SARATOGA ASSOCIATES

Landscape Architects, Architects,
Engineers, and Planners, P.C.

June 23, 2014

Mr. Pip Decker
BMR Energy LLC
1359 Broadway, Suite 802
New York, NY 10018

Re: Technical Memorandum – Munro Wind Farm Expansion Project Shadow-Flicker

Dear Mr. Decker:

As requested, Saratoga Associates Landscape Architects, Architects, Engineers, and Planners, P.C. has completed an initial shadow-flicker evaluation of the proposed Munro Wind Farm Expansion Project. The project, located in St. Elizabeth Parish, Jamaica, consists of 11 turbines along a ridgeline.

This memorandum has been developed in order to provide BMR Energy LLC (BMR Energy) with information as to the affect the project may have on the surrounding landscape.

## Background

For the purpose of this memorandum, shadow flicker shall be defined as:

> *Rotating blades of wind turbines will result in shadows moving across nearby structures and the surrounding landscape. When the repeating change of light intensity falls across a narrow opening, such as a window, it can cause a flicker effect within the structure (hereafter referred to as "receptors"), as the shadow appears to flick on and off. This effect is known as shadow-flicker and only occurs within a structure.* [1]

Shadow flicker may cause a disturbance within structures when the repeating pattern of light intensity change falls across the windows or doors of buildings. This effect is most conspicuous when windows face a rotating wind turbine and when the sun is low in the sky (e.g. shortly after sunrise or shortly before sunset). Shadow flicker only occurs under certain specific conditions and its intensity varies depending on factors such as:

[1] *Onshore Wind Energy Planning Conditions Guidance Note – A Report for the Renewables Advisory Board and BERR (October 2007).*

- The turbine blades are rotating during daylight hours (sunrise to sunset), as shadow flicker will not occur at night. Also, shadow flicker will not occur when the turbine is not in operation.
- The sun is low in the sky (e.g. shortly after sunrise or shortly before sunset) so that the shadows are cast.
- Shadow flicker will not occur on foggy or overcast days when daylight is not sufficiently bright to cast shadows.
- A receptor is within ten rotor diameters of the turbine. Evidence from operational turbines suggests that the intensity of shadow flicker is only an issue at short distances. Beyond ten rotor diameters, a person should not perceive a wind turbine to be chopping through sunlight, but rather as an object with the sun behind it. It is generally accepted that shadow flicker will have a minimal to unperceivable affect on properties at a distance greater than ten turbine rotor diameters[2] from the turbine.
- Turbine shadows can enter a structure only through unshaded windows that face the turbine.

Although shadow flicker is only considered inside structures, it should be noted that shadows outside of the structure might be apparent. These shadows are not considered a nuisance since outdoor ambient lighting is typically higher and the shadows rarely contribute to significant changes in light intensity.

Because of constantly changing solar aspect and azimuth, shadows will be cast on specific days of the year and may pass a stationary receptor relatively quickly. Shadow flicker will not be an everyday event or be of extended duration when it does occur. Additionally, shadow flicker is most likely to occur during early morning or late afternoon hours, thus specific dwellings may experience shadow flicker, but the occupants of the receptor may either be inactive or absent. For example, residential dwellings located to the west of a turbine, will fall within the shadow zone shortly after sunrise when affected residents are typically asleep with shades drawn. Dwellings located to the east of a turbine will fall within the shadow zone shortly before sunset. In this case, locations such as schools are likely to be unoccupied during this time.

The distance between a wind turbine and a receptor directly affects the intensity of the shadows cast by the blades, and therefore the intensity of flickering. Shadows cast close to a turbine (e.g. 250 meters from the turbine) will be more intense, distinct and "focused" compared to the same shadow further away (e.g. 1,120 meters from the turbine). This is because a greater proportion of the sun's disc is intermittently blocked. Similarly, flickering is more intense if created by the area of a blade closer to the rotor and

[2] *Planning for Renewable Energy - A Companion Guide to PPS22 Queen's Printer and Controller of Her Majesty's Stationery Office 2004.*

further from the tip. Beyond ten turbine diameters the intensity of the blade shadow is considered negligible and at such a distance there will be virtually no, or limited, distinct chopping of the sunlight.

## Analysis of the Zone of Influence

An analysis was conducted for the surrounding landscape within 1,120m around each proposed wind turbine location. The information presented in Figures 1 through 3 was developed using *WindPRO Basis* software (WindPro) and associated shadow module. This is a widely accepted modeling software package developed specifically for the design and evaluation of wind power projects.

## Data Input and Assumptions

In order to develop this information, variables and assumptions were required. These include:

- Terrain – Publicly available terrain information was used to create a digital elevation model (DEM).
- Latitude and Longitude – WindPro considers the azimuth and altitude of the sun in relation to the proposed turbine. For this analysis, the Project coordinates were specified by using Universal Transverse Mercator coordinate system (UTM) North American Datum (NAD) 83 Zone 18 (reflecting the appropriate zone for this region).
- Turbine Dimensions and Blade Rotation Speed – For the purpose of this analysis, the turbines were modeled using the dimensions of a Vestas V112 with a hub height of 84 meters and rotor diameter of 112 meters.
- Sun Coverage – Shadow-flicker will occur when more than 20 percent of the sun is blocked by the turbine blade. Less than 20 percent will not result in a noticeable shadow.
- Sun Angle – The angle of the sun over the horizon will be at least three degrees. A lower angle will result in the light passing through atmosphere becoming too diffused to form a coherent shadow.[3]
- Sunshine probabilities (average sunlight hours per day) – The WindPro model calculated shadow frequency based on average hours of sunshine per month. Since this is based on an average amount, it should be expected that there might be a possibility of more or less sunshine per day and month. The following hours of sunlight were used based on publicly available information for Kingston.

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8:30 | 8:38 | 8:48 | 8:54 | 8:11 | 7:54 | 8:25 | 8:11 | 7:24 | 7:29 | 8:06 | 8:05 |

[3] WindPro (EMD International A/S).

- Screening from Vegetation and Structures – Results from WindPro assumes that the area lacks vegetation and structures. This assumption is considered conservative, as shadows should not occur in areas where the turbine is substantially screened by vegetation and/or structures.[4]

- Operational Time/Rotor Orientation – The WindPro model was given the number of hours per year that the turbine might be operating for every wind direction identified below. The total hours in the table below are 8,760 hours/year, or 100% of the hours in one calendar year. Moreover, the orientation of the rotor (determined by wind direction) affects the size of a shadow cast area. To more accurately calculate the amount of time a shadow will be over a specific location (based on rotor orientation), the WindPro model considers typical wind direction. These hours, provided by BMR Energy, are used to determine average annual shadow hours for the year.

| N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 650 | 1,737 | 2,656 | 1,454 | 286 | 149 | 138 | 127 | 275 | 299 | 186 | 106 | 120 | 100 | 129 | 348 |

Using the variables identified above, WindPro calculated the number of hours per year the shadow of a rotor would theoretically fall at any given location within the 1,120-meter radius of each turbine.

## Summary

Based on the output from WindPro, as presented in Figures 1 through 3, and the apparent limited number of residential dwellings within the study area, it appears that the project should operate without significant issues from shadow flicker.

While there may be residential dwellings scattered throughout the study area. A few locations to highlight include:

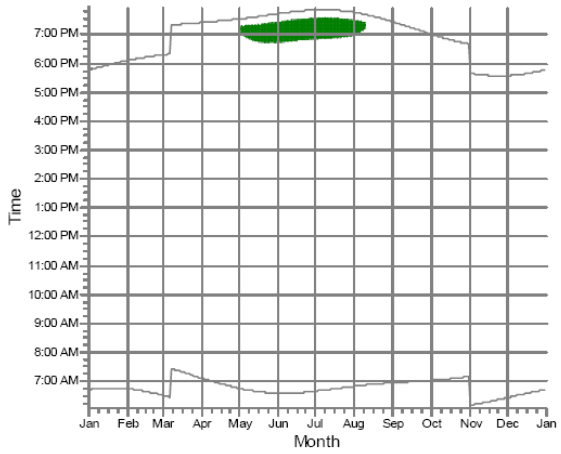
1. There is a potential for shadow flicker to affect dwellings located east of turbines 9-11 (most would have a maximum average of 30 hours of shadow flicker per year);
2. A greater number of dwellings located east of the turbines may experience shadow flicker for less than 20 hours per year, on average;
3. There appears to be few(er) dwellings located west of the turbines; and
4. Majority of the Munro Preparatory School building may experience, on average, between 10 and 20 hours of shadow flicker per year. It will be dependent on which side of the building is calculated, as the potential for a higher amount of shadow flicker will occur at the northern end of the building versus the southern end.

[4] It is important to note that the closer the vegetation is to the receptor the higher probability it will screen potential shadow flicker.

For the purpose of this memorandum, a single point within the outline of the building was further evaluated. The selected location appears to be generally at the middle of the building. Utilizing WindPro this location would, based on a "real case" scenario (i.e. includes the data and assumptions identified above), receive a potential 15 hours and 52 minutes of flicker from turbine 8. Shadow flicker is expected to occur during:

a. Early May through the end of May from 6:42 PM through 7:23 PM;
b. The month of June from 6:43 PM through 7:31 PM;
c. The month of July from 6:49 PM through 7:32 PM; and
d. The beginning of August through early August from 6:58 PM through 7:27 PM.

The graph below illustrates the timeframe in which there is a potential for shadow flicker from turbine 8 at the selected location.




Based on these timeframes, it does not appear that shadow flicker will occur during normal school hours.[5]

Generally, the potential for shadow flicker on dwellings located east of the turbines will occur during the late afternoon or evening hours. The analysis does not take into affect the screening potential of site vegetation, some of which may be seen on Figure PL-1 (photos provided by BMR Energy).

There are no guidelines that establish an acceptable degree of shadow flicker impact or suggested mitigation strategies. However, many European countries have identified 30 hours of shadow-flicker as

[5] It is anticipated that school is in session from late August through June, closing at 4:00 PM, and for three weeks during the month of July, closing at 1:00 PM.

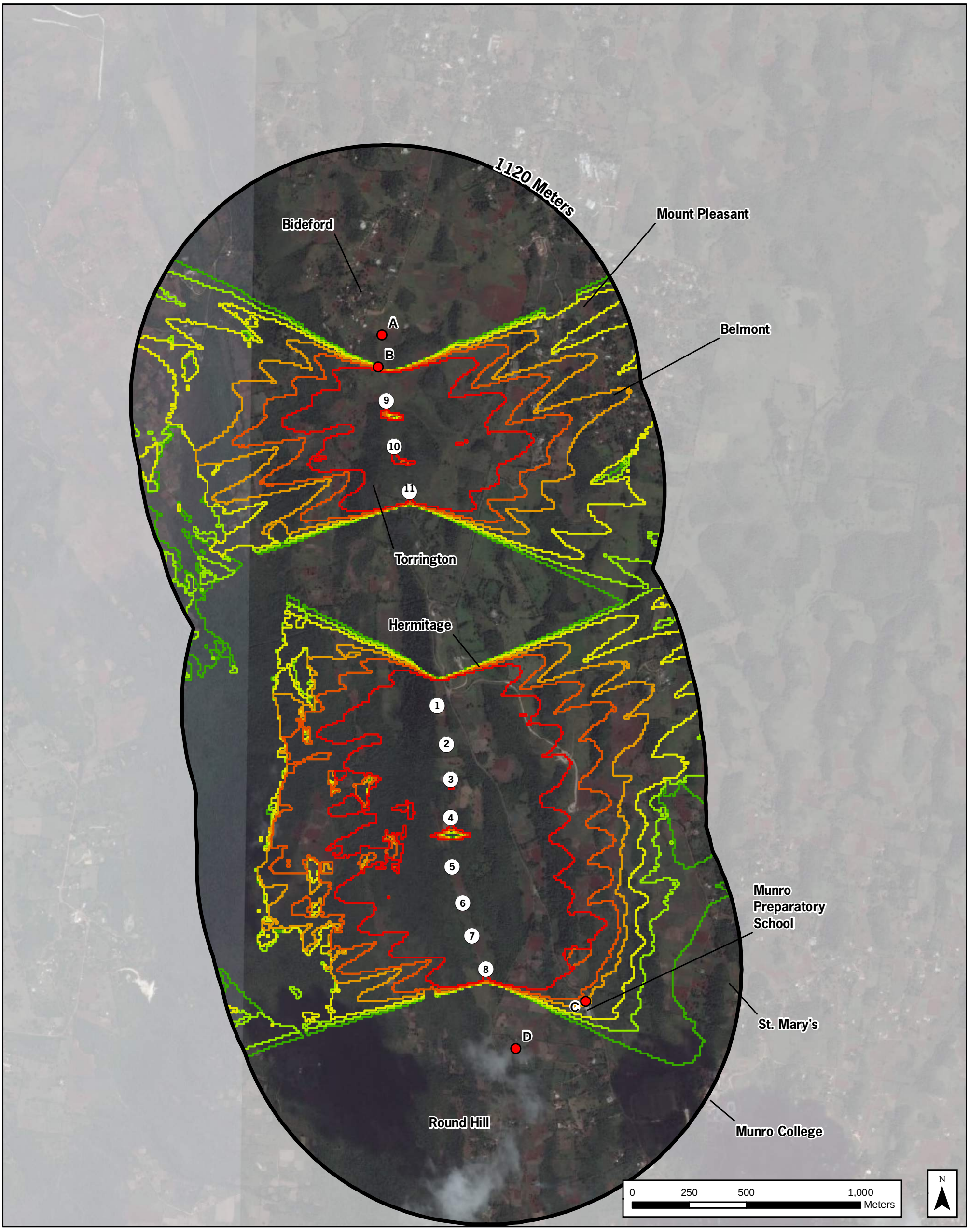
an allowable threshold; anything above this would be considered a nuisance and require mitigation. Using this threshold, it appears that there may be no dwellings that break this threshold.

As discussed above, shadow flicker will not be an everyday event or be of extended duration when it does occur. Shadow flicker is most likely to occur during early morning or late afternoon hours, thus specific dwellings may experience shadow flicker, but the occupants of the dwelling may either be inactive or absent. For those where shadow flicker hours are predicted to be greatest, the shadows might be considered an annoyance by some, and unnoticed by others. Should an issue arise, a potential mitigation solution should be evaluated on a case-by-case basis, and may include the use of strategically placed vegetation.

Should you have any questions, kindly contact me at your earliest convenience.

Very truly yours,
SARATOGA ASSOCIATES
Landscape Architects, Architects, Engineers, and Planners, P.C.

John Guariglia, RLA




# MUNRO WIND FARM EXPANSION PROJECT

Figure 1 - Topographical Shadow-Flicker Analysis

DRAFT - May 2014

**KEY**

(11) Proposed Turbine

Photo Location

Shadow Hours Per Year

- 0
- 0 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- Greater than 50



This map is computer generated using data acquired by Saratoga Associates from various sources and is intended only for reference, conceptual planning and presentation purposes. This map is not intended for and should not be used to establish boundaries, property lines, location of objects or to provide any other information typically needed for construction or any other purpose when engineered plans or land surveys are required.

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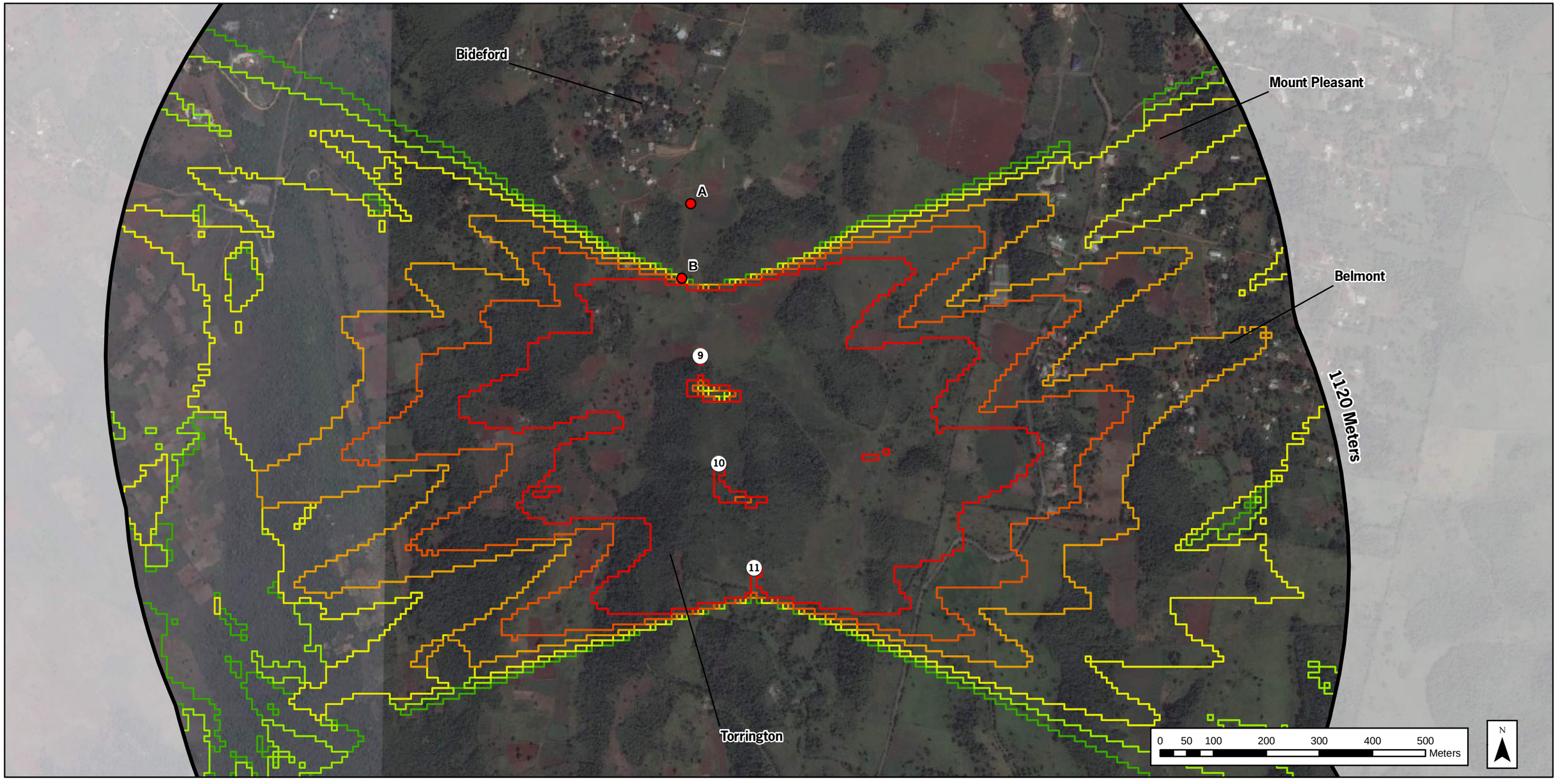
BLUE MOUNTAIN RENEWABLES




# MUNRO WIND FARM EXPANSION PROJECT

Figure 2 - Topographical Shadow-Flicker Analysis - North

DRAFT - May 2014

**KEY**

(11) Proposed Turbine

Photo Location

Shadow Hours Per Year

- 0
- 0 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- Greater than 50

PROJECT # 2014-006.10



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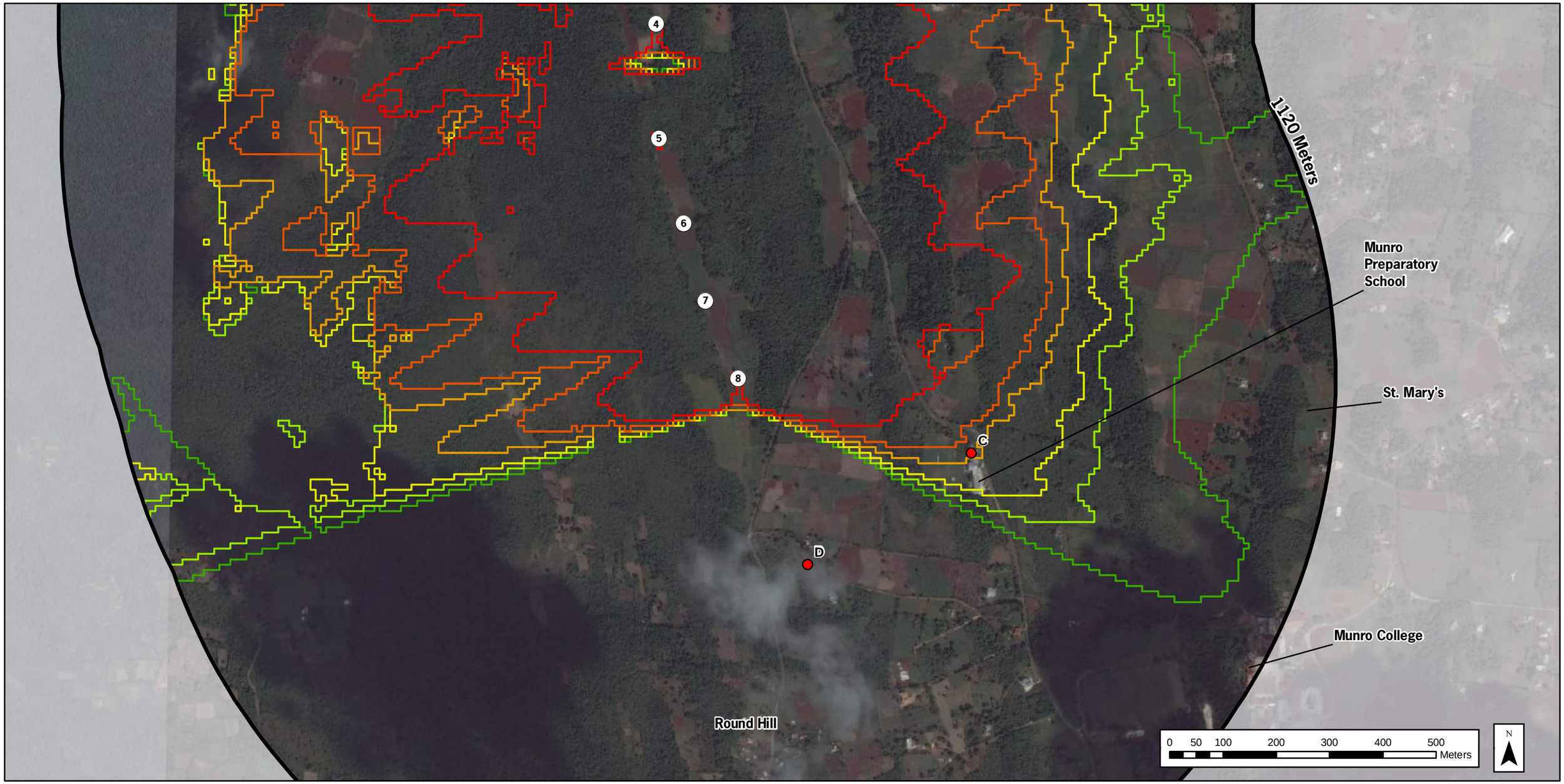


# MUNRO WIND FARM EXPANSION PROJECT

Figure 3 - Topographical Shadow-Flicker Analysis - South

DRAFT - May 2014

**KEY**

(11) Proposed Turbine

Photo Location

Shadow Hours Per Year

- 0
- 0 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- Greater than 50

PROJECT # 2014-006.10



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BLUE MOUNTAIN RENEWABLES

Photo Location A

View Orientation:
West-Southwest

Photo Location B

View Orientation:
Southwest

Photo Location C

View Orientation:
Northwest

Photo Location D

View Orientation:
Northwest

FIGURE PL-1

Charachter Photographs

St. Elizabeth Parish, Jamaica

Note: Photographs and site data provided by Blue Mountain Renewables.