Section 26
Shadow Flicker

PATRIOT RENEWABLES
Canton Mountain Wind, LLC

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26.0 SHADOW FLICKER ANALYSIS

26.1 Overview

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

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance. Shadow flicker intensity for receptor-to-turbine distances beyond 2,000 meters (6,562 feet) is very low and generally considered imperceptible. Shadow flicker intensity for receptor-to-turbine distances between 1,000 and 2,000 meters (between 3,281 and 6,562 feet) is also low and considered barely noticeable. At this distance, shadow flicker intensity would only tend to be noticed under conditions that would enhance the intensity difference, such as observing from a dark room with a single window directly facing the turbine casting the shadow. At distances less than 1,000 meters (3,281 feet), shadow flicker may be more noticeable. In general, the largest number of shadow flicker hours, along with the greatest shadow flicker intensity, occurs nearest to the wind turbines.

Canton Mountain Wind, LLC (CMW) is proposing to install eight wind turbines as part of the Canton Mountain Wind Project (Project) in Canton, Oxford County, Maine. Since the Project is using a minimum turbine siting setback requirement of 2,500 feet (to any non-participating residence), sensitive receptors (occupied residences) are generally not located in the worst-case potential shadow flicker impact zones, which ensures that shadow flicker impacts are minimized. CMW hired Tetra Tech EC, Inc. (Tetra Tech) to conduct a shadow flicker analysis for the Project.

Two different wind turbines are being considered for this Project: General Electric (GE) 2.75-MW and Gamesa 2.0-MW turbines. The GE 2.75-MW series turbines have two models, the 2.75-103 and the 2.75-100, which have 85-meter hub heights and rotor diameters of 103 meters and 100 meters, respectively. The Gamesa 2.0-MW turbine under consideration for this Project is a G90, which has a 78-meter hub height and a rotor diameter of 90 meters. The shadow flicker analysis is conservatively based on the GE 2.75-103 turbine design since the largest rotor will cast the largest shadow and would potentially result in the greatest impact. The GE 2.75-103 has the following characteristics:

- **GE Wind Energy GE 2.75-103** – 3-blade 103-meter-diameter rotor, with a hub height of 85 meters. The GE 2.75-103 has a nominal range rotor speed of 14.8 rotations per minute (rpm), which translates to a blade pass frequency of 0.74 Hz (less than 1 alternation per second).

Shadow flicker frequency is related to the wind turbine's rotor blade speed and the number of blades on the rotor. From a health standpoint, such low frequencies are harmless. For comparison, strobe lights used in discotheques have frequencies that range from about 3 Hz to 10 Hz (1 Hz = 1 flash per second). As a result, public concerns that flickering sunlight from rotating wind turbines can have negative health effects, such as triggering seizures in people with epilepsy, are unfounded. The Epilepsy Action (the working name for the British Epilepsy Foundation) states that there is no evidence that wind turbines can cause seizures. However, they recommend that wind turbine flicker frequency be limited to 3 Hz or less (http://www.epilepsy.org.uk/info/photo_other.html). Since the proposed Project's wind turbine blade pass frequency is approximately 0.74 Hz (less than 1 alternation per second), no negative health effects to individuals with photosensitive epilepsy are anticipated.

26.2 WindPro Shadow Flicker Analysis

An analysis of potential shadow flicker impacts from the proposed 8-turbine Project was conducted by Tetra Tech using the WindPro software package. The WindPro analysis determines shadow flicker impacts under realistic conditions (actual expected shadow). This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at receptors out to 2,000 meters (6,562 feet) from the nearest turbine. The realistic impact condition scenario is based on the following assumptions:

- The elevation and position geometries of the wind turbines and surrounding receptors (houses). Elevations were determined using USGS digital elevation model data. Positions were determined using Geographic Information System (GIS) and referenced to UTM Zone 19 (NAD83).
- The position of the sun and the incident sunlight relative to the wind turbine and receptors on a minute by minute basis over the course of a year.
- Historical availability of sunshine hours (percent of total available hours). Historical sunshine rates for the area (as listed by the www.city-data.com website for Livermore Falls, Maine) used in this analysis are as follows:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
56%	59%	56%	54%	55%	59%	63%	63%	62%	58%	48%	53%

- Estimated wind turbine operation and orientation based on approximately 16 months of wind data from 6/22/10 to 11/7/11 (wind speed / wind direction frequency distribution) measured at a meteorological tower located within the Project site on Canton Mountain. The WindPro-calculated wind direction frequency distribution for operating hour winds is as follows:

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
3.8%	3.6%	6.3%	5.8%	3.5%	2.9%	5.0%	8.8%	9.7%	13.7%	24.8%	12.1%

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

WindPro incorporates terrain elevation contour information and the analysis accounts for terrain elevation differences. The model does not consider vegetation, which may block or filter wind turbine shadows in the vicinity of potential receptors, resulting in a conservative worst-case set of shadow modeling results. The sun's path with respect to each turbine location is calculated by the software to determine the shadow paths cast every minute over a full year. Sun angles less than 3 degrees above the horizon and periods where the wind turbine rotor masks less than 20 percent of the solar disk were excluded, for the reasons identified in Section 26.1.

A total of 13 receptors were located by land surveyors within approximately one mile of the proposed turbine locations. A receptor in the model is defined as a 1 meter square (m^2) area (approximate size of a typical window) and 1 meter (3.28 feet) aboveground level. Average approximate eye level is set at 1.5 meters (5 feet). Figure 26-1 shows the sensitive receptor locations considered.

26.3 WindPro Shadow Flicker Analysis Results

WindPro predicts that shadow flicker impacts will primarily occur near the wind turbines. Figure 26-2 shows the WindPro-predicted expected shadow flicker impact areas. A detailed WindPro shadow flicker analysis results summary for each of the modeling receptor locations is provided in Table 26-1. Only 2 of the 13 receptors modeled had expected shadow flicker impacts predicted for more than 20 hours per year.

Table 26-1. WindPro Shadow Flicker Analysis Results Summary

WindPro Receptor ID	Latitude (Deg, Min', Sec") N	Longitude (Deg, Min', Sec") W	WindPro Expected Shadow Flicker (Hours:Minutes per Year)	Approximate Distance To Closest Turbine (feet)
1	44°29'35.28"	-70°18'04.80"	0:00	5316
2	44°30'10.87"	-70°17'56.91"	0:00	2040
3	44°30'12.60"	-70°17'36.25"	3:21	3050
4	44°30'45.07"	-70°17'32.90"	23:09	2899
5	44°30'42.92"	-70°17'33.43"	15:40	2930
6	44°32'13.94"	-70°18'13.56"	0:00	5986
7	44°31'51.19"	-70°18'47.54"	0:00	4860
8	44°32'05.13"	-70°17'30.82"	0:00	5554
9	44°31'09.08"	-70°17'21.02"	23:18	3100
10	44°31'02.81"	-70°17'06.37"	13:22	4259
11	44°31'16.66"	-70°17'10.53"	8:47	3797
12	44°31'06.12"	-70°17'09.84"	11:28	3958
13	44°31'48.77"	-70°18'33.94"	0:00	4064

The maximum predicted shadow flicker impact at any receptor is 23 hours, 18 minutes per year, which is only approximately 0.5 percent of the potential available annual daylight hours. Nearly half of the receptors are predicted to have no shadow flicker impact at all. The shadow flicker impact prediction statistics are as summarized in Table 26-2.

Table 26-2. Statistical Summary of WindPro Expected Shadow Flicker Impacts at Modeled Sensitive Receptor Locations

Cumulative Shadow Flicker Time (expected)	Number of Receptors
Total	13
= 0 Hours	6
> 0 Hours < 10 hours	2
≥ 10 Hours < 20 hours	3
≥ 20 Hours < 30 hours	2

26.4 Conclusion

The analysis of potential shadow flicker impacts from the Project on nearby houses (receptors) shows that shadow flicker impacts within the area of study are expected to be minor. The analysis conservatively assumes that all houses have a direct in-line view of the incoming shadow flicker sunlight and does not account for trees or other structures that may block sunlight. In reality, the windows of many houses will not face the sun directly during the shadow flicker impact times. For these reasons, shadow flicker impacts are expected to be less than estimated by this conservative analysis. Furthermore, the shadow flicker impacts for affected residences beyond 1,000 meters (3,281 feet) from turbines will be low intensity, and impacts to affected residences beyond 2,000 meters (6,562 feet) will be of negligible intensity.

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FIGURE 26-1
SENSITIVE RECEPTORS MODELED WITH WINDPRO TO PREDICT EXPECTED SHADOW FLICKER IMPACTS

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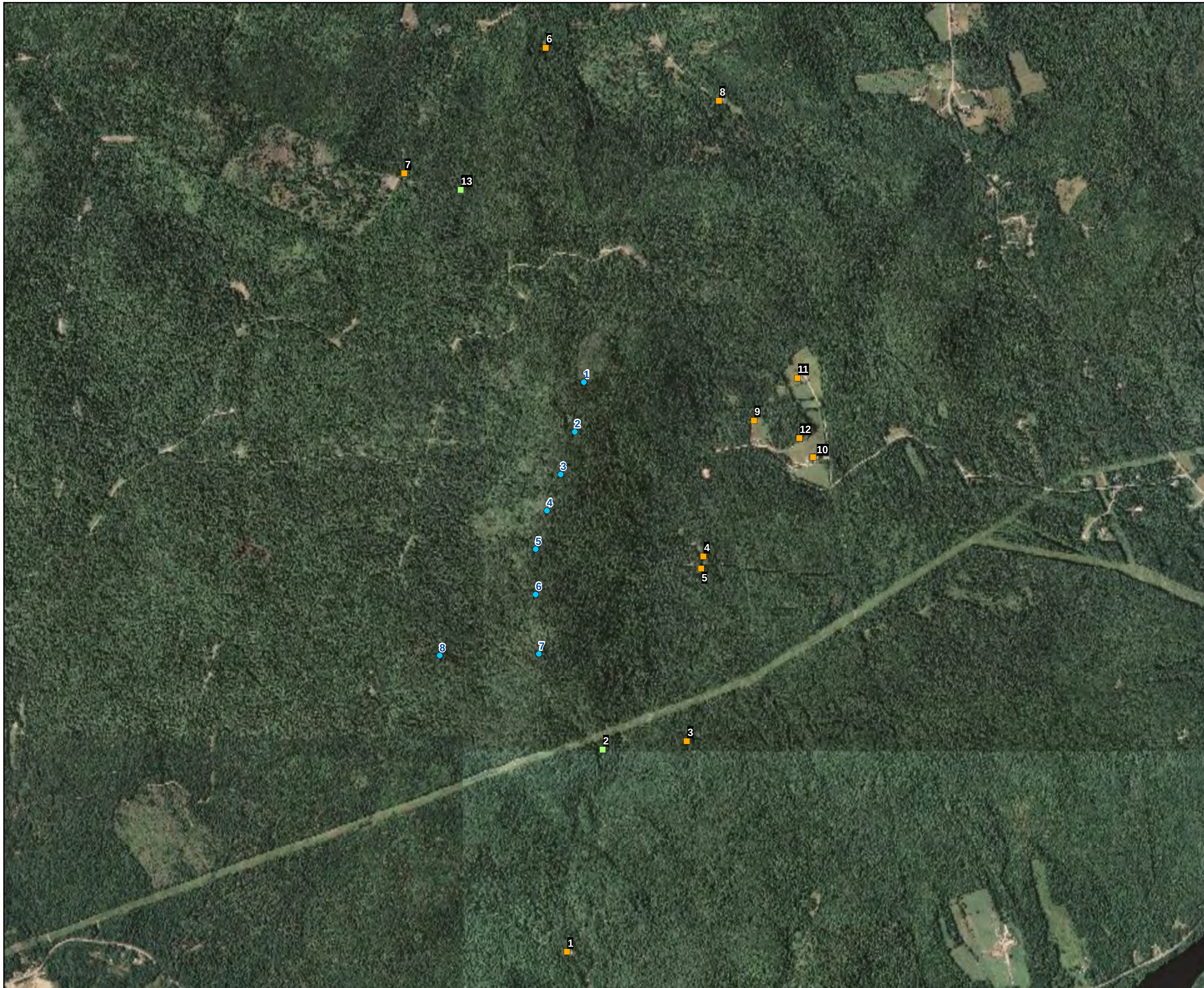
TETRA TECH EC, INC.



Legend

- Wind Turbine Location (GE 2.75)

Receptor (12/05/2011)

- Participating Receptor (12/05/2011)
- Receptor (12/05/2011)

N
W E
S

0 0.25 0.5 Miles

REFERENCE MAP

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FIGURE 26-2
WINDPRO EXPECTED SHADOW FLICKER IMPACT AREAS

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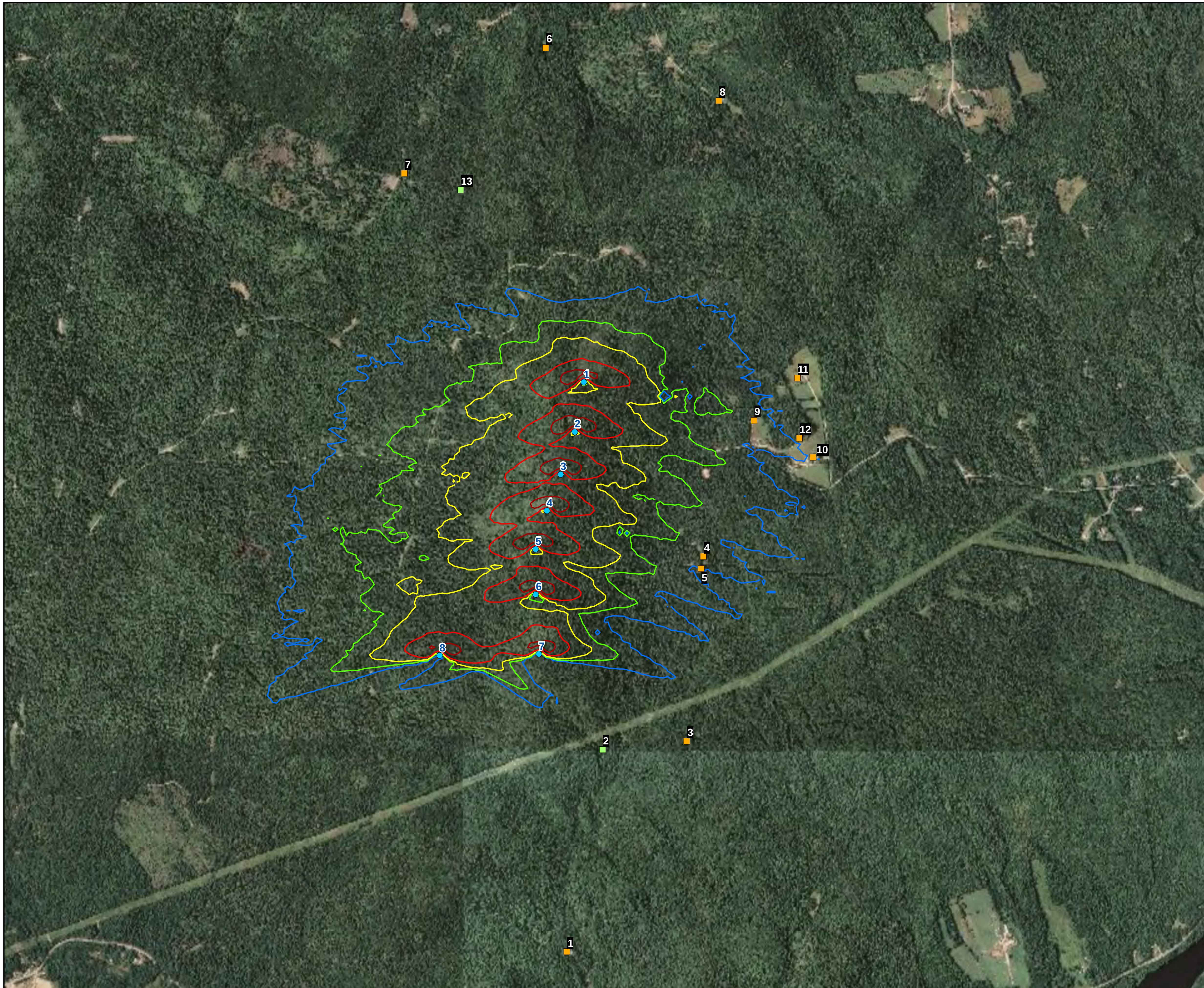
TETRA TECH EC, INC.



Legend

- Wind Turbine Location (GE 2.75)

Receptor (12/05/2011)

- Participating Receptor (12/05/2011)
- Receptor (12/05/2011)

Shadow Flicker Iso Line

- 15 hrs/yr
- 30 hrs/yr
- 50 hrs/yr
- 75 hrs/yr
- 100 hrs/yr
- 200 hrs/yr

N
W E
S

0 0.25 0.5 Miles

REFERENCE MAP