SHADOW FLICKER MODELING REPORT

Reynolds Road Wind Project
Montgomery County, New York

Prepared for:

Borrego Solar Systems, Inc
30 Century Hill Drive, Suite 301
Latham, NY 12110

Prepared by:

Epsilon Associates, Inc.
3 Mill & Main Place, Suite 250
Maynard, MA 01754

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1.0   EXECUTIVE SUMMARY

The Reynolds Road Wind Project (the Project) is a proposed wind power generation facility expected to consist of one (1) wind turbine in Montgomery County, New York. The Project is being developed by Borrego Solar Systems, Inc. (Borrego). Epsilon Associates Inc. (Epsilon) has been retained by Borrego to conduct a shadow flicker modeling study for this Project. This report presents results of the shadow flicker modeling of the proposed wind turbine in Montgomery County.

Shadow flicker modeling was conducted for one Vestas wind turbine. The purpose of this analysis is to predict the annual durations of wind turbine shadow flicker at nearby receptors.
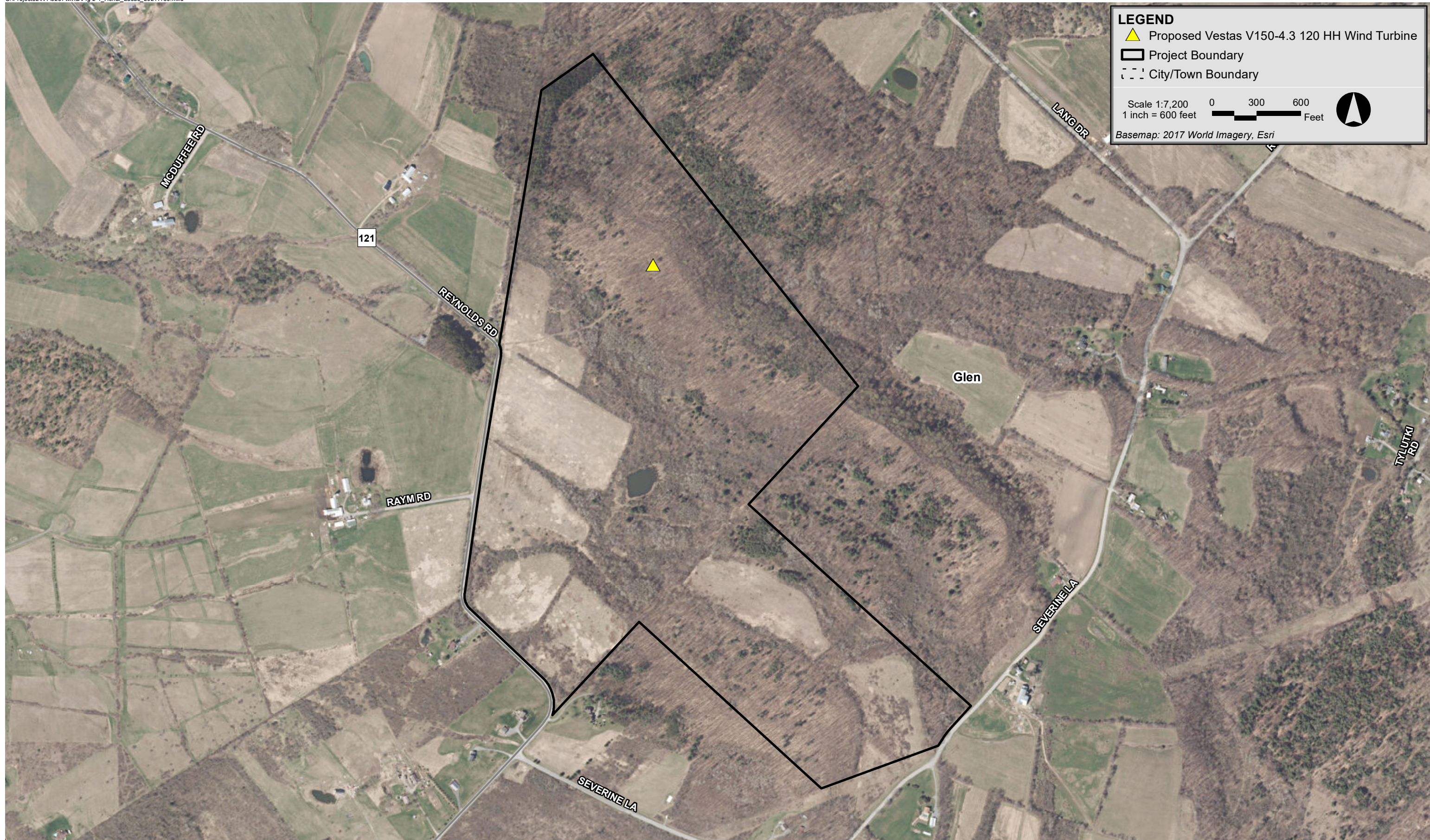
The maximum expected annual duration of shadow flicker at a modeling receptor resulting from the operation of the proposed wind turbine is 19 hours, 37 minutes. The modeling results are conservative in that modeling receptors were treated as "greenhouses" (i.e. having windows on all sides) and the surrounding area was assumed to be without vegetation or structures ("bare earth").

2.0   INTRODUCTION

The proposed Project will consist of one (1) wind turbine. The proposed wind turbine is a Vestas V150-4.3 unit with a hub height of 120 meters. Figure 2-1 shows the locations of the wind turbine in Montgomery County over aerial imagery.

Shadow flicker can be defined as an intermittent change in the intensity of light in a given area resulting from the operation of a wind turbine due to its interaction with the sun. An indoor observer experiences repeated changes in the brightness of the room as shadows cast from the wind turbine blades briefly pass by windows as the blades rotate. In order for this to occur, the wind turbine must be operating, the sun must be shining, and the window must be within the shadow region of the wind turbine, otherwise there is no shadow flicker. A stationary wind turbine only generates a stationary shadow similar to any other structure.

This report presents the findings of a shadow flicker modeling study for the Project. The wind turbine was modeled with the WindPRO software package using information provided by Borrego. The expected annual duration of shadow flicker was calculated at modeling receptors. The results of the modeling are found within this report.

LEGEND

△ Proposed Vestas V150-4.3 120 HH Wind Turbine

▢ Project Boundary

City/Town Boundary

Scale 1:7,200
1 inch = 600 feet

0   300   600
Feet

Basemap: 2017 World Imagery, Esri

MCDUFFEE RD

121

REYNOLDS RD

RAYM RD

Glen

TYLUTKI RD

SEVERINE LA

LANG DR

SEVERINE LA

411 Reynolds Road Wind   Montgomery County, New York

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Figure 2-1
Aerial Locus

3.0   SHADOW FLICKER MODELING

3.1   Modeling Methodology

Shadow flicker was modeled using a software package, WindPRO version 3.4. WindPRO is a software suite developed by EMD International A/S and is used for assessing potential environmental impacts from wind turbines. Using the Shadow module within WindPRO, worst-case shadow flicker in the area surrounding the wind turbine was calculated based on data inputs including: location of the wind turbine, location of discrete receptor points, wind turbine dimensions, flicker calculation limits, and terrain data. Based on these data, the model was able to incorporate the appropriate sun angle and maximum daily sunlight for this latitude into the calculations. The resulting worst-case calculations assume that the sun is always shining during daylight hours and that the wind turbine is always operating. The WindPRO Shadow module can be further refined by incorporating sunshine probabilities and wind turbine operational estimates by wind direction over the course of a year. The values produced by this further refinement are known as the "expected" shadow flicker. The expected annual shadow flicker durations are presented in this section.

The location of the wind turbine is shown in Figure 3-1 and the coordinates are provided in Appendix A. The wind turbine is a Vestas V150-4.3 unit with a 150-meter rotor diameter and a hub height of 120 meters. The wind turbine has the following characteristics based on the technical data provided by Borrego:

		V150-4.3
♦ Rated Power	=	4,300 kW
♦ Hub Height	=	120 meters
♦ Rotor Diameter	=	150 meters
♦ Cut-in Wind Speed	=	3 m/s
♦ Cut-out Wind Speed	=	24.5 m/s

To-date, there are no federal, state, or local regulations regarding the maximum radial distance from a wind turbine to which shadow flicker should be analyzed applicable to this Project. In the United States, shadow flicker is commonly evaluated out to a distance of ten times the rotor diameter. According to the Massachusetts Model Bylaw for wind energy facilities, shadow flicker impacts are minimal at and beyond a distance of ten rotor diameters.[1] Defining the shadow flicker calculation area has also been addressed in Europe where the ten times rotor diameter approach has been accepted in multiple European countries.[2] Some jurisdictions conservatively require a

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[1]   Massachusetts Department of Energy Resources, "Model As-of-Right Zoning Ordinance or Bylaw: Allowing Use of Wind Energy Facilities" 2009.

[2]   Parsons Brinckerhoff, "Update of UK Shadow Flicker Evidence Base" Prepared for Department of Energy and Climate Change, 2011.

larger calculation area. The New Hampshire Site Evaluation Committee through rulemaking docket 2014-04 adopted rules on December 15, 2015 outlining application requirements and criteria for energy facilities, including wind energy facilities. As part of these revised regulations, Site 301.08(a)(2) requires an evaluation distance of at least 1 mile from a wind turbine.[3] Section 16-50j-94, part (g), of the Regulations of Connecticut State Agencies identifies the components required in a shadow flicker evaluation report which includes the calculation of shadow flicker from each proposed wind turbine to any off-site occupied structure within a 1.25 mile radius.[4] For this Project, ten times the largest rotor diameter of the proposed wind turbine corresponds to a distance of 0.93 miles (1,500 m). Conservatively, this analysis includes shadow flicker calculations out to 1.25 miles (2,012 m) from each wind turbine in the model for the proposed layout.

A modeling receptor kmz dataset was provided by Borrego. This dataset included 10 receptors which were input into the WindPRO model. Each modeling point was assumed to have a window facing all directions ("greenhouse" mode) which yields conservative results. All modeling receptors are identified in Figure 3-1. The model was set to limit calculations to 2,012 meters from a wind turbine, the equivalent of 1.25 miles. Consequently, shadow flicker at any of the 10 modeling receptors greater than the corresponding limitation distance from a wind turbine was zero.

The terrain height contour elevations for the modeling domain were generated from elevation information derived from the National Elevation Dataset (NED) developed by the U.S. Geological Survey. Conservatively, obstacles, i.e. buildings and vegetation, were excluded from the analysis. This is effectively a "bare earth" scenario which is conservative. When accounted for in the shadow flicker calculations, such obstacles may significantly mitigate or eliminate the flicker effect depending on their size, type, and location. In addition, shadow flicker durations were calculated only when the angle of the sun was at least 3° above the horizon.
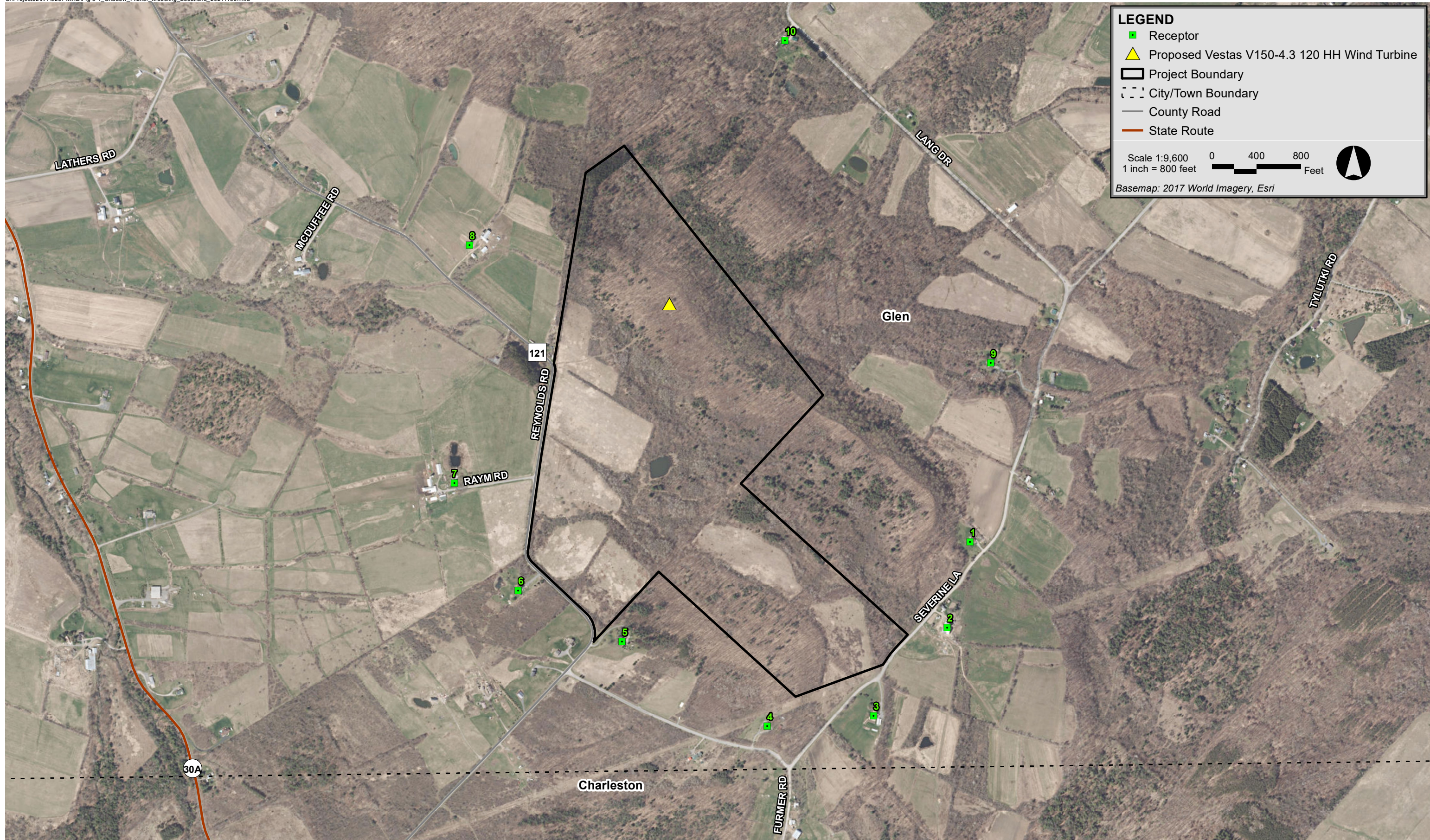
Monthly sunshine probability values were input for each month from January to December. These numbers were obtained from a publicly available historical dataset for Albany, New York from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI).[5] Table 3-1 shows the percentage of sunshine hours by month used in the shadow flicker modeling. These values are the percentages that the sun is expected to be shining during daylight hours.

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[3]   State of New Hampshire Site Evaluation Committee Site 300 Rules (2015), available at http://www.gencourt.state.nh.us/rules/state_agencies/site100-300.html Accessed in November 2021.

[4]   State of Connecticut CSC Wind Regulations (2014), available at https://eregulations.ct.gov/eRegsPortal/Browse/RCSA?id=Title_16Subtitle_16-50jSection_16-50j-94&content=shadow%20flicker/ Accessed in November 2021.

[5]   NCEI (formerly NCDC), http://www1.ncdc.noaa.gov/pub/data/ccd-data/pctpos15.dat. Accessed in November 2021.

The number of hours the wind turbine is expected to operate for the 16 cardinal wind directions was input into the model. An hourly dataset for a one year period of wind directions and scaled wind speed was provided by Borrego for a height of 120 meters. Epsilon used this data to calculate the typical annual number of operational hours per wind direction sector. These hours per wind direction sector are used by WindPRO to estimate the "wind direction" and "operation time" reduction factors. Based on this dataset, the wind turbine would operate 87% of the year. Table 3-2 shows the distribution of operational hours for the 16 wind directions.

LEGEND

- Receptor
- Proposed Vestas V150-4.3 120 HH Wind Turbine
- Project Boundary
- City/Town Boundary
- County Road
- State Route

Scale 1:9,600
1 inch = 800 feet

0   400   800

Feet

Basemap: 2017 World Imagery, Esri

411 Reynolds Road Wind   Montgomery County, New York

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Figure 3-1
Shadow Flicker Modeling Locations

Table 3-1   Monthly Percent of Possible Sunshine

Month	Possible Sunshine
January	46%
February	52%
March	51%
April	55%
May	53%
June	55%
July	62%
August	58%
September	54%
October	46%
November	33%
December	36%

Table 3-2   Operational Hours per Wind Direction Sector

Wind Sector	Operational Hours
N	89
NNE	112
NE	271
ENE	397
E	326
ESE	250
SE	259
SSE	265
S	215
SSW	251
SW	428
WSW	661
W	1692
WNW	1817
NW	436
NNW	149
Annual	7618

3.2   Shadow Flicker Modeling Results

Following the modeling methodology outlined in Section 3.1, WindPRO was used to calculate shadow flicker at the 10 discrete modeling receptor points. Table B-1 in Appendix B presents the expected flicker at each modeling receptor.

The predicted expected annual shadow flicker duration ranged from 0 hours, 0 minutes per year to 19 hours, 37 minutes per year for all 10 receptors. The maximum expected flicker modeled occurs at receptor (#8). Seven of the ten receptors were predicted to experience no annual shadow flicker. One receptor was predicted to experience some shadow flicker but less than 10 hours per year. The modeling results showed that two receptors would be expected to have between 10 hours and 30 hours of shadow flicker per year. Zero (0) receptors are expected to have over 30 hours of flicker per year.

Appendix A
Wind Turbine Coordinates

Table A-1: Wind Turbine Coordinates

Wind Turbine ID	Wind Turbine Type	Hub Height (m)	Coordinates NAD83 UTM Zone 18N (meters)	
			X (Easting)	Y (Northing)
1	V150-4.3	120	555342.43	4747054.74

Appendix B
Shadow Flicker Modeling Results: Modeling Receptors

Table B-1: Shadow Flicker Modeling Results at Discrete Points - Sorted by Receptor ID

Receptor ID	Coordinates UTM NAD83 Zone 18N (meters)		Expected Shadow Flicker Hours per Year
	X (Easting)	Y (Northing)	(HH:MM/year)
1	556166.39	4746403.45	0:00
2	556103.25	4746169.25	0:00
3	555901.89	4745928.07	0:00
4	555610.85	4745899.19	0:00
5	555213.74	4746130.72	0:00
6	554929.31	4746270.69	0:00
7	554754.25	4746564.91	0:00
8	554795.97	4747216.38	19:37
9	556223.27	4746893.28	12:25
10	555659.87	4747776.29	1:20