26.0 SHADOW FLICKER

Epsilon Associates, Inc. conducted a shadow flicker analysis for the project proposed turbine locations (Exhibit 26-1). As described in Section 1.0 (Project Description), the project will use the Vestas V-126 STE, a 3.45 MW generator derated to 3.3 MW, on a 117 meter (m) base.

The purpose of the shadow flicker assessment was to predict the annual duration of shadow flicker at sensitive receptors in the vicinity of the project. The assessment evaluated potential shadow flicker impacts from the project using the most conservative or "worst case" assumptions. Specifically, when considering shadow flicker impacts, the model assumed that the sun was always shining, the blades were always at right angles to the receptor, and the turbine blades were always spinning.

Shadow flicker is predicted to occur at only two structures, both in Osborn. One is on land leased by the project for the duration of operation (see Section 2, Exhibit 2-1 for the lease from Tree Top Manufacturing). The second is predicted to have a worst case annual duration of 14 hours and 27 minutes, which is below the 30-hour annual limit set forth in 06-096 CMR 382(4)(B).

Exhibit 26-1

Shadow Flicker Assessment

SHADOW FLICKER MODELING ANALYSIS

Weaver Wind
Hancock County, Maine

Prepared for:

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Prepared by:

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October 18, 2018

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1.0 EXECUTIVE SUMMARY

Weaver Wind (the Project) is a proposed 72.6 megawatt (MW) wind power generation facility composed of 22 wind turbines in Hancock County, Maine. The Project is being developed by Weaver Wind, LLC. Epsilon Associates, Inc. (Epsilon) has been retained by Stantec Consulting Services Inc. (Stantec) to conduct a shadow flicker analysis for the proposed wind turbines.

Shadow flicker modeling was conducted for 22 Vestas V126-3.45 MW wind turbines that are proposed to be located in the towns of Osborn and Eastbrook, ME. The purpose of this assessment is to predict the annual duration of shadow flicker at sensitive receptors in the vicinity of the Project to address the state and local regulations with regards to shadow flicker.

The maximum worst-case annual duration of shadow flicker at a modeling receptor resulting from the operation of the 22 proposed wind turbines is 49 hours, 57 minutes. This is at a participating receptor on property leased by the Project for the anticipated duration of the Project's life. The second highest modeled annual duration of shadow flicker at a modeling receptor is 14 hours, 27 minutes, which is less than the State limit of 30 hours per year. In the Town of Eastbrook, no shadow flicker is predicted at any of the sensitive receptors modeled. The modeling results are conservative in that modeling receptors were treated as "greenhouses", the surrounding area was assumed to be without vegetation or structures ("bare earth"), and no adjustments for typical meteorological conditions were applied.

2.0 INTRODUCTION

The proposed Weaver Wind Project to be located in Hancock County, Maine will consist of 22 Vestas wind turbines. The wind turbines will be V126-3.45MW units with a hub height of 117 meters and a rotor diameter of 126 meters.

With respect to wind turbines, 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. Indoors, an observer experiences repeated changes in the brightness of the room as shadows cast from the wind turbine blades briefly pass by the windows as the blades rotate. In order for this to occur, the wind turbine must be operating and the sun must be shining. A stationary wind turbine would only generate a stationary shadow similar to any other structure.

This report presents the findings of the shadow flicker modeling in Hancock County for 22 wind turbines. The wind turbines were modeled in WindPRO using information provided by Weaver Wind, LLC and Stantec. The worst-case annual duration of shadow flicker was calculated at 63 discrete modeling locations and shadow flicker isolines for the area surrounding the Project were generated. The results of this analysis are found within this report.

3.0 REGULATIONS

3.1 Federal Regulations

There are no federal community shadow flicker regulations applicable to this Project.

3.2 Maine State Regulations

The State of Maine Department of Environmental Protection Wind Energy Act Standards Chapter 382 contains the following text regarding shadow flicker:

> ***Shadow Flicker.*** *An applicant must demonstrate that the generating facilities of a proposed wind energy development have been designed to avoid unreasonable adverse shadow flicker effects at any occupied building located on property not owned by the applicant, subject to a lease for a duration at least as long as the anticipated project life, or subject to an easement for shadow flicker in excess of 30 hours per year.*
>
> *A. An applicant must submit a shadow flicker analysis based on WindPRO, or other modeling software approved by the Department. The analysis must assume that all shadows cast by rotating turbine blades on occupied buildings are unobstructed, and shall not take into account any existing vegetative buffers. The shadow flicker analysis shall model impacts to any occupied building within one mile, measured horizontally, from a proposed turbine.*
>
> *B. A proposed development may not result in shadow flicker effect occurring at an occupied building for more than 30 hours per calendar year. An applicant may request that this general restriction be waived by showing that 30 hours or less of shadow flicker per year will occur during times when an affected public building is in use, or where an affected private building is used seasonally or intermittently such that occupants will experience 30 hours or less of shadow flicker per year. An applicant may also qualify for a waiver by submitting evidence of agreements or easements with affected property owners in which the property owners state that they do not object to the projected level of shadow flicker.*
>
> *C. If the shadow flicker analysis predicts that any occupied building will receive more than 30 hours of shadow flicker per calendar year, the applicant may propose mitigation measures to reduce this impact to 30 hours or less per calendar year.*

3.3 County Regulations

Epsilon is not aware of any ordinances with respect to shadow flicker in Hancock County.

3.4 Local Regulations

3.4.1 Town of Osborn

There are no applicable ordinances with respect to shadow flicker in the Town of Osborn.

3.4.2 Town of Eastbrook

Section 4.0 of the Eastbrook Wind Energy Facility Ordinance reads the following to define a Wind Energy Facility, Type 3:

> "*a Wind Energy Facility having a generating capacity of 100kW or greater and a maximum height of 500 feet and which requires a state permit issued by the Department of Environmental Protection under the Site Location of Development Act, 38 MRSA §481, et seq.*"

Section 20.6 of the Eastbrook Wind Energy Facility Ordinance specifies the following requirements with respect to shadow flicker for Type 2 and Type 3 Wind Energy Facilities applicable to the Project:

> *"Type 2 and Type 3 Wind Energy Facilities may not cause an unreasonable adverse shadow flicker or blade reflection effect at any Occupied Building or residence located on a Non-Participating Landowner's property. For the purposes of this section, "unreasonable adverse shadow flicker or blade reflection" means shadow flicker or blade reflection occurring for 3 days or*[1] *more in any one month that, if annualized, would total more than 10 hours of flicker or reflection per year. In addition, a wind turbine, including its blades, must be constructed of non-reflective materials or its surface painted so as to be non-reflective. As part of its application, the applicant shall include a detailed shadow flicker and blade glint assessment, developed through modeling and prepared by a person qualified to conduct such an assessment, and an estimate of the projected extent of flicker and glint. The assessment must meet the following:*
>
> > *A. The assessment must identify Sensitive Receptors and public ways, model the locations and durations of shadow flicker caused by the proposed WEF within the study area and project the frequency and duration of shadow flicker within 200 feet of those locations throughout the study area."*

[1] Epsilon assumes this is a typographical error in the ordinance and that the intended word is "or".

Section 4.0 of the Eastbrook Wind Energy Facility Ordinance defines a "Sensitive Receptor" as:

> "*a residence or other place or structure intended for human habitation, whether inhabited or not, public park, state or federal wildlife area, school, daycare center, elder care facility, medical facility, place of seated assemblage, nonagricultural business, or manicured area of a recreational establishment designed for public use, including but not limited to a golf course, campground or other nonagricultural business licensed by a state or federal agency. A sensitive area is more likely to be sensitive to the exposure of noise, shadow flicker or other potentially adverse effects of a Wind Energy Facility.*"

4.0 SHADOW FLICKER ANALYSIS

4.1 Modeling Methodology

Shadow flicker was modeled using a software package, WindPRO version 3.2.712. WindPRO is a software suite developed by EMD International A/S and is used for assessing potential environmental impacts from wind turbines. Worst-case shadow flicker in the area surrounding the wind turbines was calculated based on data inputs including: location of the wind turbines, location of discrete modeling points, wind turbine dimensions, 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 WindPRO shadow flicker module can be further refined by incorporating sunshine probabilities and wind turbine operational estimates by wind direction over the course of a year. A further refinement of shadow flicker based on these statistics was not performed in this analysis; i.e. only worst-case values were calculated.

The proposed wind turbine layout for the Project was provided by Stantec on August 16, 2018. A total of 22 Weaver Wind turbines were included in the analysis. The locations for the wind turbines, all to be located in Hancock County, are presented in Figure 4-1. Each wind turbine has the following characteristics based on the technical data provided by Stantec:

- Rated Power = 3,450 kW
- Hub Height = 117 meters (above ground level)
- Rotor Diameter = 126 meters
- Cut-in Wind Speed = 3 m/s
- Cut-out Wind Speed = 22.5 m/s

The State of Maine specifies that a shadow flicker model should include impacts to any occupied building within 1 mile radially from any proposed wind turbine. Therefore, this analysis included shadow flicker calculations out to 1 mile (1,609 meters) from each wind turbine.

The modeling locations, i.e. residences, in the vicinity of the Project were provided by the Project team in September 2014. The 63 modeling locations, all within Hancock County, are shown in Figure 4-1 and are listed in Appendix A. Stantec confirmed that there has been no change in residences since that time. A total of 59 of the modeling locations (#1 through #58, and #62) are within the Town of Osborn and four (#59 through #61, and #63) are within the Town of Eastbrook. Each modeling point was assumed to have a window facing all directions ("greenhouse" mode) which yields conservative results. In order to address the Town of Eastbrook ordinance regarding sensitive receptors, Epsilon obtained Hancock County conservation land data from the Project team. No conservation lands or other Sensitive Receptors as defined within the Eastbrook Ordinance and located within the

Town of Eastbrook were within the calculation area, and as such, are not displayed on the figures. The model was programmed to limit calculations to the distance of 1 mile from a wind turbine. Therefore, shadow flicker at sensitive receptors a distance greater than 1 mile from a wind turbine were zero. In addition to modeling discrete receptors, shadow flicker was calculated at grid points in the area surrounding the modeled wind turbines. 20-meter spacing was used for this grid.

The terrain height contour elevations for the modeling domain were generated from elevation information derived from a National Elevation Database (NED) developed by the U.S. Geological Survey and processed by the U.S. Department of Agriculture. Conservatively, obstacles which may block the line-of-sight between a wind turbine and receptor, i.e. buildings and vegetation, were excluded from the analysis. In addition, shadow flicker was calculated only when the angle of the sun was at least 3° above the horizon.

4.2 Results

Following the modeling methodology outlined in Section 4.1, WindPRO was used to calculate shadow flicker at the 63 discrete modeling points in Hancock County and to generate shadow flicker isolines based on the grid calculations for each of the proposed options.

The majority of the modeling locations (61) were predicted to experience no shadow flicker under worst-case conditions with the installment of 22 proposed wind turbines. Two of the 59 modeling locations (#58 and 62)[2] in the Town of Osborn were predicted to experience shadow flicker from the Project. The maximum amount of predicted shadow flicker was 49 hours, 57 minutes. None of the four residences in the Town of Eastbrook were modeled to experience any shadow flicker under worst-case conditions. Appendix A presents the worst-case shadow flicker results for all 63 modeled sensitive receptors in Hancock County. The results of the shadow flicker modeling are shown graphically in Figure 4-2 as isolines. This figure shows the modeled shadow flicker on public ways.

[2] Receptors 58 and 62 are identified on Figure 4-2.

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LEGEND

- Proposed Vestas V126-3.45 Wind Turbine
- Modeling Receptor
- Town Boundary

Scale 1:42,000
1 inch = 3,500 feet

0 1,750 3,500 Feet

Aurora
Osborn
Eastbrook
T28 MD BPP
T22 MD BPP
T16 MD BPP

Comstock Rd
Leighton Brook Rd
Spectacle Pond Rd
Airline Rd - Route 9
Middle Branch Rd
Grant Farm Rd
Cronin Ln
Spec Pond Rd
Een Ridge Rd
Shady Ln
Kingman Beach Rd
Sand Beach Rd
Loggin Dr
Smelt Dr
Birch Rd
Hemlock Way
Pine Dr
Narrows Rd
Schoppe Ridge Rd
S Spectacle Pond Rd
Trout Brook Rd
Bog River Rd
Stone Dam Rd
Bull Hill Rd
Sugar Hill Rd
75-00-0
Fly Heath Rd
Jeremiah Spring Rd

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 22 23 24 25

bing

Weaver Wind **Eastbrook/Osborn, Hancock County, Maine**

Epsilon ASSOCIATES INC.

Figure 4-1
Aerial Locus

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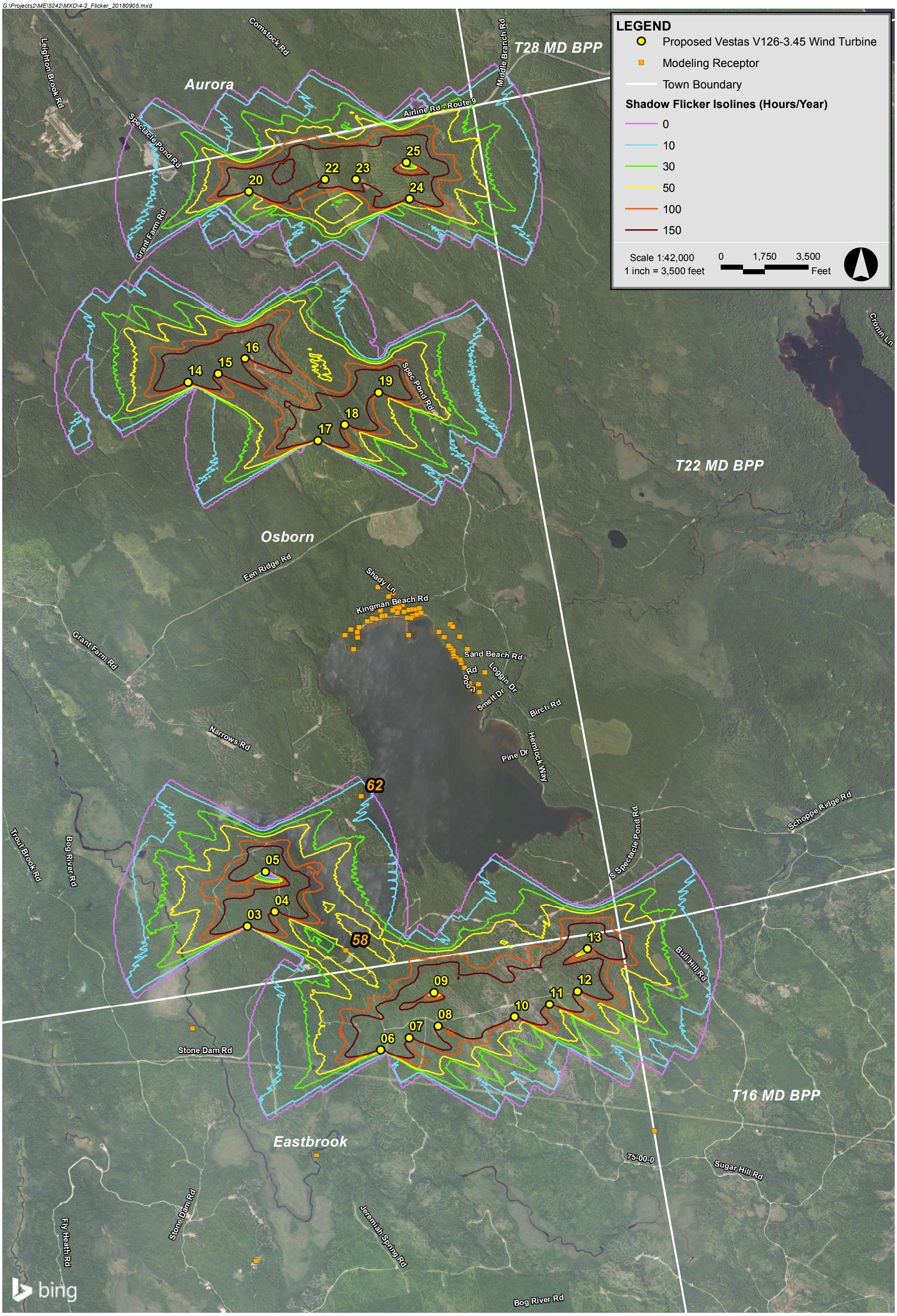

Weaver Wind **Eastbrook/Osborn, Hancock County, Maine**

Epsilon ASSOCIATES INC.

Figure 4-2
Shadow Flicker Modeling Results

5.0 EVALUATION OF SHADOW FLICKER

5.1 State of Maine

According to the Wind Energy Act Standards of the Department of Environmental Protection, shadow flicker at an occupied building within 1 mile of a wind turbine is limited to 30 hours per year. The shadow flicker modeling results at all modeling receptors have been compared to this limit.

Two of the 63 modeling locations (#58 and 62) were predicted to experience shadow flicker from the Project under worst-case conditions. The maximum amount of predicted shadow flicker is 49 hours, 57 minutes. This is at a participating receptor on property leased for the Project. The maximum modeled annual duration of shadow flicker at the remaining modeling receptors is 14 hours, 27 minutes. These results are conservative as the wind turbines are assumed to always be rotating and the sun is always shining during the day. The remaining receptors are not expected to experience any duration of shadow flicker. The shadow flicker at these receptors is below the State limit of 30 hours per year; therefore, this Project is in compliance with the State of Maine regulation with respect to shadow flicker.

5.2 Town of Eastbrook

According to the Wind Energy Facility Ordinance shadow flicker at an occupied building or residence is limited to 10 hours per year. The shadow flicker modeling results at locations in Eastbrook have been compared to this limit.

Based on the modeling methodology and results, shadow flicker durations at the modeled receptors in the Town of Eastbrook will be less than 10 hours per year, and therefore the Project complies with the Eastbrook Wind Energy Facility Ordinance.

6.0 CONCLUSIONS

The proposed Weaver Wind Project to be located in Hancock County, Maine will consist of 22 Vestas wind turbines. The wind turbines will be V126-3.45MW units with a hub height of 117 meters and a rotor diameter of 126 meters. Epsilon used WindPRO to model anticipated worst-case shadow flicker in the Towns of Osborn and Eastbrook. The wind turbine layout was predicted to produce shadow flicker at two of the 59 modeling locations in the Town of Osborn and zero of the four (4) in the Town of Eastbrook. The maximum modeled annual duration of shadow flicker at a receptor is 49 hours, 57 minutes. This is at a participating receptor. The maximum modeled annual duration of shadow flicker at the remaining modeling receptors is 14 hours, 27 minutes. Predicted shadow flicker for the Weaver Wind Project therefore complies with all relevant State and local shadow flicker regulations.

Appendix A
Shadow Flicker Modeling Results: Modeling Receptors

Modeling Receptor ID	Town	UTM NAD83 Zone 19N Coordinates		Worst-Case Annual Shadow Flicker (HH:MM/yr)
		X (Easting)	Y (Northing)	
1	Osborn	561955.90	4958950.86	0:00
2	Osborn	561902.03	4958892.68	0:00
3	Osborn	562082.40	4958821.21	0:00
4	Osborn	562028.13	4958779.58	0:00
5	Osborn	562168.04	4958720.61	0:00
6	Osborn	562198.73	4958680.36	0:00
7	Osborn	562149.73	4958674.33	0:00
8	Osborn	562159.98	4958636.99	0:00
9	Osborn	562106.93	4958649.03	0:00
10	Osborn	562133.76	4958582.97	0:00
11	Osborn	562076.93	4958609.19	0:00
12	Osborn	561987.25	4958546.56	0:00
13	Osborn	561927.21	4958610.30	0:00
14	Osborn	561947.33	4958543.18	0:00
15	Osborn	561871.25	4958506.00	0:00
16	Osborn	561830.51	4958513.06	0:00
17	Osborn	561768.36	4958475.58	0:00
18	Osborn	561669.89	4958404.53	0:00
19	Osborn	561649.57	4958345.46	0:00
20	Osborn	561571.08	4958377.81	0:00
21	Osborn	561651.20	4958282.71	0:00
22	Osborn	561602.00	4958140.15	0:00
23	Osborn	561500.04	4958309.59	0:00
24	Osborn	562218.74	4958590.90	0:00
25	Osborn	562275.95	4958615.45	0:00
26	Osborn	562321.37	4958541.90	0:00
27	Osborn	562297.31	4958517.67	0:00
28	Osborn	562257.57	4958520.17	0:00
29	Osborn	562275.51	4958310.05	0:00
30	Osborn	562326.88	4958618.50	0:00
31	Osborn	562361.89	4958622.61	0:00
32	Osborn	562372.23	4958560.17	0:00
33	Osborn	562404.49	4958635.69	0:00
34	Osborn	562423.55	4958580.22	0:00
35	Osborn	562783.73	4958443.08	0:00
36	Osborn	562809.90	4958412.00	0:00
37	Osborn	562897.00	4958293.43	0:00
38	Osborn	562987.44	4958140.56	0:00
39	Osborn	563203.05	4957852.72	0:00
40	Osborn	563123.01	4957710.40	0:00
41	Osborn	563137.02	4957614.11	0:00
42	Osborn	563054.84	4957648.96	0:00
43	Osborn	563020.93	4957686.18	0:00
44	Osborn	563014.35	4957719.33	0:00
45	Osborn	562987.74	4957745.18	0:00
46	Osborn	562989.55	4957779.41	0:00
47	Osborn	562958.22	4957907.75	0:00
48	Osborn	562912.82	4957969.86	0:00
49	Osborn	562901.63	4958005.41	0:00
50	Osborn	562848.90	4958041.00	0:00
51	Osborn	562826.37	4958046.78	0:00
52	Osborn	562822.27	4958077.29	0:00
53	Osborn	562814.79	4958122.54	0:00
54	Osborn	562787.41	4958154.60	0:00
55	Osborn	562761.67	4958181.46	0:00
56	Osborn	562709.21	4958286.26	0:00
57	Osborn	562644.43	4958348.96	0:00
58	Osborn	561505.82	4954463.61	49:57
62	Osborn	561693.14	4956343.13	0:00
59	Eastbrook	565266.52	4952261.41	0:00
60	Eastbrook	561149.09	4951963.20	0:00
61	Eastbrook	559639.39	4953508.98	14:27
63	Eastbrook	560412.76	4950672.94	0:00