REPORT

# Wild Rose 2 Wind Power Project

*Shadow Flicker Assessment*

Submitted to:

**Andrea Kausel**

Capstone Infrastructure Corporation
on behalf of Wild Rose 2 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

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# Distribution List

1 electronic copy - Wild Rose 2 Wind LP

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# Table of Contents



**TABLES**



**FIGURES**

# 1.0 INTRODUCTION

Wild Rose 2 Wind LP (Wild Rose 2) own the approved by not yet constructed Wild Rose 2 Wind Power Project (the Project), which will be located in Cypress County, Alberta, approximately 30 km southeast of Medicine Hat. The Alberta Utilities Commission (AUC) approved the Project in April 2017 (AUC 2017), and approved requests to extend the Project development schedule in October 2019 (AUC 2019) and November 2020 (AUC 2020).

The version of the Project approved by the AUC (the Approved Project) consists of 60 Siemens SWT 3.2-113 wind turbine generators, each with a nominal power rating of 3.2 MW, a collector system, and an electrical substation.

Wild Rose 2 is now proposing changes to the Approved Project design (the Updated Project). The Updated Project will consist of 38 Siemens Gamesa SG 5.0-145 wind turbine generators, each with a nominal power rating of 5.2 MW, a collector system, and an electrical substation.

Power generating facilities in Alberta are regulated by the AUC through Rule 007 (AUC 2022). The current version of Rule 007 requires preparation of a shadow flicker assessment for the Project. According to Rule 007, the shadow flicker assessment must: *"…predict the extent of shadow flicker at receptors [occupied dwellings] within 1.5 kilometres from the centre point of each turbine where the potential for shadow flicker is possible"* (AUC 2022).

Wild Rose 2 has retained Golder Associates Ltd. (WSP Golder) to prepare a shadow flicker assessment for the Updated Project, in accordance with Rule 007. Note that applications for the Approved Project were filed and approved before the AUC required shadow flicker assessments for wind power facilities. As such, a shadow flicker assessment was not prepared for the Approved Project.

The results of WSP Golder's shadow flicker assessment for the Updated Project are presented in this report. This report is structured as follows:

- Section 1 provides a brief introduction.
- Section 2 presents a description of the wind turbine generators proposed for the Updated Project.
- Section 3 outlines the assessment approach, including a description of:
  - assessment cases
  - shadow flicker receptors
  - assessment criteria
  - shadow flicker modelling methods
- Section 4 provides results for each assessment case.
- Section 5 discusses the results of the shadow flicker assessment.
- Section 6 provides a brief conclusion.

# 2.0 PROJECT DESCRIPTION

The Updated Project will consist of 38 Siemens Gamesa SG 5.0-145 wind turbine generators, along with a collector system and substation. The Updated Project wind turbines will consist of three-blade rotors and tubular towers. The Updated Project wind turbine generators will have a hub height of 95.5 m and a rotor diameter of 145 m.

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

**Table 1: Location of Updated Project Wind Turbine Generators**

| Turbine Identification Code | Description | Universal Transverse Mercator Coordinates (Zone 12) | |
|---|---|---|---|
| | | Easting (m) | Northing (m) |
| T01 | Siemens Gamesa SG 5.0-145 wind turbine | 527898 | 5519590 |
| T02 | Siemens Gamesa SG 5.0-145 wind turbine | 527999 | 5519088 |
| T03 | Siemens Gamesa SG 5.0-145 wind turbine | 528388 | 5518746 |
| T04 | Siemens Gamesa SG 5.0-145 wind turbine | 531181 | 5520834 |
| T05 | Siemens Gamesa SG 5.0-145 wind turbine | 531473 | 5520144 |
| T06 | Siemens Gamesa SG 5.0-145 wind turbine | 532100 | 5519290 |
| T07 | Siemens Gamesa SG 5.0-145 wind turbine | 532347 | 5518691 |
| T10 | Siemens Gamesa SG 5.0-145 wind turbine | 531124 | 5515547 |
| T11 | Siemens Gamesa SG 5.0-145 wind turbine | 531514 | 5515106 |
| T12 | Siemens Gamesa SG 5.0-145 wind turbine | 532098 | 5516799 |
| T13 | Siemens Gamesa SG 5.0-145 wind turbine | 532453 | 5516414 |
| T15 | Siemens Gamesa SG 5.0-145 wind turbine | 533515 | 5517273 |
| T16 | Siemens Gamesa SG 5.0-145 wind turbine | 533823 | 5516805 |
| T17 | Siemens Gamesa SG 5.0-145 wind turbine | 534395 | 5516406 |
| T18 | Siemens Gamesa SG 5.0-145 wind turbine | 534895 | 5516156 |
| T19 | Siemens Gamesa SG 5.0-145 wind turbine | 535509 | 5515879 |
| T20 | Siemens Gamesa SG 5.0-145 wind turbine | 534493 | 5517965 |
| T21 | Siemens Gamesa SG 5.0-145 wind turbine | 534912 | 5517550 |
| T22 | Siemens Gamesa SG 5.0-145 wind turbine | 535579 | 5517271 |
| T23 | Siemens Gamesa SG 5.0-145 wind turbine | 530509 | 5513883 |
| T24 | Siemens Gamesa SG 5.0-145 wind turbine | 536397 | 5515189 |
| T25 | Siemens Gamesa SG 5.0-145 wind turbine | 536467 | 5514687 |
| T26 | Siemens Gamesa SG 5.0-145 wind turbine | 536358 | 5513664 |
| T27 | Siemens Gamesa SG 5.0-145 wind turbine | 536613 | 5513254 |
| T28 | Siemens Gamesa SG 5.0-145 wind turbine | 537272 | 5513184 |
| T29 | Siemens Gamesa SG 5.0-145 wind turbine | 535550 | 5513017 |
| T30 | Siemens Gamesa SG 5.0-145 wind turbine | 536196 | 5512434 |
| T31 | Siemens Gamesa SG 5.0-145 wind turbine | 537348 | 5512185 |
| T32 | Siemens Gamesa SG 5.0-145 wind turbine | 535462 | 5512399 |
| T33 | Siemens Gamesa SG 5.0-145 wind turbine | 535408 | 5511832 |

**Table 1: Location of Updated Project Wind Turbine Generators**

| Turbine Identification Code | Description | Universal Transverse Mercator Coordinates (Zone 12) | |
|---|---|---|---|
| | | Easting (m) | Northing (m) |
| T34 | Siemens Gamesa SG 5.0-145 wind turbine | 530743 | 5513437 |
| T35 | Siemens Gamesa SG 5.0-145 wind turbine | 537076 | 5511170 |
| T36 | Siemens Gamesa SG 5.0-145 wind turbine | 537357 | 5510727 |
| T37 | Siemens Gamesa SG 5.0-145 wind turbine | 536874 | 5510003 |
| T38 | Siemens Gamesa SG 5.0-145 wind turbine | 537170 | 5509680 |
| A05 | Siemens Gamesa SG 5.0-145 wind turbine | 536428 | 5511942 |
| A07 | Siemens Gamesa SG 5.0-145 wind turbine | 533095 | 5517640 |
| A09 | Siemens Gamesa SG 5.0-145 wind turbine | 533671 | 5518360 |

# 3.0 ASSESSMENT APPROACH

## 3.1 Assessment Cases

Shadow flicker occurs when the spinning rotor of a wind turbine generator 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 generator falls across the receptor point, the wind turbine generator 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 Updated Project considered two assessment cases, representing two different sets of environmental conditions.

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

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

## 3.2 Receptors

Rule 007 requires that shadow flicker be predicted and assessed at receptors corresponding to occupied dwellings located within 1.5 km of the Updated Project wind turbine generators (AUC 2022). WSP Golder established a study area for the shadow flicker assessment as a 1.5 km buffer on the Updated Project wind turbine generators. All occupied dwellings within this study area were treated as shadow flicker receptors for the Updated Project.

Potential shadow flicker receptors were identified using publicly available satellite imagery, information presented in the noise impact assessment for the Approved Project (DNV-GL 2016), and information provided by Wild Rose 2. A total of 21 occupied dwellings were identified within the study area and treated as shadow flicker receptors for the Updated Project.

When assessing potential shadow flicker effects, each receptor was assumed to be sensitive to shadow flicker in any direction. In other words, each receptor was assumed to have windows facing in all directions. This approach is often called greenhouse mode modelling. Greenhouse mode modelling is conservative since receptors 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 flicker screens were not considered when modelling receptors, which adds further conservatism to the shadow flicker assessment.

Table 2 presents locations for the 21 receptors considered in the Updated Project shadow flicker assessment. For each receptor, Table 2 also identifies and provides the distance to the closest Updated Project wind turbine generator. Figure 1 presents a map showing the locations of the Updated Project wind turbine generators and the shadow flicker receptors.

**Table 2: Shadow Flicker Receptors**

| Receptor Identification Code[(a)] | Receptor Description | Universal Transverse Mercator Coordinates (Zone 12) | | Closest Updated Project Wind Turbine | Distance to Closest Updated Project Wind Turbine (m) |
|---|---|---|---|---|---|
| | | Easting (m) | Northing (m) | | |
| R01 | occupied dwelling | 531357 | 5522150 | T04 | 1,328 |
| R03 | occupied dwelling | 530032 | 5520760 | T04 | 1,151 |
| R04 | occupied dwelling | 530025 | 5520370 | T04 | 1,246 |
| R05 | occupied dwelling | 532473 | 5519970 | T06 | 776 |
| R07 | occupied dwelling | 529165 | 5519210 | T03 | 905 |
| R08 | occupied dwelling | 534431 | 5519140 | A09 | 1,089 |
| R09 | occupied dwelling | 533361 | 5519060 | A09 | 766 |
| R12 | occupied dwelling | 531072 | 5518040 | T07 | 1,432 |
| R13 | occupied dwelling | 531085 | 5518010 | T07 | 1,434 |
| R14 | occupied dwelling | 528246 | 5517920 | T03 | 838 |
| R17 | occupied dwelling | 527856 | 5517720 | T03 | 1,156 |
| R23 | occupied dwelling | 531251 | 5516250 | T10 | 714 |
| R25 | occupied dwelling | 529829 | 5515580 | T10 | 1,295 |
| R26 | occupied dwelling | 532750 | 5515539 | T13 | 924 |
| R27 | occupied dwelling | 532807 | 5515430 | T13 | 1,046 |
| R28 | occupied dwelling | 537446 | 5515420 | T24 | 1,074 |

**Table 2: Shadow Flicker Receptors**

| Receptor Identification Code[(a)] | Receptor Description | Universal Transverse Mercator Coordinates (Zone 12) | | Closest Updated Project Wind Turbine | Distance to Closest Updated Project Wind Turbine (m) |
|---|---|---|---|---|---|
| | | Easting (m) | Northing (m) | | |
| R29 | occupied dwelling | 534057 | 5515050 | T18 | 1,388 |
| R30 | occupied dwelling | 534830 | 5514990 | T19 | 1,119 |
| R33 | occupied dwelling | 531330 | 5514040 | T23 | 836 |
| R34 | occupied dwelling | 538605 | 5513840 | T28 | 1,486 |
| R47 | occupied dwelling | 537417 | 5508850 | T38 | 866 |

a) Receptor identification codes are consistent with the Approved Project noise impact assessment (DNV-GL 2016). Receptor identification codes in Table 2 are non-continuous because the Approved Project consists of a larger number of wind turbine generators spread across a larger spatial area than the Updated Project (i.e., the Approved Project NIA included a larger number of receptors than the Updated Project shadow flicker assessment).

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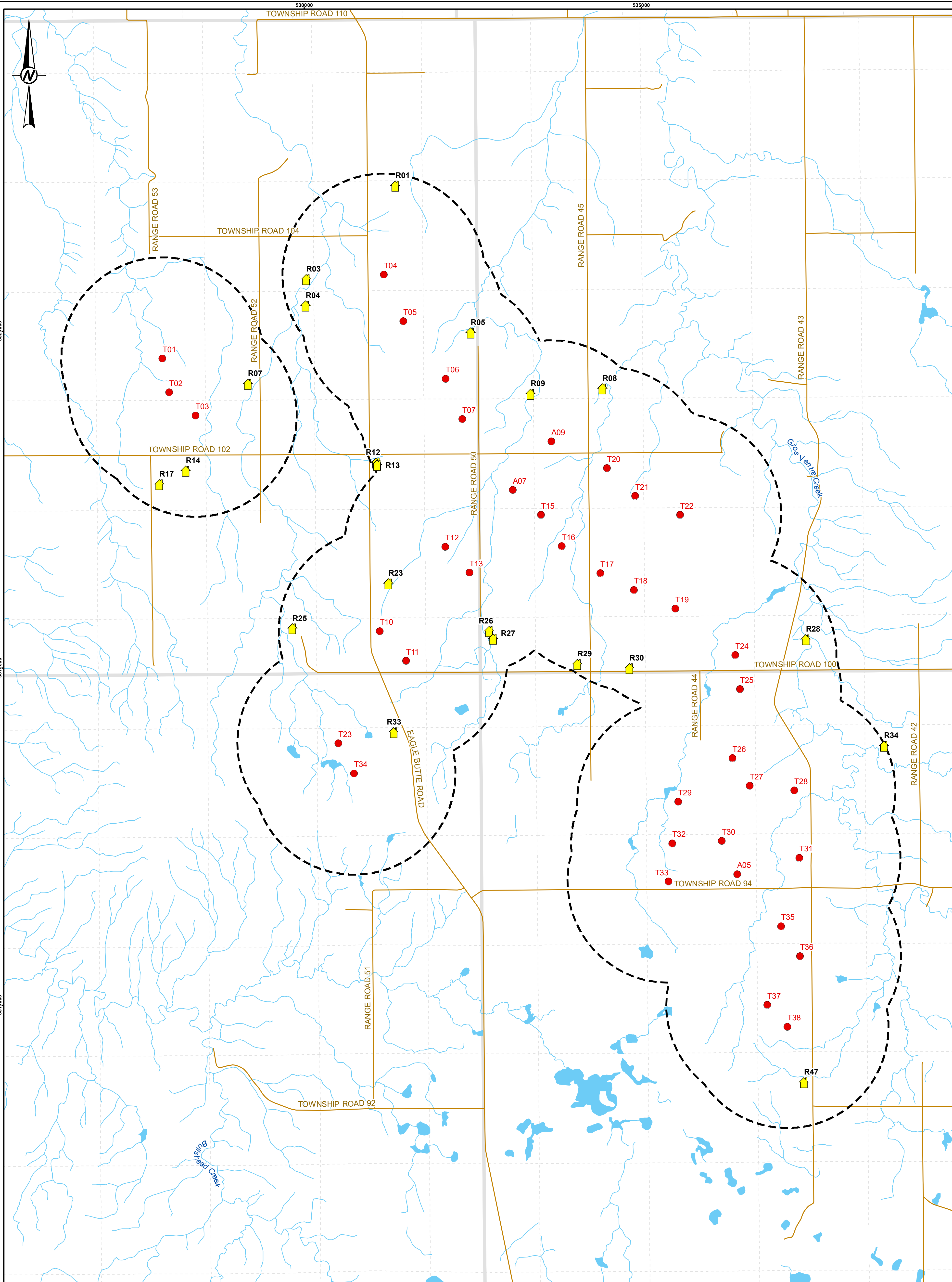


**LEGEND**

- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- SHADOW FLICKER RECEPTOR
- TURBINE
- STUDY AREA

0 1 2

1:55,000 KILOMETRES

**REFERENCE(S)**

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
WILD ROSE 2 WIND LP

PROJECT
WILD ROSE 2 WIND POWER PROJECT

TITLE
**STUDY AREA**

CONSULTANT

WSP GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-12-20 |
| DESIGNED | VY |
| PREPARED | LB |
| REVIEWED | VY |
| APPROVED | AF |

| PROJECT NO. | PHASE | REV. | FIGURE |
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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 wind power facilities in Alberta. In the absence of federal or provincial guidance, the shadow flicker assessment for the Updated Project compared predicted shadow flicker to widely used guidelines, 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 (Koppen et al. 2017; LUNG 2017; Nova Scotia 2021).

## 3.4 Modelling Methods

Potential shadow flicker effects from the Updated Project were modelled using WindPro® v2.7, a commercial software tool developed and distributed by EMD International A/S. Separate WindPro® models were developed for Assessment Case A and Assessment Case B.

Inputs to the WindPro® models for both assessment cases included the location, hub height, and rotor diameter for the Updated Project wind turbine generators, location of shadow flicker receptors, and terrain elevation contours at 5 m intervals. Additional inputs to the WindPro® model for Assessment Case B included statistical data about monthly sunshine and annual wind direction in the study area.

Table 3 presents statistical sunshine data used in the WindPro® model for Assessment Case B. This statistical sunshine data was obtained from a meteorological station located in Suffield, Alberta. Table 4 presents statistical wind direction data used in the WindPro® model for Assessment Case B. This statistical wind direction data was obtained from Project meteorological towers.

**Table 3: Statistical Sunshine Data Used to Model Assessment Case B**

| 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 Assessment Case B**

| Wind Direction | Hours Per Year |
|---|---|
| north | 379 |
| north-northeast | 313 |
| east-northeast | 377 |
| east | 377 |
| east-southeast | 287 |
| south-southeast | 636 |
| south | 1,065 |
| south-southwest | 1,313 |
| west-southwest | 1,571 |
| west | 1,150 |
| west-northwest | 720 |
| north-northwest | 572 |
| ***Total*** | ***8,760*** |

The WindPro® models predicted shadow flicker effects at each of the receptors listed in Table 2 based on the daily and yearly path of the sun through the sky at the Project latitude. In Assessment Case A, the WindPro® model assumed that the sun was always shining, the wind turbine generators were always active, and the turbine rotors were always oriented perpendicular to the line joining the sun and each receptor. In Assessment Case B, 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 Assessment Case A and Assessment Case B, each receptor was modelled in greenhouse mode (i.e., sensitive to shadow flicker in every direction). Modelling for both Assessment Case A and Assessment Case B 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

Table 5 presents shadow flicker modelling results for the Updated Project. Shadow flicker results are presented for each of the receptors identified in Table 2. For Assessment Case A, results are presented 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 Assessment Case B, results are presented in the form of total hours of shadow flicker per year. Note that daily results are not available for Assessment Case B because the modelling algorithm is based on monthly sunshine statistics and annual wind direction data. Figure 2 presents a contour map of modelling results in the form of total hours of shadow flicker per year for Assessment Case B.

**Table 5: Shadow Flicker Modelling Results for the Updated Project**

| Receptor Identification Code | Assessment Case A | | | Assessment Case B |
|---|---|---|---|---|
| | 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 |
| R01 | 0.00 | 0 | 0 | 0.00 |
| R03 | 21.30 | 68 | 30 | 6.82 |
| R04 | 24.75 | 82 | 29 | 9.22 |
| R05 | 47.07 | 135 | 39 | 14.60 |
| R07 | 41.87 | 123 | 39 | 13.52 |
| R08 | 36.55 | 74 | 34 | 9.47 |
| R09 | 40.45 | 126 | 32 | 11.52 |
| R12 | 14.73 | 58 | 24 | 6.15 |
| R13 | 21.10 | 94 | 23 | 8.42 |
| R14 | 0.00 | 0 | 0 | 0.00 |
| R17 | 0.00 | 0 | 0 | 0.00 |
| R23 | 25.63 | 93 | 25 | 10.30 |
| R25 | 14.83 | 57 | 26 | 4.53 |
| R26 | 19.85 | 88 | 26 | 6.65 |
| R27 | 22.62 | 114 | 25 | 7.93 |
| R28 | 37.68 | 112 | 31 | 11.58 |
| R29 | 7.32 | 47 | 14 | 3.10 |
| R30 | 7.58 | 44 | 17 | 2.42 |
| R33 | 75.58 | 134 | 43 | 21.08 |
| R34 | 7.37 | 31 | 22 | 2.37 |
| R47 | 0.00 | 0 | 0 | 0.00 |

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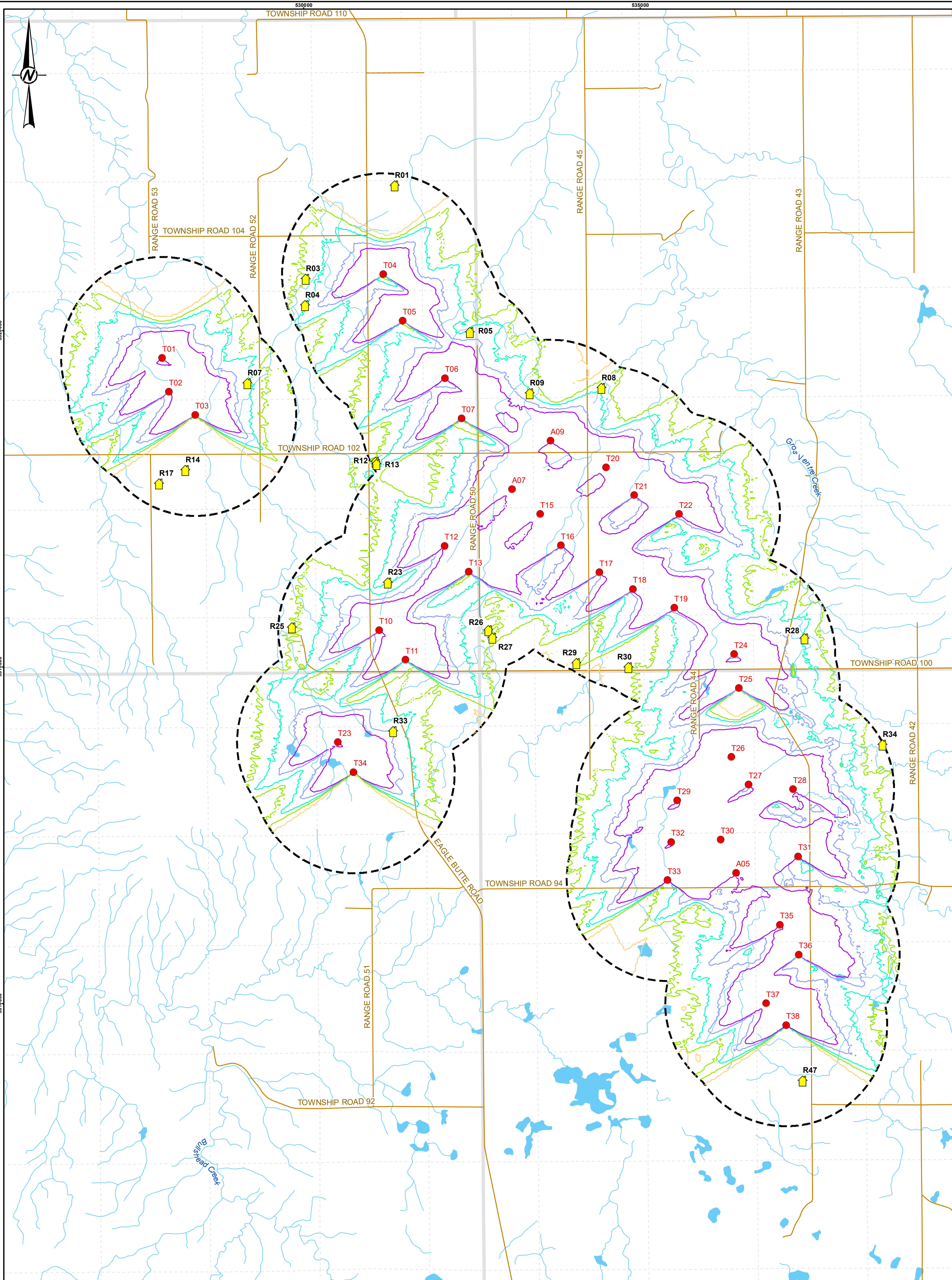


**LEGEND**

- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- SHADOW FLICKER RECEPTOR
- TURBINE
- STUDY AREA

**PREDICTED PROJECT SHADOW FLICKER (HOURS/YEAR)**

- ~0
- 5
- 10
- 20
- 30

0 1 2

1:55,000 KILOMETRES

**REFERENCE(S)**

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
WILD ROSE 2 WIND LP

PROJECT
WILD ROSE 2 WIND POWER PROJECT

TITLE
**PROJECT SHADOW FLICKER; STATISTICAL SUNSHINE AND WIND DIRECTION**

CONSULTANT

wsp GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2022-12-20 |
| DESIGNED | VY |
| PREPARED | LB |
| REVIEWED | VY |
| APPROVED | AF |

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# 5.0 DISCUSSION

The results presented in Table 5 indicate that 17 receptors may experience some shadow flicker from the Updated Project.

In Assessment Case A, which assumes the sun is always shining and turbines are always operating with rotors perpendicular to the line joining the sun and receptor points, modelling predicts that six receptors may experience more than 30 hours of shadow flicker per year (R05, R07, R08, R09, R28, and R33) and these same six receptors may experience more than 30 minutes of shadow flicker on a single day. The modelling assumptions used in Assessment Case A are unrealistic and highly conservative (i.e., tending to overestimate potential shadow flicker effects).

Assessment Case B predicts potential shadow flicker effects under more realistic, but still conservative, environmental conditions. Assessment Case B 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 points). Assessment Case B is still a conservative treatment of potential shadow flicker effects since it assumes the Updated Project wind turbine generators are always active (i.e., rotor always spinning), assumes that receptors are sensitive to shadow flicker in every direction (i.e., greenhouse mode), and does not account for screening by trees, outbuildings, or other local structures. As indicated in Table 5, modelling for Assessment Case B predicts that no receptor will experience more than 30 hours of shadow flicker per year from the Updated Project.

# 6.0 CONCLUSION

A shadow flicker assessment was completed for the Updated Project. The shadow flicker assessment evaluated two conservative modelling scenarios: Assessment Case A and Assessment Case B. In accordance with Rule 007, the shadow flicker assessment considered potential effects at 21 occupied dwellings located within 1.5 km of the Updated Project wind turbine generators.

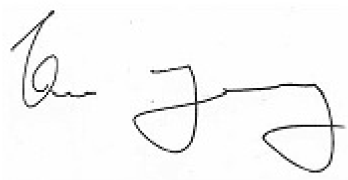
Assessment Case A assumed the sun is always shining during daylight hours (i.e., no cloudy periods), all Updated Project wind turbine generators are always active (i.e., rotors spinning), and all Updated Project wind turbine generators are always oriented with their rotors perpendicular to the line joining the sun and all receptors. Assessment Case B 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 receptors are sensitive to shadow flicker in every direction (i.e., greenhouse mode) and neither assessment case accounted for screening of shadow flicker by vegetation, outbuildings, or other structures.

In Assessment Case A, modelling predicts that six receptors may experience more than 30 hours of shadow flicker per year (R05, R07, R08, R09, R28, and R33) and these same six receptors may experience more than 30 minutes of shadow flicker on a single day. Review of publicly available satellite imagery shows vegetation and/or outbuildings in close proximity to each of these receptors. The presence of these features will likely reduce potential shadow flicker effects by providing partial line-of-sight screening for Updated Project turbines during those hours of the day when the sun is low enough to create long shadows.

In Assessment Case B, none of the receptors are predicted to experience more than 30 hours of shadow flicker per year. In Assessment Case B, a maximum of 21.08 hours of shadow flicker per year is predicted for receptor R33. As mentioned above, the amount of shadow flicker actually experienced by receptor R33 will likely be reduced by the presence of vegetation in close proximity to the dwelling.

In conclusion, the present assessment demonstrates there is minimal potential for shadow flicker effects from the Updated Project.

**Golder Associates Ltd.**



Victor Young, MSc
*Acoustic Scientist*

Andrew Faszer, BSc, PEng
*Senior Engineer*

VY/AF/pls/jr

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WSP GOLDER

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