REPORT

Buffalo Atlee Wind Farm 4 Shadow Flicker Assessment

Buffalo Atlee 4 Wind LP

Submitted to:

Buffalo Atlee 4 Wind LP

155 Wellington Street West, Suite 2930
Toronto, Ontario
M5V 3H1

Submitted by:

Golder Associates Ltd.

2800, 700 - 2nd Street SW, Calgary, Alberta, T2P 2W2, Canada

+1 403 299 5600

21451207-2000

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Distribution List

1 electronic copy - Buffalo Atlee 4 Wind LP

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1.0 INTRODUCTION

Buffalo Atlee 4 Wind LP is developing the Buffalo Atlee Wind Farm 4 (the Project) east of the Hamlet of Jenner, Alberta, in Special Areas No. 2. The Project will consist of two Siemens Gamesa SG 4.5-145 wind turbines. The total installed nominal generating capacity of the Project will be 10 megawatts (MW).

Buffalo Atlee 4 Wind LP retained Golder Associates Ltd. (Golder) to assess shadow flicker resulting from the Project wind turbines. The results of the Project shadow flicker assessment are summarized in this report.

This report is structured as follows:

- Section 1 provides a brief introduction
- Section 2 presents a description of the Project wind turbines
- Section 3 outlines the assessment approach, including a description of:
  - assessment cases
  - shadow flicker receptors
  - assessment criteria
  - shadow flicker modelling methods
- Section 4 presents and discusses the results for each assessment case
- Section 5 provides a brief conclusion

2.0 PROJECT DESCRIPTION

The Project will consist of two Siemens Gamesa SG 4.5-145 wind turbines. The Project wind turbines will consist of three-blade rotors and tubular towers that will operate at a hub height of 102.5 m and a rotor diameter of 145 m, totalling 175 m above ground level.

Table 1 presents the location of Project wind turbines. A map showing the locations of Project wind turbines is presented in Section 3.2 of this report (see Figure 1).

Table 1: Project Wind Turbines

Turbine Identification Code	Universal Transverse Mercator Coordinates [Zone 12]	
	Easting [m]	Northing [m]
BA4_T1	490974	5620992
BA4_T2	491498	5619715

3.0 ASSESSMENT APPROACH

3.1 Assessment Cases

Shadow flicker occurs when the spinning rotor of a wind turbine is located between the sun and a receptor point (e.g., an occupied dwelling). As the turbine blades alternately block sunlight and allow sunlight to shine through, the shadow at the receptor point may be observed to flicker under certain environmental conditions. For shadow flicker to occur, the sun must be shining, the sun must be low enough in the sky that the shadow of the wind turbine falls across the receptor point, the wind turbine must be active (i.e., the rotor must be spinning), and the turbine rotor must be oriented such that the blades are not parallel to the line joining the sun and receptor point. The shadow flicker assessment for the Project considered two assessment cases representing two different sets of environmental conditions.

“Worst Case” assumes that the sun is always shining during daylight hours (i.e., there are no cloudy periods), all Project wind turbines are always active (i.e., rotors spinning), and all Project wind turbines are always oriented with their rotors perpendicular to the line joining the sun and all receptor points. “Worst Case” is highly conservative (i.e., likely to overestimate potential shadow flicker effects) because the sun is not always shining, and Project wind turbines are not always active. In addition, the orientation of Project wind turbines will change continuously based on wind direction, so turbine rotors are not always oriented perpendicular to the line joining the sun and receptor points.

“Expected Case” makes use of statistical weather data to reduce some of the conservatism inherent in the “Worst Case” assessment. In particular, “Expected Case” uses statistical weather data to estimate the probability of sunshine for each month of the year. In addition, “Expected Case” uses statistical weather data to estimate the probability of different wind directions, and hence turbine orientations. Even with the use of statistical weather data, “Expected Case” is still a conservative evaluation of potential shadow flicker effects because it assumes that Project wind turbines are always active (i.e., turbine rotors are always spinning), which is not the case.

For each assessment case, shadow flicker was predicted for the Project in isolation. To evaluate the potential for cumulative effects, each assessment case also predicted shadow flicker for the Project in combination with any non-Project wind turbines located within 2 km of a Project wind turbine. The only non-Project wind turbine located within 2 km of a Project wind turbine is turbine #1 from the Buffalo Atlee Wind Farm 2, which is being proposed for development by Buffalo Atlee 2 Wind LP in the area south of the Project (Golder 2020). This non-Project turbine, which will hereafter be referred to as BA2_T1, is located approximately 1.5 km south of Project turbine BA4_T2.

A map showing the location of BA2_T1 is presented in Section 3.2 of this report (see Figure 1). A regulatory application for Buffalo Atlee Wind Farm 2 is currently moving through the Alberta Utilities Commission’s review process (Proceeding No. 25100).

3.2 Receptors

The Project shadow flicker assessment considered potential effects at receptors corresponding to occupied dwellings located within a 2 km buffer around the Project wind turbines. There is only one such dwelling, hereafter referred to as receptor RA.

When assessing potential shadow flicker effects, receptor RA was assumed to be sensitive to shadow flicker in any direction. In other words, receptor RA was assumed to have windows facing in all directions. This approach is often referred to as greenhouse mode modelling. Greenhouse mode modelling is conservative, since the receptor may not actually have windows facing in all directions. In addition, trees, outbuildings, and other local structures can screen shadow flicker effects. These local shadow screens were not considered when modelling receptor RA, which adds further conservatism to the shadow flicker assessment.

Table 2 presents the location of shadow flicker receptor RA. Table 2 also identifies and provides the distance to the closest Project wind turbine. Figure 1 presents a map showing the locations the Project wind turbines and shadow flicker receptor RA. Figure 1 also shows the location of the turbine BA2_T1, which is the only non-Project wind turbine located within 2 km of a Project wind turbine.

Table 2: Shadow Flicker Receptors

Receptor Identification Code	Universal Transverse Mercator Coordinates [NAD83, Zone 12]		Receptor Description	Closest Project Wind Turbine	Distance to Closest Project Wind Turbine [m]
	Easting [m]	Northing [m]			
RA[(a)]	490484	5619719	occupied dwelling	BA4_T2	1,014

(a) This receptor was identified as “R2” in the shadow flicker assessment prepared for Buffalo Atlee Wind Farm 2 (Golder 2020).

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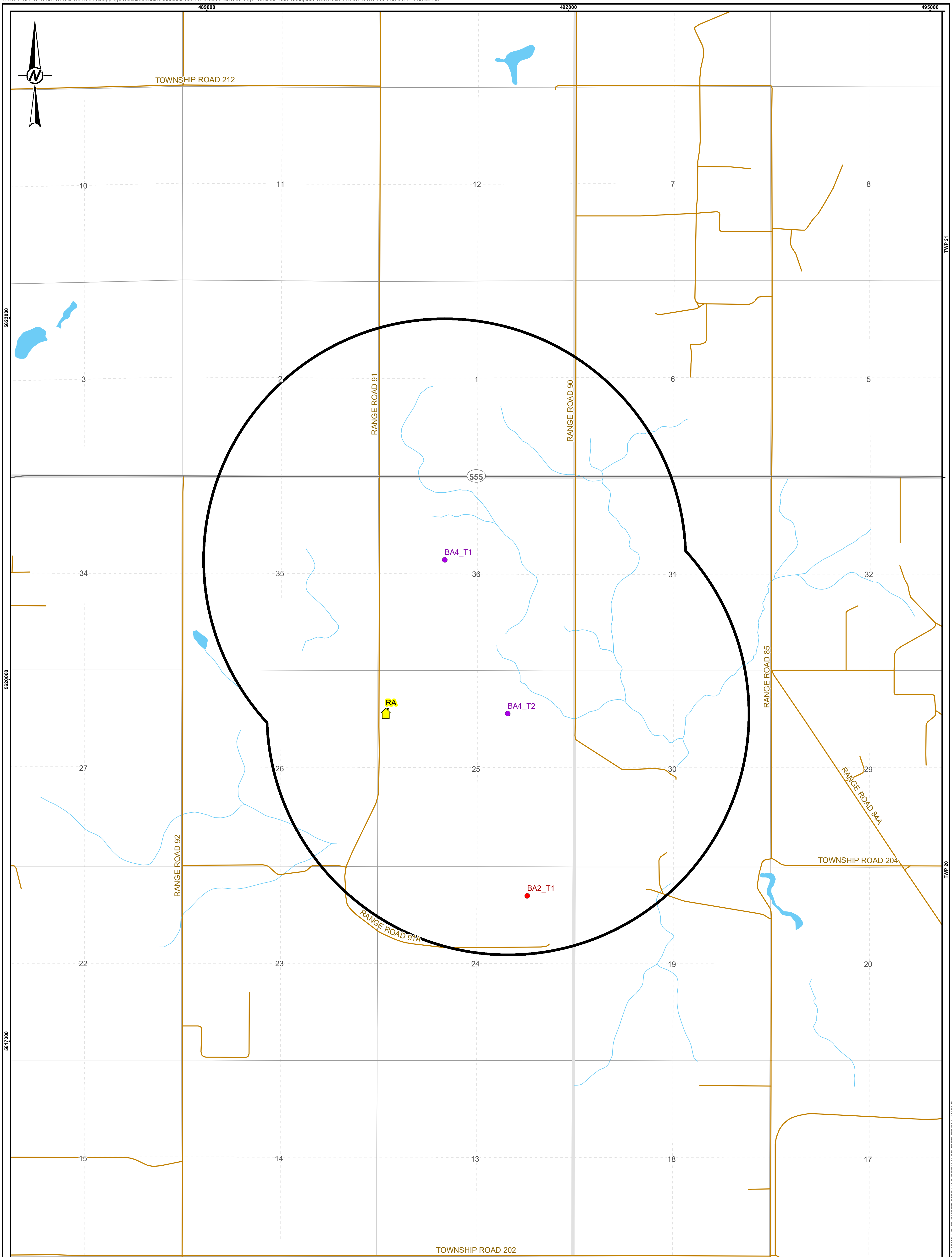

LEGEND

- BUFFALO ATLEE 2 WIND TURBINE
- DWELLING RECEPTOR
- PROJECT WIND TURBINE
- SECONDARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- SHADOW FLICKER STUDY AREA
- WATERBODY

0 600 1,200

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REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
CAPSTONE

PROJECT
BUFFALO ATLEE

TITLE
WIND TURBINES AND RECEPTORS

CONSULTANT

GOLDER

YYYY-MM-DD	2021-03-09
DESIGNED	VY
PREPARED	PS
REVIEWED	VY
APPROVED	AF

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3.3 Assessment Criteria

There are no federal or provincial guidelines or regulations that specify limits or criteria for assessing shadow flicker effects for facilities in Alberta or elsewhere in Canada. In the absence of federal or provincial guidance, the Project shadow flicker assessment compared the predicted shadow flicker from the Project to widely used guidelines (Koppen et al. 2017; LUNG 2017), which recommend that exposure to shadow flicker be limited to a maximum of 30 hours per year and a maximum of 30 minutes per day.

3.4 Modelling Methods

Shadow flicker effects were modelled using WindPro v2.7, a commercial software tool developed and distributed by EMD International A/S. Separate WindPro models were created for the "Worst Case" and the "Expected Case".

Inputs to the WindPro models for both assessment cases included location, hub height, and rotor diameter for the Project and BA2_T1 wind turbines, location of shadow flicker receptor RA, and terrain elevation contours at 5 m intervals. Additional inputs to the WindPro model for the "Expected Case" included statistical data about monthly sunshine and long-term wind direction in the Project study area.

Table 3 presents the statistical sunshine data used in the WindPro model for the "Expected Case". This statistical sunshine data was obtained from a meteorological station located in Suffield, Alberta, which is approximately 50 km south-southwest of the Project. Table 4 presents statistical wind direction data used in the WindPro model for the "Expected Case". This statistical wind direction data is based on extrapolated, long-term adjusted data from the Project meteorological tower.

Table 3: Statistical Sunshine Data Used to Model the "Expected Case"

Month	Average Daily Sunshine Hours
January	3.34
February	4.39
March	5.56
April	7.26
May	8.85
June	9.92
July	10.59
August	9.78
September	6.62
October	5.84
November	4.03
December	2.92

Table 4: Statistical Wind Direction Data Used to Model the "Expected Case"

Wind Direction (degrees relative to North)	Hours Per Year
0 – North	447
30	429
60	499
90 – East	701
120	701
150	701
180 – South	832
210	929
240	867
270 – West	876
300	946
330	832
Total	**8,760**

The WindPro models predicted shadow flicker effects at receptor RA based on the daily and yearly path of the sun through the sky at the Project latitude. In the “Worst Case”, the WindPro model assumed that the sun was always shining, the wind turbines were always active, and the turbine rotors were always oriented perpendicular to the line joining the sun and receptor RA. In the “Expected Case”, the WindPro model adjusted the predictions to account for statistical monthly sunshine data and to account for turbine orientation based on statistical wind direction data. In both the “Worst Case” and the “Expected Case”, receptor RA was modelled in greenhouse mode (i.e., sensitive to shadow flicker in every direction). Modelling for both the “Worst Case” and the “Expected Case” considered screening by terrain features (e.g., hills and valleys), but neither assessment case considered screening effects from trees, outbuildings, or other local structures.

4.0 RESULTS

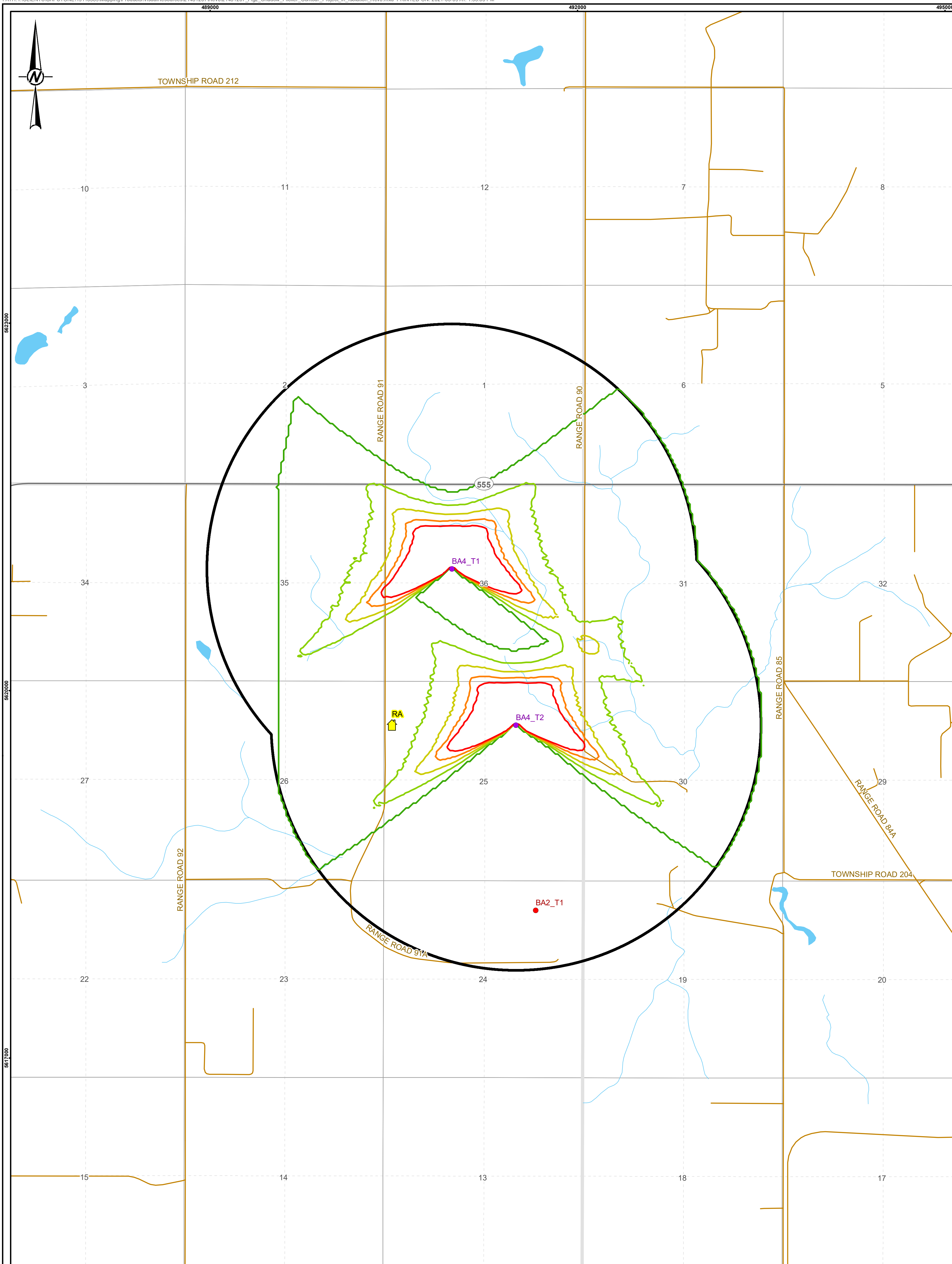
For the Project wind turbines in isolation, Table 5 presents shadow flicker modelling results for the “Worst Case” and the “Expected Case”. Table 6 presents similar information for the two Project wind turbines in combination with turbine BA2_T1. For the “Worst Case”, both tables present results in the form of total hours of shadow flicker per year, number of days per year with shadow flicker, and maximum minutes of shadow flicker on a single day. For the “Expected Case”, both tables present results in the form of total hours of shadow flicker per year. Note that daily results are not available for the “Expected Case” because the modelling algorithm is based on monthly sunshine statistics and long-term wind direction data. For the Project wind turbines in isolation, Figure 2 presents a contour map of modelling results in the form of total hours of shadow flicker per year for the “Expected Case”. Figure 3 presents a similar contour map for the two Project wind turbines in combination with turbine BA2_T1.

Table 5: Shadow Flicker Modelling Results – Project in Isolation

Receptor Identification Code	“Worst Case”			“Expected Case”
	Total Hours of Shadow Flicker Per Year	Number of Days Per Year with Shadow Flicker	Maximum Minutes of Shadow Flicker on a Single Day	Total Hours of Shadow Flicker Per Year
RA	15.2	42	33	5.2

Table 6: Shadow Flicker Modelling Results – Project in Combination with BA2_T1

Receptor Identification Code	“Worst Case”			“Expected Case”
	Total Hours of Shadow Flicker Per Year	Number of Days Per Year with Shadow Flicker	Maximum Minutes of Shadow Flicker on a Single Day	Total Hours of Shadow Flicker Per Year
RA	15.2	42	33	5.2



LEGEND

- BUFFALO ATLEE 2 WIND TURBINE
- DWELLING RECEPTOR
- PROJECT WIND TURBINE
- SHADOW FLICKER STUDY AREA
- SECONDARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY

SHADOW FLICKER [HOURS/YEAR]

- ~0
- 10
- 20
- 30
- 40

0 600 1,200

1:30,000 METRES

NOTE(S)

1. LOCATIONS OUTSIDE THE "~0" CONTOUR LINE WILL EXPERIENCE NO SHADOW FLICKER AS A RESULT OF THE PROJECT.

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
CAPSTONE

PROJECT
BUFFALO ATLEE

TITLE
SHADOW FLICKER CONTOUR MAP - PROJECT IN ISOLATION - STATISTICAL SUNSHINE AND WIND DIRECTION ("EXPECTED CASE")

CONSULTANT

GOLDER

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DESIGNED	VY
PREPARED	SK
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APPROVED	AF

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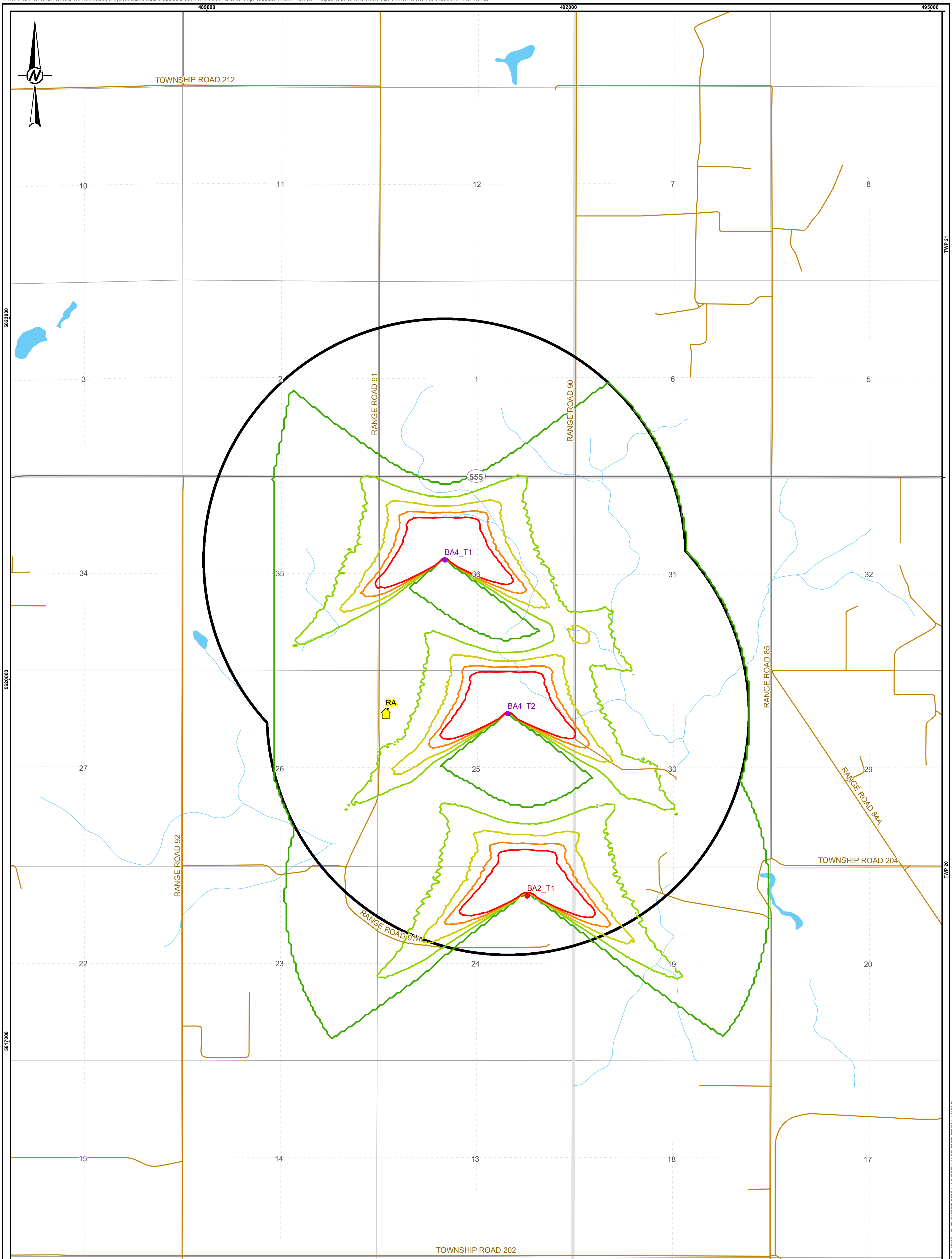

LEGEND

- BUFFALO ATLEE 2 WIND TURBINE
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- PROJECT WIND TURBINE
- SHADOW FLICKER STUDY AREA
- SECONDARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY

SHADOW FLICKER [HOURS/YEAR]

- ~0
- 10
- 20
- 30
- 40

0 600 1,200

1:30,000 METRES

NOTE(S)

1. LOCATIONS OUTSIDE OF THE ~0 CONTOUR WILL EXPERIENCE NO SHADOW FLICKER AS A RESULT OF THE PROJECT OR NON-PROJECT WIND TURBINES.

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
CAPSTONE

PROJECT
BUFFALO ATLEE

TITLE
SHADOW FLICKER MODELLING RESULTS - PROJECT IN COMBINATION WITH BA2_T1 - STATISTICAL SUNSHINE AND WIND DIRECTION ("EXPECTED CASE")

CONSULTANT

GOLDER

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In the “Worst Case”, which assumes the sun is always shining and turbines are always operating with rotors perpendicular to the line joining the sun and receptor RA, results presented in Table 5 suggest that receptor RA will experience less than 30 hours of shadow flicker per year but will experience a maximum shadow flicker duration greater than 30 minutes on a single day. In the “Expected Case”, which accounts for statistical sunshine and wind direction data, modelling predicts that receptor RA will experience 5.2 hours of shadow flicker per year.

The results presented in Table 6 indicate there will be no cumulative effects at receptor RA from shadow flicker associated with non-Project wind turbines. Specifically, turbine BA2_T1 from Buffalo Atlee 2 Wind Farm 2 will not produce any shadow flicker at receptor RA.

The modelling assumptions used in the “Worst Case” are unrealistic and highly conservative (i.e., tending to overestimate potential shadow flicker effects). The “Expected Case” predicts potential shadow flicker effects under more realistic, but still conservative, environmental conditions. The “Expected Case” makes use of statistical sunshine data (rather than assuming the sun is always shining) and statistical wind direction data (rather than assuming turbine rotors are always perpendicular to the line joining the sun and receptor RA). The “Expected Case” is still a conservative treatment of potential shadow flicker effects, however, since the “Expected Case” assumes the wind turbines are always active (i.e., rotors always spinning), assumes that receptor RA is sensitive to shadow flicker in all directions (i.e., greenhouse mode), and does not account for screening by trees, outbuildings, or other local structures.

5.0 CONCLUSION

A shadow flicker assessment was completed for Buffalo Atlee Wind Farm 4. The shadow flicker assessment evaluated two conservative modelling scenarios: “Worst Case” and “Expected Case”. The shadow flicker assessment considered potential effects at the only occupied dwelling located within 2 km of Project wind turbines: receptor RA.

The “Worst Case” assessment assumed the sun is always shining during daylight hours (i.e., there are no cloudy periods), wind turbines are always active (i.e., rotors spinning), and wind turbines are always oriented with their rotors perpendicular to the line joining the sun and receptor RA. The “Expected Case” assessment used statistical weather data to estimate the probability of sunshine for each month of the year and to estimate the probability of different wind directions, and hence turbine orientations. Both assessment cases assumed that receptor RA is sensitive to shadow flicker in any direction (i.e., greenhouse mode) and neither assessment case accounted for the screening of shadow flicker by vegetation, outbuildings, or other structures.

For both the “Worst Case” and “Expected Case”, receptor RA is predicted to experience some shadow flicker as a result of the Project. In the “Worst Case”, modelling predicts that shadow flicker at receptor RA will not exceed the 30 hours per year maximum recommended in widely used technical guidelines, but shadow flicker will exceed the 30 minutes per day maximum recommended in the same guidelines (Koppen et al. 2017; LUNG 2017). In the “Expected Case”, modelling predicts that receptor RA will experience 5.2 hours of shadow flicker per year. Actual shadow flicker experienced by RA is likely to be further reduced by the presence of outbuildings, which may provide partial screening for the Project turbines during those hours when the sun is low enough to create long shadows.

For both the “Worst Case” and “Expected Case”, there are predicted to be no cumulative shadow flicker effects arising from simultaneous operation of the Project and non-Project wind turbines. Specifically, the Project will result in shadow flicker at receptor RA but, as predicted in an earlier assessment (Golder 2020), turbine BA2_T1 will not result in shadow flicker at receptor RA.

In conclusion, the present assessment demonstrates there is minimal potential for shadow flicker effects from the Project. In particular, the assessment concludes that shadow flicker at receptor RA will be less than 30 hours per year.

Signature Page

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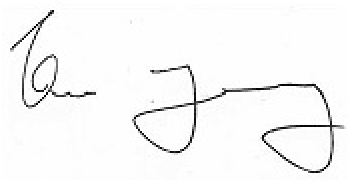

Victor Young, M.Sc.
Acoustic Scientist

Andrew Faszer, INCE, P.Eng.
Senior Engineer

VY/AF/rd

6.0 REFERENCES

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