
R-154-NP	469,239	4,850,862	393.0	0:00	0:00
R-155-P	459,614	4,850,833	381.4	14:23	10:59
R-156-NP	465,542	4,850,820	395.7	0:20	0:20
R-157-NP	460,425	4,850,811	380.8	1:35	1:35
R-158-P	468,022	4,850,804	390.5	0:00	0:00
R-159-P	466,167	4,850,796	396.8	0:00	0:00
R-160-P	468,541	4,850,773	391.2	0:00	0:00
R-161-P	461,395	4,850,748	384.9	5:43	5:43
R-162-P	464,614	4,850,738	395.8	3:06	3:06
R-163-NP	470,092	4,850,723	393.4	0:00	0:00
R-164-NP	458,335	4,850,683	378.2	29:26	23:33
R-165-NP	466,889	4,850,658	390.6	0:00	0:00
R-167-NP	455,863	4,850,559	372.5	24:56	22:45
R-170-NP	457,455	4,850,250	381.1	28:32	28:32
R-173-P	459,306	4,850,090	378.2	4:22	4:22
R-174-NP	467,682	4,850,042	393.3	0:00	0:00
R-175-NP	455,144	4,849,978	370.0	9:44	9:44
R-177-NP	456,729	4,849,881	379.0	20:03	20:03
R-178-NP	460,164	4,849,828	385.2	3:53	3:53
R-179-P	463,116	4,849,825	394.3	0:00	0:00
R-180-P	461,841	4,849,796	392.4	0:00	0:00
R-181-NP	462,563	4,849,723	396.0	0:00	0:00
R-182-NP	468,475	4,849,669	397.1	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-188-NP	458,746	4,849,447	384.2	3:32	3:32
R-196-NP	457,456	4,848,776	378.7	7:33	7:33
R-199-NP	456,062	4,848,677	379.2	0:37	0:37
R-217-NP	456,087	4,847,814	376.5	0:00	0:00
R-253-NP	461,112	4,849,989	382.1	0:00	0:00
R-254-NP	460,873	4,849,909	388.2	0:00	0:00
R-255-NP	460,873	4,849,951	388.3	0:00	0:00
R-256-NP	460,824	4,849,954	387.7	0:00	0:00
R-257-NP	460,717	4,849,948	387.4	0:00	0:00
R-258-NP	460,675	4,849,947	387.1	0:00	0:00
R-259-NP	460,689	4,850,008	386.5	0:00	0:00
R-260-NP	460,724	4,850,007	387.1	0:00	0:00
R-261-NP	460,753	4,850,006	387.3	0:00	0:00
R-262-NP	460,784	4,850,006	387.3	0:00	0:00
R-263-NP	460,807	4,850,006	387.4	0:00	0:00
R-264-NP	460,877	4,850,022	386.6	0:00	0:00
R-265-NP	460,903	4,850,009	386.2	0:00	0:00
R-266-NP	460,937	4,850,015	384.7	0:00	0:00
R-267-NP	460,957	4,850,014	384.2	0:00	0:00
R-268-NP	460,977	4,850,014	383.7	0:00	0:00
R-269-NP	461,012	4,849,997	383.8	0:00	0:00
R-270-NP	460,634	4,850,014	386.7	0:00	0:00
R-271-NP	460,639	4,850,059	384.5	0:00	0:00
R-272-NP	460,552	4,850,058	382.3	1:52	1:52
R-273-NP	460,554	4,850,036	383.2	1:52	1:52
R-274-NP	460,593	4,850,084	381.7	0:00	0:00
R-275-NP	460,594	4,850,059	383.3	0:00	0:00
R-276-NP	460,640	4,850,105	381.9	0:00	0:00
R-277-NP	460,642	4,850,126	381.4	0:00	0:00
R-278-NP	460,553	4,850,112	380.4	1:48	1:48
R-279-NP	460,552	4,850,157	379.6	1:45	1:45

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-280-NP	460,592	4,850,130	380.2	1:37	1:37
R-281-NP	460,592	4,850,166	379.8	1:37	1:37
R-282-NP	460,641	4,850,172	380.8	0:00	0:00
R-283-NP	460,639	4,850,152	381.0	0:00	0:00
R-284-NP	460,684	4,850,177	381.3	0:00	0:00
R-285-NP	460,721	4,850,172	382.2	0:00	0:00
R-286-NP	460,737	4,850,172	382.8	0:00	0:00
R-287-NP	460,782	4,850,112	386.4	0:00	0:00
R-288-NP	460,728	4,850,114	384.8	0:00	0:00
R-289-NP	460,713	4,850,112	384.1	0:00	0:00
R-290-NP	460,697	4,850,112	383.5	0:00	0:00
R-291-NP	460,683	4,850,112	382.9	0:00	0:00
R-292-NP	460,690	4,850,071	384.5	0:00	0:00
R-293-NP	460,723	4,850,073	385.6	0:00	0:00
R-294-NP	460,762	4,850,073	386.4	0:00	0:00
R-295-NP	460,572	4,850,217	378.0	1:41	1:41
R-296-NP	460,606	4,850,217	378.8	1:32	1:32
R-297-NP	460,694	4,850,222	380.6	0:00	0:00
R-298-NP	460,731	4,850,219	381.3	0:00	0:00
R-299-NP	460,758	4,850,218	382.0	0:00	0:00
R-300-NP	460,645	4,850,283	379.8	0:00	0:00
R-301-NP	460,645	4,850,317	380.5	0:00	0:00
R-302-NP	460,693	4,850,312	381.6	0:00	0:00
R-303-NP	460,701	4,850,286	381.5	0:00	0:00
R-304-NP	460,700	4,850,274	381.4	0:00	0:00
R-305-NP	460,646	4,850,349	381.0	0:00	0:00
R-306-NP	460,645	4,850,377	381.3	1:16	1:16
R-307-NP	460,686	4,850,379	381.1	0:00	0:00
R-308-NP	460,692	4,850,342	381.3	0:00	0:00
R-309-NP	460,729	4,850,385	380.2	0:00	0:00
R-310-NP	460,759	4,850,383	379.9	0:00	0:00

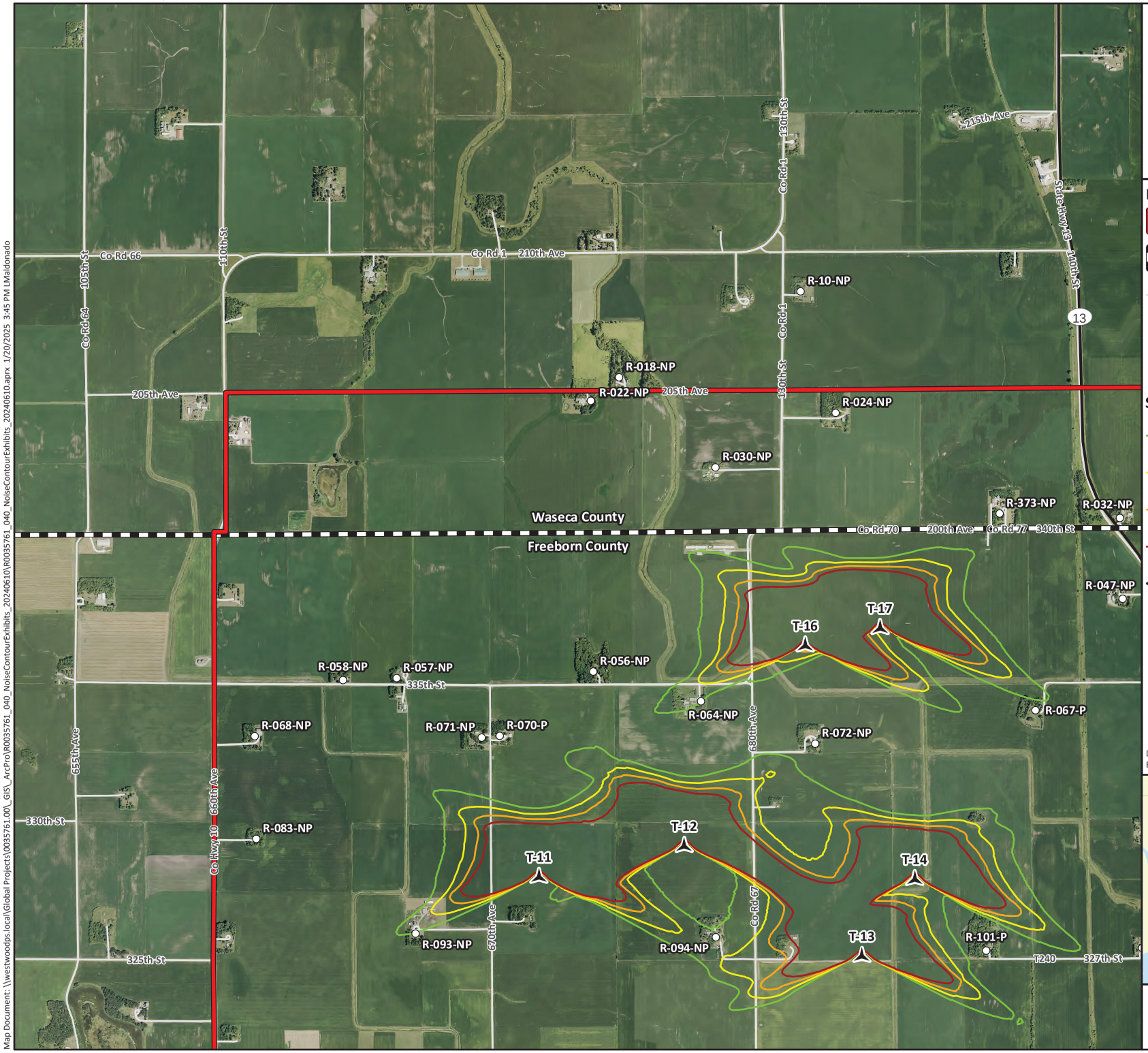
Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-311-NP	460,787	4,850,383	379.7	0:00	0:00
R-312-NP	460,638	4,850,440	381.7	1:14	1:14
R-313-NP	460,829	4,850,390	379.6	0:00	0:00
R-314-NP	460,825	4,850,350	379.8	0:00	0:00
R-315-NP	460,823	4,850,330	380.4	0:00	0:00
R-316-NP	460,819	4,850,291	380.8	0:00	0:00
R-317-NP	460,826	4,850,244	382.6	0:00	0:00
R-318-NP	460,873	4,850,216	384.8	0:00	0:00
R-319-NP	460,872	4,850,251	383.5	0:00	0:00
R-320-NP	460,869	4,850,266	382.8	0:00	0:00
R-321-NP	460,865	4,850,278	382.1	0:00	0:00
R-322-NP	460,872	4,850,291	381.3	0:00	0:00
R-323-NP	460,871	4,850,323	380.9	0:00	0:00
R-324-NP	460,872	4,850,348	380.5	0:00	0:00
R-325-NP	460,870	4,850,372	380.3	0:00	0:00
R-326-NP	460,871	4,850,386	380.1	0:00	0:00
R-327-NP	460,822	4,850,430	379.2	0:00	0:00
R-328-NP	460,868	4,850,426	379.8	0:00	0:00
R-329-NP	460,911	4,850,379	380.7	0:00	0:00
R-330-NP	460,936	4,850,386	380.9	0:00	0:00
R-331-NP	460,957	4,850,386	381.2	0:00	0:00
R-332-NP	460,968	4,850,386	381.3	0:00	0:00
R-333-NP	460,886	4,850,428	379.9	0:00	0:00
R-334-NP	460,914	4,850,428	380.2	0:00	0:00
R-335-NP	460,929	4,850,427	380.6	0:00	0:00
R-336-NP	460,950	4,850,430	380.9	0:00	0:00
R-337-NP	461,005	4,850,422	381.6	0:00	0:00
R-338-NP	460,968	4,850,283	381.6	0:00	0:00
R-339-NP	460,969	4,850,254	381.9	0:00	0:00
R-340-NP	460,954	4,850,213	382.7	0:00	0:00
R-341-NP	460,919	4,850,213	384.3	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-342-NP	460,959	4,850,178	382.9	0:00	0:00
R-343-NP	460,945	4,850,171	383.3	0:00	0:00
R-344-NP	460,930	4,850,173	383.9	0:00	0:00
R-345-NP	460,914	4,850,174	384.6	0:00	0:00
R-346-NP	460,692	4,850,528	379.0	1:04	1:04
R-347-NP	460,694	4,850,573	378.4	2:57	2:57
R-348-NP	460,749	4,850,528	378.2	0:00	0:00
R-349-NP	460,788	4,850,579	378.5	0:59	0:59
R-350-NP	460,789	4,850,528	378.4	0:00	0:00
R-351-NP	460,820	4,850,578	378.6	0:11	0:11
R-352-NP	460,820	4,850,529	378.5	0:00	0:00
R-353-NP	460,875	4,850,528	379.3	0:00	0:00
R-354-NP	460,912	4,850,527	379.7	0:00	0:00
R-355-NP	460,942	4,850,574	379.2	0:00	0:00
R-356-NP	460,966	4,850,578	379.5	0:00	0:00
R-357-NP	460,959	4,850,528	379.9	0:00	0:00
R-358-NP	460,922	4,850,477	380.0	0:00	0:00
R-359-NP	460,906	4,850,477	379.9	0:00	0:00
R-360-NP	460,959	4,850,475	380.1	0:00	0:00
R-361-NP	461,080	4,850,367	382.5	0:00	0:00
R-362-NP	461,240	4,850,431	383.7	0:00	0:00
R-363-NP	461,262	4,850,431	382.8	0:00	0:00
R-364-NP	461,218	4,850,378	385.7	0:00	0:00
R-365-NP	461,254	4,850,379	383.9	0:00	0:00
R-366-NP	461,222	4,850,325	384.0	0:00	0:00
R-367-NP	461,172	4,850,336	384.9	0:00	0:00
R-368-NP	461,183	4,850,285	383.0	0:00	0:00
R-369-NP	461,138	4,850,287	382.2	0:00	0:00
R-370-NP	461,153	4,850,163	381.3	0:00	0:00
R-371-NP	461,196	4,850,166	381.6	0:00	0:00
R-372-NP	461,222	4,850,158	381.7	0:00	0:00

Receptor ID	Easting [m]	Northing [m]	Elevation [m]	38-Turbine Layout Realistic Shadow [hrs/yr]	Primary Turbines Only Realistic Shadow [hrs/yr]
R-373-NP	460,510	4,855,205	377.1	10:38	10:38
R-374-NP	458,120	4,847,906	380.6	0:00	0:00

Appendix E

Layout A - Shadow Flicker Contour Maps



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Bent Tree North Wind Project

Freeborn, Steele, & Waseca Counties, Minnesota

Layout A Shadow Flicker

Appendix E

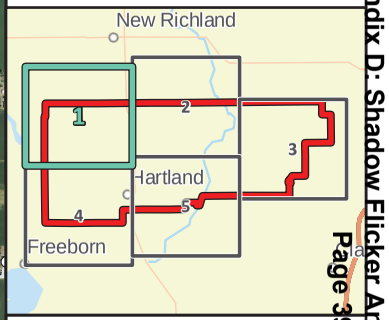
Legend

- Project Boundary
- County Boundary
- Local Road
- Proposed Primary Turbine
- Noise Receptor

Shadow Flicker (Hrs/Yr)

- 20
- 30
- 40
- 50
- Major Road

Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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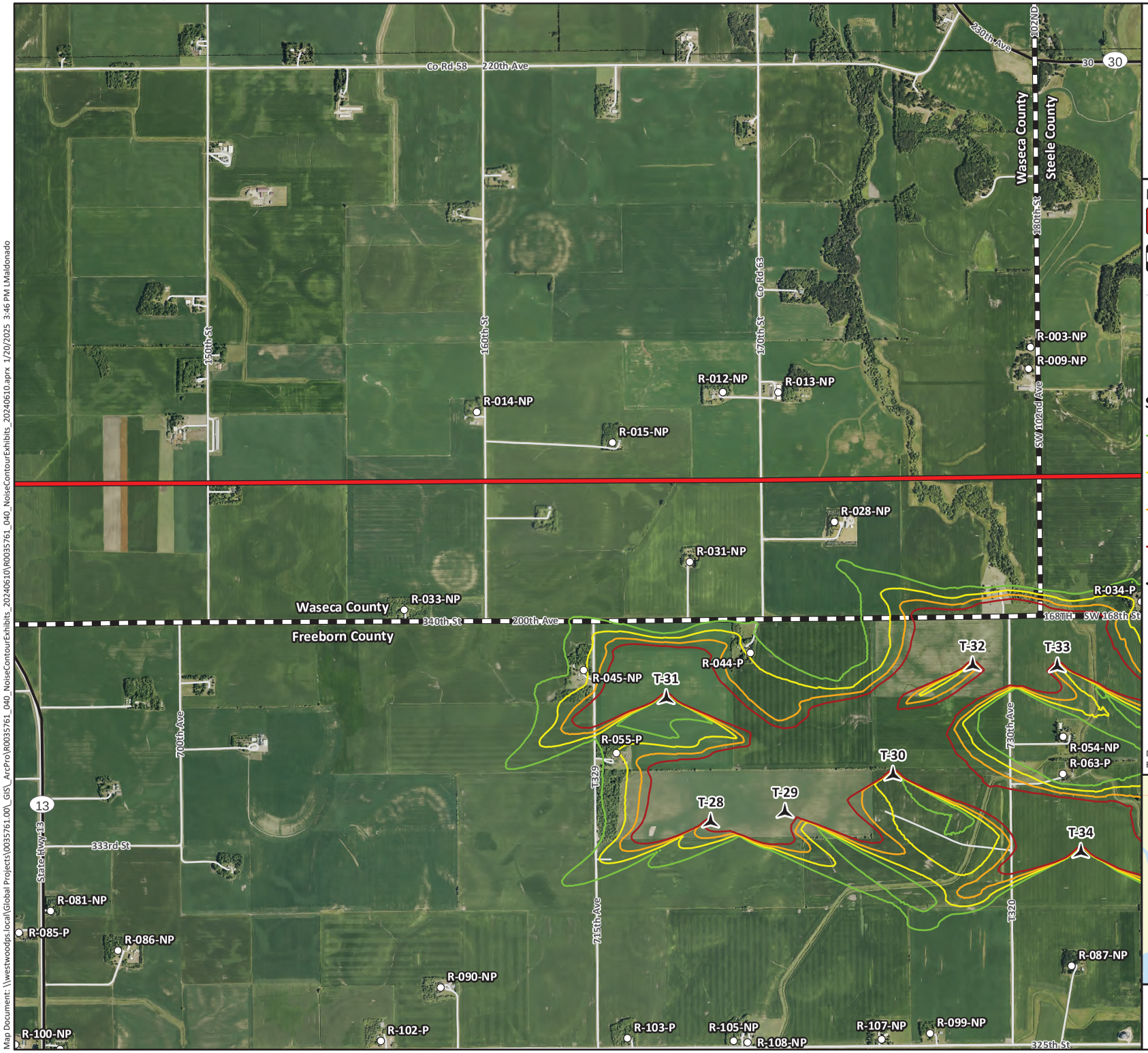

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Bent Tree North Wind Project

Freeborn, Steele, & Waseca Counties, Minnesota

Layout A Shadow Flicker

Appendix E

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- Project Boundary
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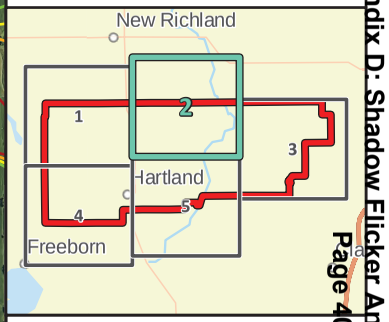
Shadow Flicker (Hrs/Yr)

- 20
- 30
- 40
- 50
- Major Road

Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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0 2,500 Feet

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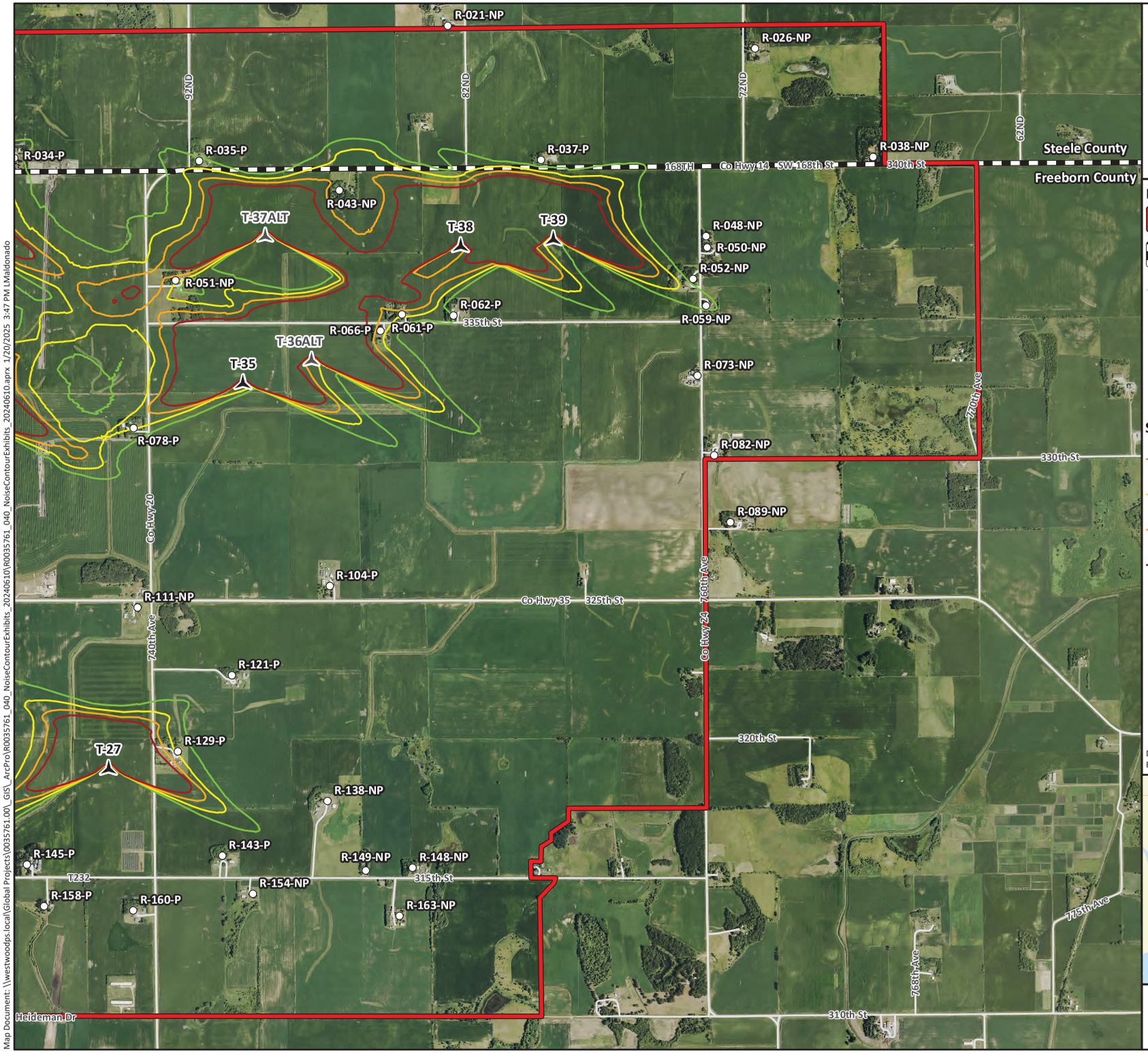

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Bent Tree North Wind Project

Freeborn, Steele, & Waseca Counties, Minnesota

Layout A Shadow Flicker
Appendix E

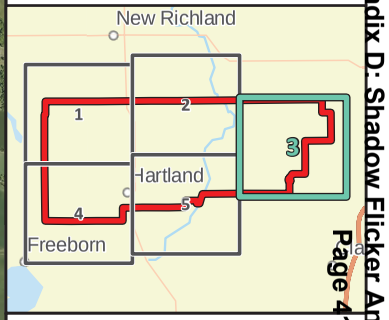
Legend

- Project Boundary
- County Boundary
- Local Road
- Proposed Primary Turbine
- Proposed Alternate Turbine
- Noise Receptor

Shadow Flicker (Hrs/Yr)

- 20
- 30
- 40
- 50

Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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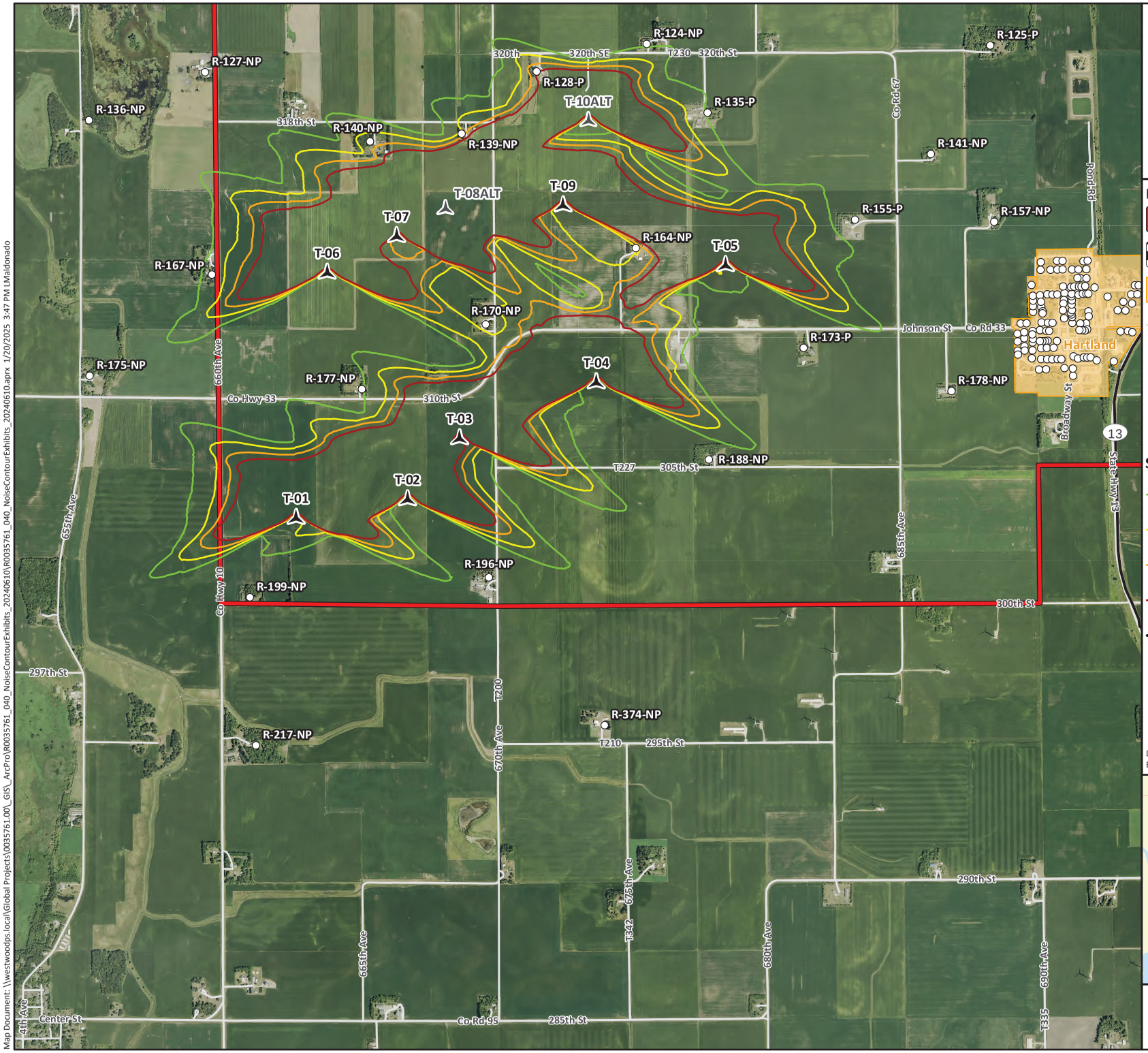

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Bent Tree North Wind Project

Freeborn, Steele, & Waseca Counties, Minnesota

Layout A Shadow Flicker

Appendix E

Legend

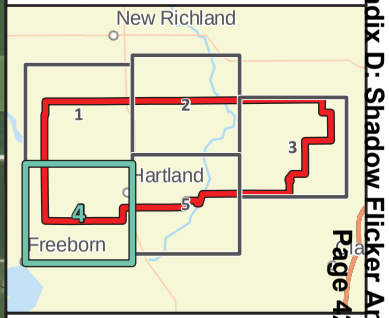
- Project Boundary
- County Boundary
- Town of Hartland
- Local Road
- Proposed Primary Turbine
- Proposed Alternate Turbine
- Noise Receptor

Shadow Flicker (Hrs/Yr)

- 20
- 30
- 40
- 50

- Major Road

Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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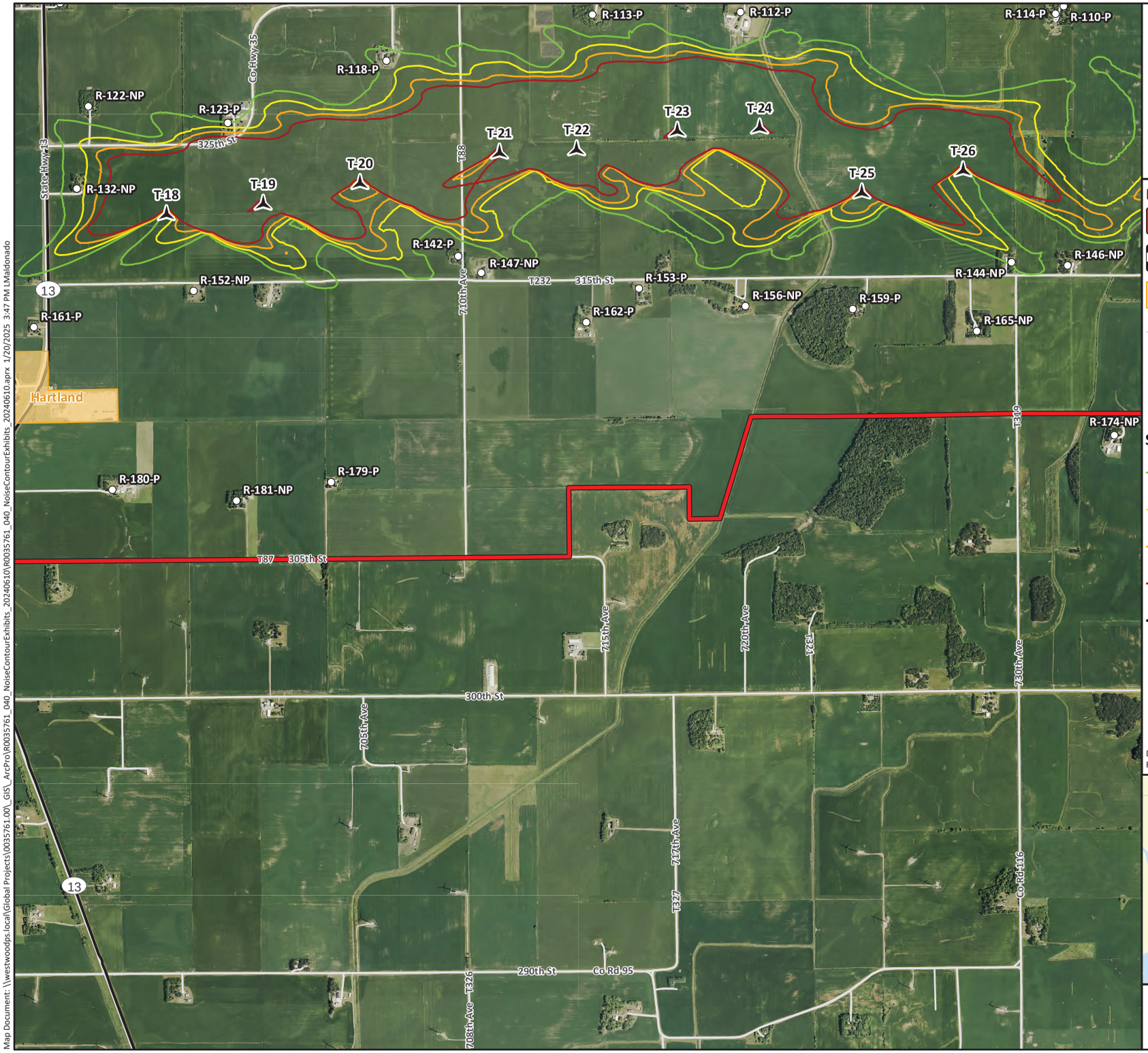

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Bent Tree North Wind Project

Freeborn, Steele, & Waseca Counties, Minnesota

Layout A Shadow Flicker Appendix E

Legend

- Project Boundary
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Shadow Flicker (Hrs/Yr)

- 20
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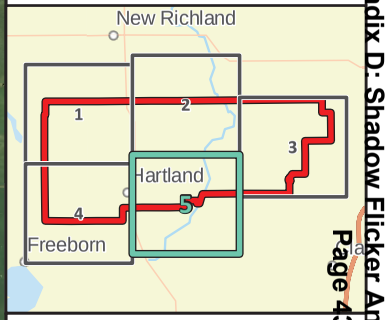
- 40
- 50
- Major Road

Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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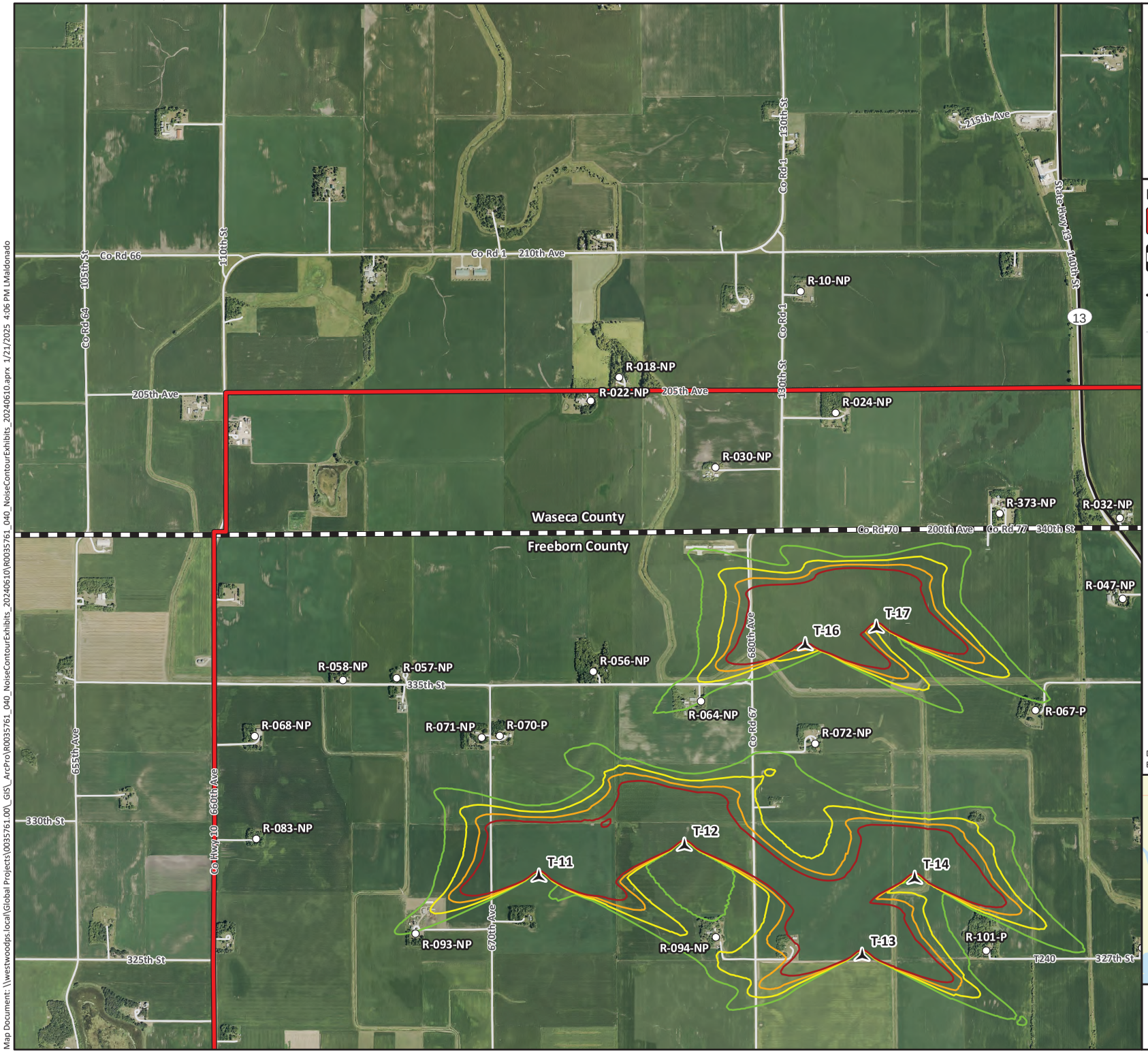
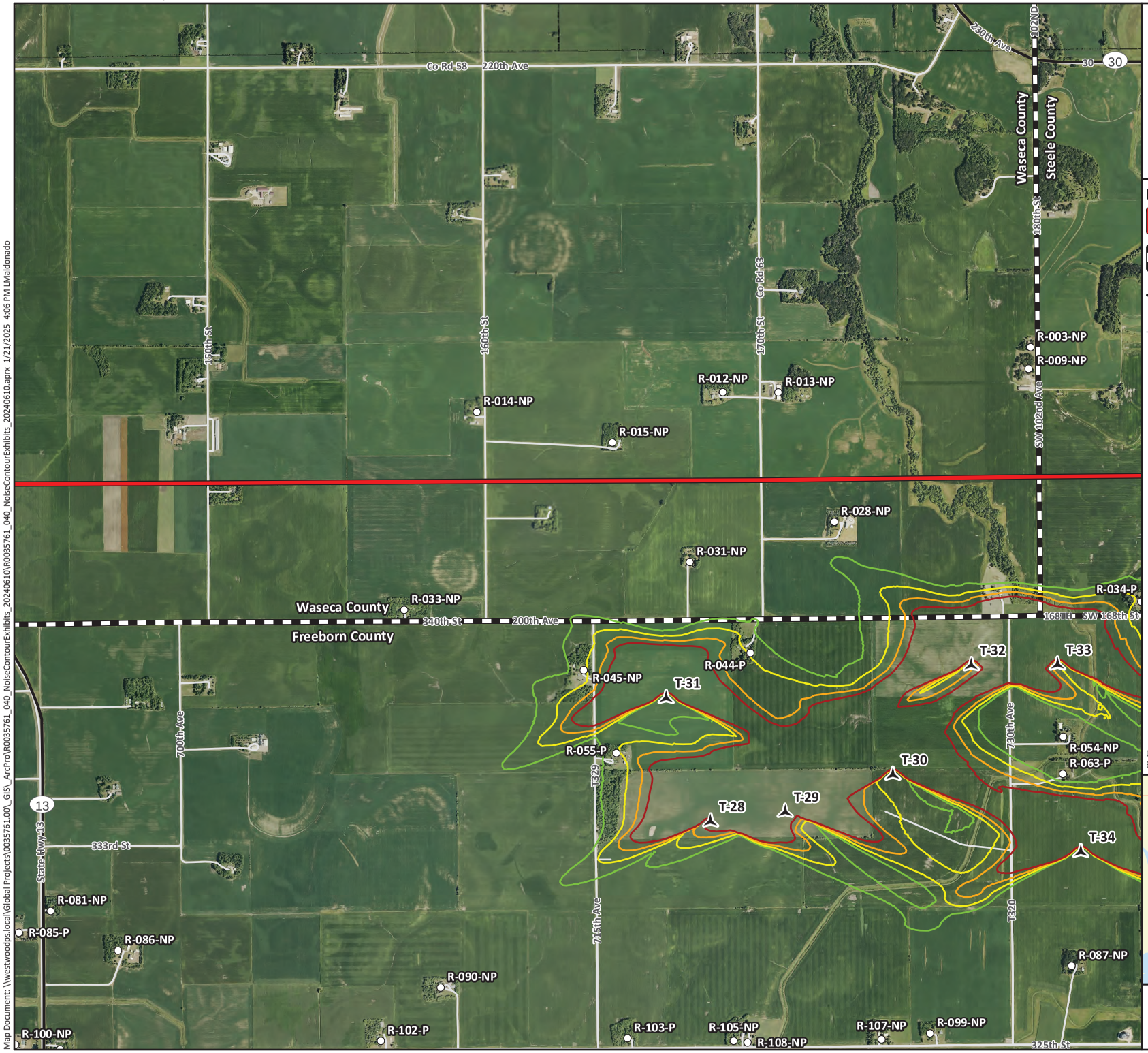
Appendix F
Layout B - Shadow Flicker Contour Maps





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Bent Tree North Wind Project

Freeborn, Steele, & Waseca Counties, Minnesota

Layout B Shadow Flicker

Appendix F

Legend

- Project Boundary
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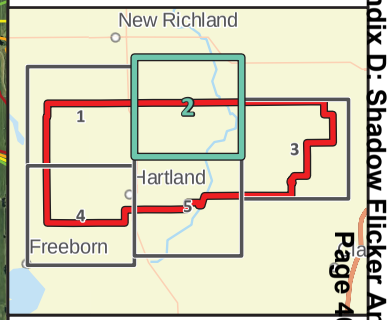
- Local Road
- Proposed Primary Turbine
- Noise Receptor

Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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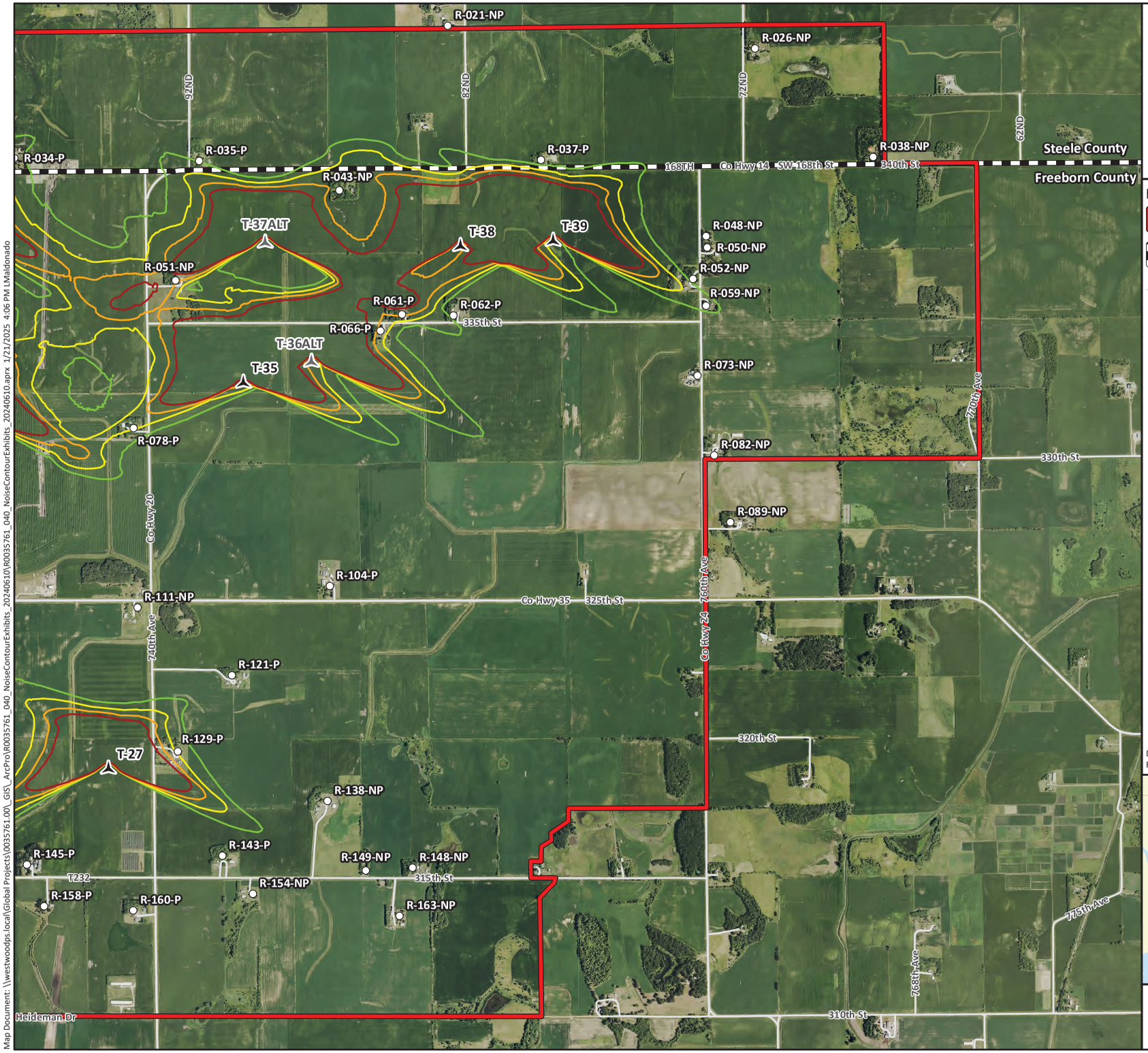

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Freeborn, Steele, & Waseca Counties, Minnesota

Layout B Shadow Flicker

Appendix F

Legend

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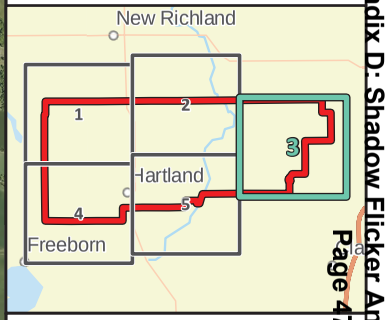
- Noise Receptor

Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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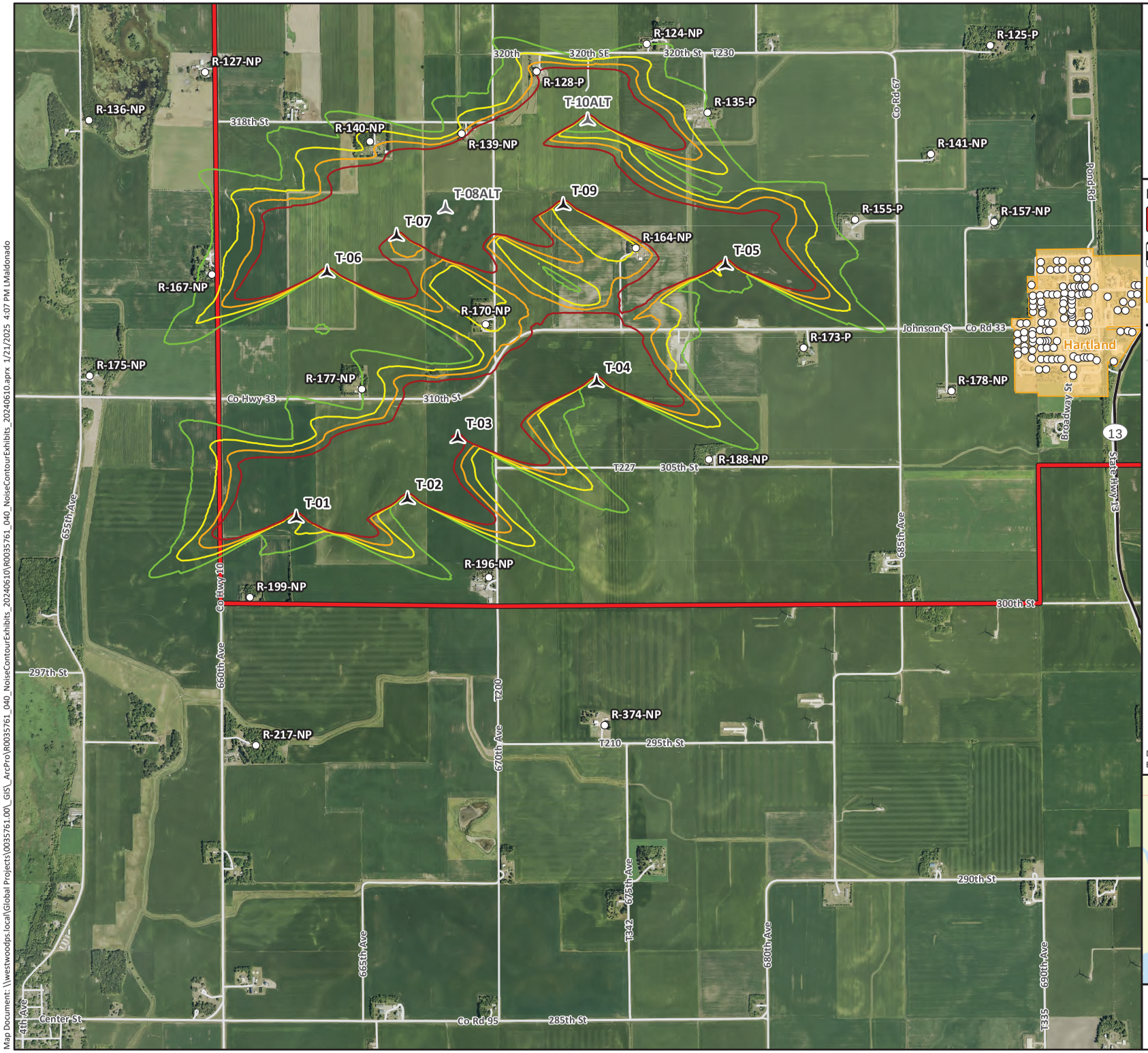
Appendix D: Shadow Flicker Analysis



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Bent Tree North Wind Project

Freeborn, Steele, & Waseca Counties, Minnesota

Layout B Shadow Flicker

Appendix F

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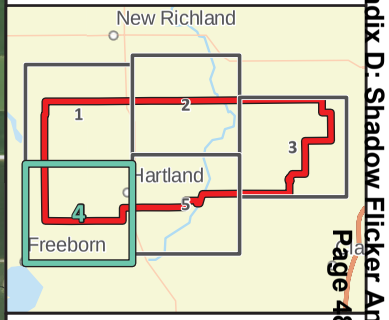
Data Source(s): Westwood (2025); NAIP (2023); U.S. Census Bureau (2024); MN Geospatial Commons (2023).



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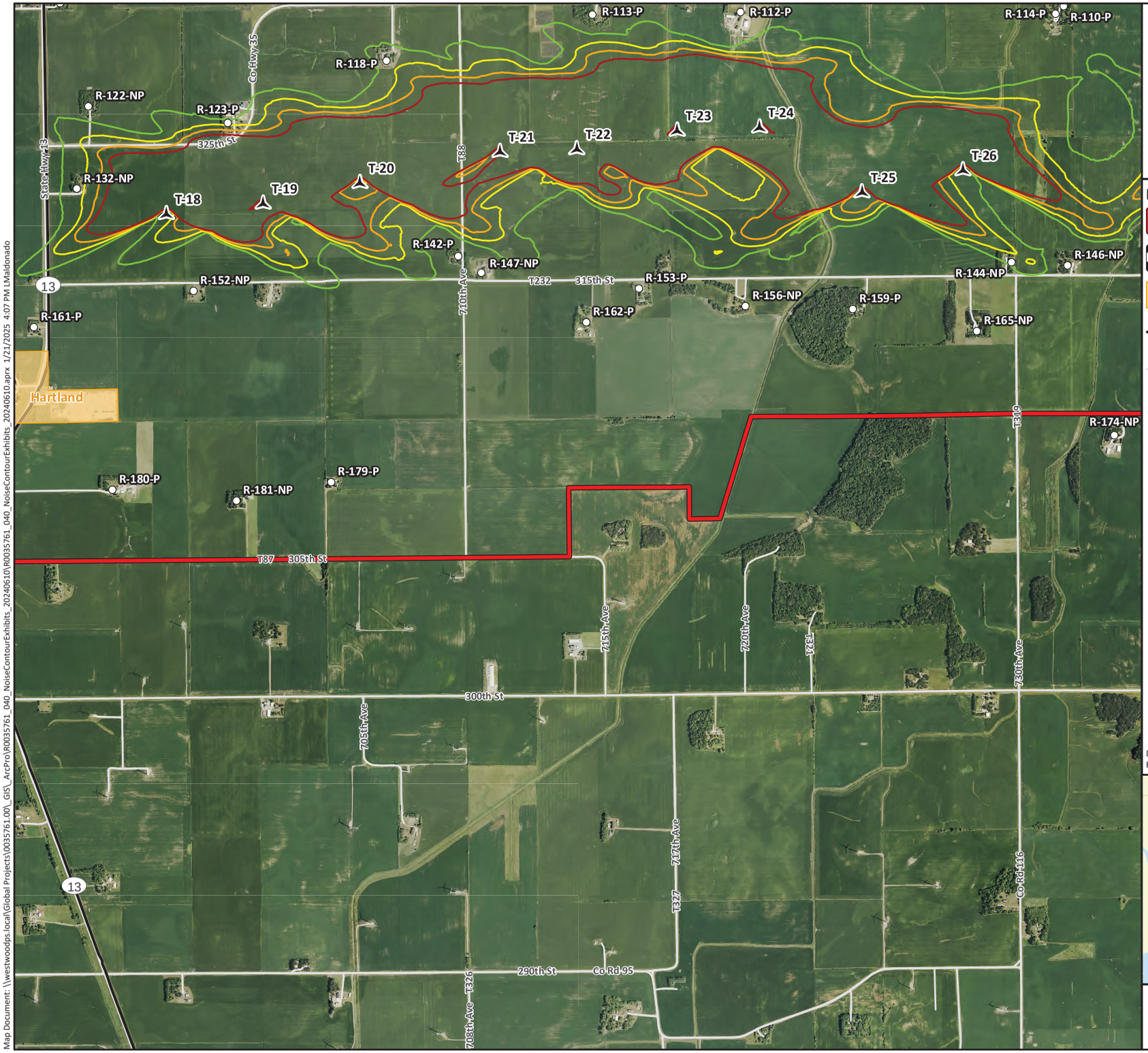

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Freeborn, Steele, & Waseca Counties, Minnesota

Layout B Shadow Flicker

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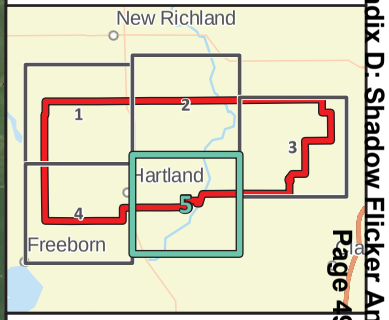

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