KING ROCKS WIND FARM

Shadow Flicker and Blade Glint Assessment

Urbis Pty Ltd

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Objective: King Rocks Wind Farm Shadow Flicker and Blade Glint Assessment

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EXECUTIVE SUMMARY

DNV has been commissioned by Urbis Pty Ltd ("the Customer") to independently assess the expected annual shadow flicker durations in the vicinity of the proposed King Rocks Wind Farm ("the Project") in Western Australia. The results of the assessment are described in this document.

Background and methodology

DNV has assessed the expected annual shadow flicker durations for the Project against limits specified in the Draft National Wind Farm Development Guidelines (Draft National Guidelines) [1]. The methodology used in this assessment has been informed by these guidelines and various standard industry practices.

The Draft National Guidelines recommend limits of 30 hours per year on the theoretical shadow flicker duration, and 10 hours per year on the actual shadow flicker duration.

A Project layout consisting of 30 wind turbines with a rotor diameter of 180 m and a hub height of 150 m has been considered. The locations of 10 receptors within 5 km of the Project have been provided by the Customer. The Customer has advised one of these receptors is not a dwelling, and that receptor has therefore not been considered further in this assessment.

The theoretical shadow flicker durations at dwellings in the vicinity of the Project have been determined using a purely geometric analysis. The actual shadow flicker duration likely to be experienced at each dwelling has also been predicted by estimating the possible reduction in shadow flicker due to turbine orientation and cloud cover.

The calculation of the predicted actual shadow flicker duration does not take into account other potential reductions due to low wind speed, vegetation, or other shielding effects around each house in calculating the number of shadow flicker hours.

Outcomes of the assessment

Based on this assessment, no dwellings are expected to experience high intensity shadow flicker, meaning shadow flicker of at least a moderate level of intensity or above, which is expected to occur up to a distance of around 10 rotor diameters from the wind farm.

If required, the effects of shadow flicker may be reduced through a number of mitigation measures such as the removal or relocation of turbines, the use of smaller turbines, installation of screening structures or planting of trees to block shadows cast by the turbines, or the use of turbine control strategies to shut down turbines when shadow flicker is likely to occur.

Since a non-reflective finish is generally applied to wind turbine blades, blade glint is not expected to be an issue for the Project.

1 INTRODUCTION

Urbis Pty Ltd ("the Customer") has commissioned DNV to independently assess the expected annual shadow flicker durations in the vicinity of the proposed King Rocks Wind Farm ("the Project") in Western Australia. The results of this work are reported here. This document has been prepared in accordance with the Urbis Sub-consultant Agreement between Urbis Pty Ltd and DNV Australia Pty Ltd, dated 13 April 2022, and is subject to the terms and conditions in that agreement.

This assessment evaluates the shadow flicker durations in the vicinity of the Project for the current proposed turbine layout and configuration in accordance with the Draft National Wind Farm Development Guidelines (Draft National Guidelines) [1]. The methodology used in this study has been informed by these guidelines and various standard industry practices.

2 DESCRIPTION OF THE SITE AND PROJECT

2.1 The site

The Project is located in southwestern Western Australia, approximately 35 km northeast of Hyden townsite and 350 km east of Perth. An overview of the site location is presented in Figure 2, and an indicative site plan provided by the Customer is presented in Figure 3 [2].

The terrain at the site is relatively simple with elevations ranging from approximately 350 m to 430 m above sea level. Ground cover on the site consists primarily of open farmland interspersed with windbreaks and small areas of trees. The eastern boundary of the site adjoins a larger area of moderately dense native vegetation. A digital elevation model of the surrounding terrain, extending approximately 20 km from the site, was derived from publicly available SRTM1 data [3].

2.2 The Project

2.2.1 Proposed wind farm layout

The Project is proposed to consist of up to 30 wind turbines [4]. A map of the site showing the turbine layout and terrain elevations considered in this assessment is shown in Figure 4, and the coordinates of the proposed turbine locations are given in Table 1.

DNV has modelled the shadow flicker based on a theoretical turbine model with a with a rotor diameter of 180 m, hub height of 150 m, and upper tip height of 240 m [4]. These dimensions represent the maximum turbine dimensions currently under consideration for the Project.

2.2.2 Receptor locations

The locations of 10 receptors (dwellings and other significant buildings) within 5 km of the Project were provided to DNV by the Customer [5, 6].

Of these 10 receptors, five receptors are located within 2750 m of the proposed turbine locations (which corresponds to 15 times the rotor diameter plus 50 m). The coordinates of those five receptors are presented in Table 2, and their locations are shown in Figure 4. Receptors located more than 15 times the rotor diameter from the turbines are considered unlikely to be impacted by shadow flicker, as discussed further in Sections 3.1 and 4.1. Two of the receptors shown in Table 2 and Figure 4 have been identified by the Customer as belonging to landowners involved with the Project.

The Customer has also advised that one of the landowner receptors shown in Table 2 and Figure 4 (receptor B, located within the Project boundary) is not a dwelling. Therefore, receptor B has not been considered further in this assessment. DNV has assumed that all other receptors are habitable dwellings.

DNV has not carried out a detailed and comprehensive survey of sensitive land uses and building locations in the area and is relying on information provided by the Customer.

3 REGULATORY REQUIREMENTS

3.1 Shadow flicker

The development of wind farms in Western Australia is governed by the Western Australian Planning Commission's Position Statement on renewable energy facilities ("the WA Position statement"), published in March 2020 [7]. However, the WA Position Statement does not address the potential for wind farms to cause shadow flicker impacts at nearby dwellings, therefore DNV has relied on other suitable guidelines to assess the shadow flicker for the Project, as discussed below.

The EPHC, in conjunction with Local Governments and the Planning Ministers' Council, released a draft version of the National Wind Farm Development Guidelines in July 2010 (Draft National Guidelines) [1]. The Draft National Guidelines cover a range of issues across the different stages of wind farm development. In relation to shadow flicker, the Draft National Guidelines provide background information, a proposed methodology, recommended limits, and a suite of assumptions for assessing shadow flicker durations in the vicinity of a wind farm.

The Draft National Guidelines recommend that the modelled theoretical shadow flicker duration should not exceed 30 hours per year at any dwelling. The Draft National Guidelines also recommend that the shadow flicker duration at a dwelling be assessed by calculating the maximum shadow flicker occurring within 50 m of the centre of the dwelling. These limits are assumed to apply to a single dwelling, and it is noted that there is no requirement under the Draft National Guidelines to assess shadow flicker durations at locations other than in the vicinity of dwellings.

The impact of shadow flicker is typically only significant up to a limited distance from the wind turbines. Beyond this distance limit the shadow is diffused such that the variation in light levels is not likely to be sufficient to cause annoyance. This issue is discussed in the Draft National Guidelines, where it is stated that:

> *"Shadow flicker can theoretically extend many kilometres from a wind turbine. However the intensity of the shadows decreases with distance. While acknowledging that different individuals have different levels of sensitivity and may be annoyed by different levels of shadow intensity, these guidelines limit assessment to moderate levels of intensity (i.e., well above the minimum theoretically detectable threshold) commensurate with the nature of the impact and the environment in which it is experienced."*

The Draft National Guidelines suggest a shadow flicker distance limit equal to 265 times the maximum blade chord length, which would correspond to approximately 1000 to 1600 m for modern wind turbines (which typically have maximum blade chord lengths of 4 to 6 m). However, the UK wind industry considers that a distance limit of around 10 rotor diameters from a turbine [8, 9] or approximately 1200 m to 1900 m for modern wind turbines (which typically have rotor diameters of 120 m to 190 m), is appropriate.

For the purposes of this assessment, DNV has considered the guidance and recommendations given in the Draft National Guidelines in relation to shadow flicker along with the shadow flicker distance limit applied by the UK wind industry, as discussed further in Section 4.1.2.

3.2 Blade glint

In relation to blade glint, the Draft National Guidelines state that:

> *"The sun's light may be reflected from the surface of wind turbine blades. Blade Glint has the potential to annoy people. All major wind turbine manufacturers currently finish their blades with a low reflectivity treatment. This prevents a potentially annoying reflective glint from the surface of the blades and the possibility of a strobing reflection when the turbine blades are spinning. Therefore the risk of blade glint from a new development is considered to be very low."*

4 ASSESSMENT METHODOLOGY

4.1 Shadow flicker

4.1.1 Overview

Shadow flicker may occur under certain combinations of geographical position and time of day when the sun passes behind the rotating blades of a wind turbine and casts a moving shadow over neighbouring areas. When viewed from a stationary position the moving shadows cause periodic flickering of the light from the sun, giving rise to the phenomenon of 'shadow flicker'.

The effect is most noticeable inside buildings, where the flicker appears through a window opening. The likelihood and duration of the effect depends upon a number of factors, including:

- the direction of the property relative to the turbine
- the distance of the property from the turbine (the further the observer is from the turbine, the less pronounced the effect will be)
- the turbine height and rotor diameter
- the time of year and day (the position of the sun in the sky)
- the weather conditions (cloud cover reduces the occurrence of shadow flicker)
- the wind direction (the shape of the shadow will be determined by the position of the sun relative to the blades which will be oriented to face the wind).

Example photographs of wind turbines and associated shadows which have the potential to cause flicker are shown in Figure 1 below.

Figure 1 Examples of wind turbine shadows

4.1.2 Theoretical modelled duration

The theoretical number of hours of shadow flicker experienced annually at a given location can be calculated using a geometrical model which incorporates the sun path, topographic variation over the site area, and wind turbine details such as rotor diameter and hub height.

The wind turbines have been modelled assuming they are spherical objects, which is equivalent to assuming the turbines are always oriented perpendicular to the sun-turbine vector. This assumption will mean the model calculates the maximum duration for which there is potential for shadow flicker to occur, up to a specified distance limit.

In line with the methodology proposed in the Draft National Guidelines, DNV has assessed the shadow flicker at the provided dwellings and has determined the highest shadow flicker duration within 50 m of each of these locations.

Shadow flicker has been calculated at dwellings at heights of 2 m, to represent ground floor windows, and 6 m, to represent second floor windows. The shadow receptors are simulated as fixed points, representing the worst-case scenario, as real windows could be facing a particular direction less affected by shadows cast from the turbines. The shadow flicker calculations for dwelling locations have been carried out with a temporal resolution of 1 minute. The shadow flicker map was generated using a temporal resolution of 5 minutes and a spatial resolution of 10 m to reduce computational requirements to acceptable levels.

As part of the shadow flicker assessment, it is necessary to make an assumption regarding the maximum length of a shadow cast by a wind turbine that is likely to cause annoyance due to shadow flicker. As noted in Section 3.1, the UK wind industry considers that 10 rotor diameters is appropriate [8, 9] while the Draft National Guidelines suggest a distance limit equivalent to 265 times the maximum blade chord [1].

For the current assessment, DNV has applied a maximum shadow length of 10 times the rotor diameter (10D), corresponding to a distance limit of 1800 m for the Project, which DNV considers is more appropriate than a limit of 265 times the maximum blade chord. Beyond this distance limit, it is assumed that any shadow flicker experienced will be below a "moderate level of intensity" and unlikely to cause annoyance. However, it is recognised that different people have different levels of sensitivity to shadow flicker and may therefore be affected by shadow flicker intensities below the "moderate level of intensity" assumed by this distance limit. To account for this possibility, DNV has also assessed the shadow flicker for an increased distance limit of 15 times the rotor diameter (15D), or 2700 m, which should include shadow flicker below a "moderate level of intensity".

In this report, shadow flicker of a moderate level of intensity or above is referred to as "high intensity" shadow flicker, and is assumed to occur up to a distance of approximately 10D from the wind farm. Conversely, shadow flicker below a moderate level of intensity is referred to as "low intensity" shadow flicker, and is assumed to occur beyond a distance of 10D and up to a distance of approximately 15D from the wind farm.

The model also makes the following assumptions and simplifications:

- there are clear skies every day of the year
- the blades of the turbines are always perpendicular to the direction of the line of sight from the location of interest to the sun
- the turbines are always rotating.

The first two of these items are addressed in the calculation of the predicted actual shadow flicker duration as described in Section 4.1.4. The third item is not considered but is unlikely to have a significant impact on the results. The settings used to execute the model can be seen in Table 3.

To illustrate typical results, an indicative shadow flicker map for a turbine located in a flat area is shown in Figure 5. The geometry of the shadow flicker map can be characterised as a butterfly shape, with the four protruding lobes corresponding to slowing of solar north-south travel around the summer and winter solstices for morning and evening. The lobes to the north of the indicative turbine location result from the summer months and conversely the lobes to the south result from the winter months. The lobes to the west result from morning sun while the lobes to the east result from evening sun. When the sun is low in the sky, the length of shadows cast by the turbine increases, increasing the area around the turbine affected by shadow flicker.

4.1.3 Factors affecting duration

Shadow flicker duration calculated in this manner overestimates the annual number of hours of shadow flicker experienced at a specified location for several reasons, including:

1. The wind turbine will not always be oriented such that its rotor is in the worst-case position (i.e., perpendicular to the sun-turbine vector). Any other rotor orientation will reduce the area of the projected shadow and hence the shadow flicker duration.

   The wind speed frequency distribution or wind rose at the site can be used to determine probable turbine orientation and to calculate the resulting reduction in shadow flicker duration.

2. The occurrence of cloud cover has the potential to significantly reduce the number of hours of shadow flicker.

   Cloud cover measurements recorded at nearby meteorological stations may be used to estimate probable levels of cloud cover and to provide an indication of the resulting reduction in shadow flicker duration.

3. Aerosols (moisture, dust, smoke, etc.) in the atmosphere have the ability to influence shadows cast by a wind turbine.

   The length of the shadow cast by a wind turbine is dependent on the degree that direct sunlight is diffused, which is in turn dependent on the amount of dispersants (humidity, smoke, and other aerosols) in the path between the light source (sun) and the receiver.

4. The modelling of the wind turbine rotor as a sphere rather than individual blades results in an overestimate of shadow flicker duration.

   Turbine blades are of non-uniform thickness with the thickest part of the blade (maximum chord) close to the hub and the thinnest part (minimum chord) at the tip. Diffusion of sunlight, as discussed above, results in a limit to the maximum distance that a shadow can be perceived. This maximum distance will also be dependent on the thickness of the turbine blade, and the human threshold for perception of light intensity variation. As such, a shadow cast by the blade tip will be shorter than the shadow cast by the thickest part of the blade.

5. The analysis does not consider that when the sun is positioned directly behind the wind turbine hub, there is no variation in light intensity at the receiver location and therefore no shadow flicker.

6. The presence of vegetation or other physical barriers around a shadow receptor location may shield the view of the wind turbine, and therefore reduce the incidence of shadow flicker.
7. Periods where the wind turbine is not in operation due to low winds, high winds, or for operational and maintenance reasons will also reduce the annual shadow flicker duration.

4.1.4 Predicted actual duration

As discussed above in Section 4.1.3, there are a number of factors which may reduce the incidence of shadow flicker that are not taken into account in the calculation of the theoretical shadow flicker duration. An attempt has been made to quantify the likely reduction in shadow flicker duration due to cloud cover and, therefore, produce a prediction of the actual shadow flicker duration likely to be experienced at a receptor.

Cloud cover is typically measured in 'oktas', effectively eighths of the sky covered with cloud. DNV has obtained data from the following Bureau of Meteorology (BoM) stations:

- Hyden (10568), located approximately 34 km from the Project [10]
- Narembeen (10612), located approximately 77 km from the Project [11]
- Southern Cross (12074), located approximately 114 km from the Project [12]
- Corrigin (10536), located approximately 124 km from the Project [13].

The number of oktas of cloud cover visible across the sky at these stations is recorded twice daily, at 9 am and 3 pm, and the observations are provided as monthly averages. After averaging the 9 am and 3 pm observations for the stations considered, the results indicate that the average monthly cloud cover in the region ranges between 29% and 56%, and the average annual cloud cover is approximately 44%. This implies that on an average day, 44% of the sky in the vicinity of the wind farm is covered with clouds. Although it is not possible to definitively calculate the effect of cloud cover on shadow flicker duration, a reduction in the shadow flicker duration proportional to the amount of cloud cover is considered to be a reasonable assumption.

Similarly, turbine orientation can have an impact on the shadow flicker duration. The shadow flicker duration is greatest when the turbine rotor plane is approximately perpendicular to a line joining the sun and an observer, and a minimum when the rotor plane is approximately parallel to a line joining the sun and an observer. A wind direction frequency distribution derived from wind measurements at the site was provided by the Customer [14] and used to estimate the reduction in shadow flicker duration due to rotor orientation. The measured wind rose is shown overlaid on the indicative shadow flicker map in Figure 5. An assessment of the likely reduction in shadow flicker duration due to variation in turbine orientation was conducted on an annual basis.

It should be noted that the method prescribed by the Draft National Guidelines for assessing actual shadow flicker duration recommends that only reductions due to cloud cover, and not turbine orientation, be included. However, DNV considers that the additional reduction due to turbine orientation is appropriate as the projected area of the turbine, and therefore the expected shadow flicker duration, is reduced when the turbine rotor is not perpendicular to the line joining the sun and dwelling. Due to limitations in the availability of suitable cloud cover data, the methodology used in this assessment also deviates somewhat from the method recommended by the Draft National Guidelines for assessing the reduction in shadow flicker due to cloud cover. However, considering the available cloud cover data, the approach described above is deemed to provide a reasonable estimate of the likely impact of cloud cover on the shadow flicker duration.

While the calculation of the predicted actual shadow flicker duration considers the likely reductions due to cloud cover and rotor orientation, it does not take into account other potential reductions due to low wind speed (or turbine shutdown), vegetation, or other shielding effects around each dwelling.

4.2 Blade glint

Blade glint involves the regular reflection of sun off rotating turbine blades. Its occurrence depends on a combination of circumstances arising from the orientation of the nacelle, angle of the blade and the angle of the sun. The reflectiveness of the surface of the blades is also important. Blade glint is not generally a problem for modern wind turbines, provided the blades are coated with a non-reflective paint, and it is not considered further here.

5 ASSESSMENT RESULTS

5.1 Shadow flicker

5.1.1 Predicted shadow flicker durations

Shadow flicker predictions were generated at the provided dwelling locations, as outlined in Table 2.

The results of the theoretical and predicted actual shadow flicker modelling are shown in the form of shadow flicker maps in Figure 6 and Figure 7. The shadow flicker values presented in these maps represent the worst case between the results at 2 m and 6 m above ground for each modelled grid point.

As shown in Table 4, based on DNV's modelling no dwellings are expected to experience high intensity shadow flicker.

Beyond the 10D distance limit, it is assumed that any shadow flicker experienced will be of a low intensity and unlikely to cause annoyance. However, it is recognised that different people have different levels of sensitivity to shadow flicker and may therefore be affected by low intensity shadow flicker assumed by this distance limit. To inform the potential for this outcome, and although not part of the methodology outlined in the Draft National Guidelines, DNV has also assessed the shadow flicker impacts for the Project for an increased distance limit that is intended to include shadow flicker of low intensity. For the purpose of assessing low intensity shadow flicker, the distance limit has been increased by 50% (to 15D). The results of this additional assessment are also included in the map presented in Figure 6. These results indicate that three dwellings may have the potential to be exposed to low intensity shadow flicker. These dwellings are noted in Table 4.

5.1.2 Mitigation options

If required, the effects of shadow flicker may be reduced through a number of mitigation measures. These include the removal or relocation of turbines, the use of turbines with a smaller rotor diameter, installation of screening structures or planting of trees to block shadows cast by the turbines, or the use of turbine control strategies to shut down turbines when shadow flicker is likely to occur.

5.2 Blade glint

As discussed in Section 4.2, blade glint is not expected to be an issue for the Project provided that a non-reflective paint is applied to the wind turbine blades.

6 CONCLUSIONS

A shadow flicker assessment was carried out for dwelling locations in the vicinity of the Project.

For the purpose of this assessment, DNV has considered a layout consisting of 30 turbines with a rotor diameter of 180 m and a hub height of 150 m. These dimensions represent the maximum turbines dimensions currently under consideration for the Project.

Based on DNV's modelling, no dwellings are expected to experience high intensity shadow flicker, which is expected to occur up to a distance of around 10 rotor diameters from the wind farm.

Since a non-reflective finish is proposed for the wind turbine blades, blade glint is not expected to be an issue for the Project.

7 REFERENCES

[1] Environment Protection and Heritage Council (EPHC), "National Wind Farm Development Guidelines - Draft," July 2010.

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[14] Information within email from M Gammon (Urbis) to N Brammer (DNV), 10 March 2022.

[15] "Planning for Renewable Energy - A Companion Guide to PPS22," Office of the Deputy Prime Minister, UK, 2004.

LIST OF TABLES

Table 1 Proposed turbine layout for the Project [4]

Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]	Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]
T01	707755	6431272	426	T16	705917	6433350	378
T02	708224	6430627	410	T17	705244	6427880	385
T03	706100	6429954	391	T18	705761	6428228	382
T04	706213	6428641	386	T19	705728	6431357	387
T05	706763	6431668	401	T20	705641	6430669	397
T06	707939	6430065	401	T21	708516	6429274	385
T07	706554	6429166	394	T22	708760	6429886	391
T08	707686	6429460	391	T23	704132	6433463	355
T09	707311	6432008	404	T24	704680	6427605	384
T10	706555	6430630	407	T25	707977	6427979	379
T11	706217	6432579	379	T26	704704	6432944	364
T12	706607	6433064	388	T27	707255	6430868	419
T13	705253	6433340	371	T28	705851	6432045	379
T14	704572	6433934	360	T29	707673	6427391	384
T15	708222	6428624	383	T30	706954	6429753	396

1. Coordinate system: MGA zone 50, GDA94 datum.

Table 2 Sensitive receptors within 2750 m of turbines at the Project site [5, 6]

Receptor ID	Landowner status[1]	Easting[2] [m]	Northing[2] [m]	Nearest turbine Distance (m)	Nearest turbine Turbine ID
A	*Landowner*	*703858*	*6431265*	*1873*	*T19*
B[3]	*Landowner*	*706336*	*6429068*	*239*	*T07*
C (primary)	Neighbour	702778	6434616	1779	T23
C (secondary)	Neighbour	702763	6434782	1902	T23
G	Neighbour	704838	6425301	2309	T24

1. Receptors belonging to landowners for the Project are indicated by *italic underlined text*.
2. Coordinate system: MGA zone 50, GDA94 datum. Coordinates were provided by the Customer in a different coordinate system and/or datum and have been converted using mapping software, which may result in small discrepancies depending on the software and transformation approach used.
3. The Customer has advised that this receptor is not a dwelling, and so it has not been considered further in this assessment.

Table 3 Shadow flicker model settings for theoretical shadow flicker calculation

Model setting	
Shadow distance limit (10D)	1800 m
Year of calculation	2034
Minimum elevation of the sun	3°
Time step	1 min (5 min for map)
Rotor modelled as	Sphere (disc for turbine orientation reduction calculation)
Sun modelled as	Disc
Offset between rotor and tower	None
Receptor height (single storey)	2 m
Receptor height (double storey)	6 m
Locations used for determining maximum shadow flicker within 50 m of each receptor	8 points evenly spaced (every 45°) on 25 m and 50 m radius circles centred on the provided receptor location

Table 4 Theoretical and predicted actual annual shadow flicker duration for high intensity shadow flicker (to 10D distance)

Receptor ID[1]	Easting[2] [m]	Northing[2] [m]	Landowner status	Contributing turbines	Theoretical annual At dwelling [hr/yr]		Theoretical annual Max within 50 m [hr/yr]		Predicted actual annual[3] At dwelling [hr/yr]		Predicted actual annual[3] Max within 50 m [hr/yr]	
					2 m	6 m	2 m	6 m	2 m	6 m	2 m	6 m
A[4]	703858	6431265	Landowner	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C (primary)[4]	702778	6434616	Neighbour	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C (secondary)[4]	702763	6434782	Neighbour	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recommended duration limits (hr/yr)					**30**	**30**	**30**	**30**	**10**	**10**	**10**	**10**

1. Receptor B identified in Table 2 has been omitted from this table as the Customer has advised that this receptor is not a dwelling. Dwellings identified in Table 2 for which there is no theoretical shadow flicker occurrence up to a distance limit of 15 times the rotor diameter are also exlcuded from this table.
2. Coordinate system: MGA zone 50, GDA94 datum. Coordinates were provided by the Customer in a different coordinate system and/or datum and have been converted using mapping software, which may result in small discrepancies depending on the software and transformation approach used.
3. Considering likely reductions in shadow flicker duration due to cloud cover and turbine orientation.
4. Dwelling is not predicted to experience any high intensity shadow flicker, but may experience some low intensity shadow flicker.

LIST OF FIGURES

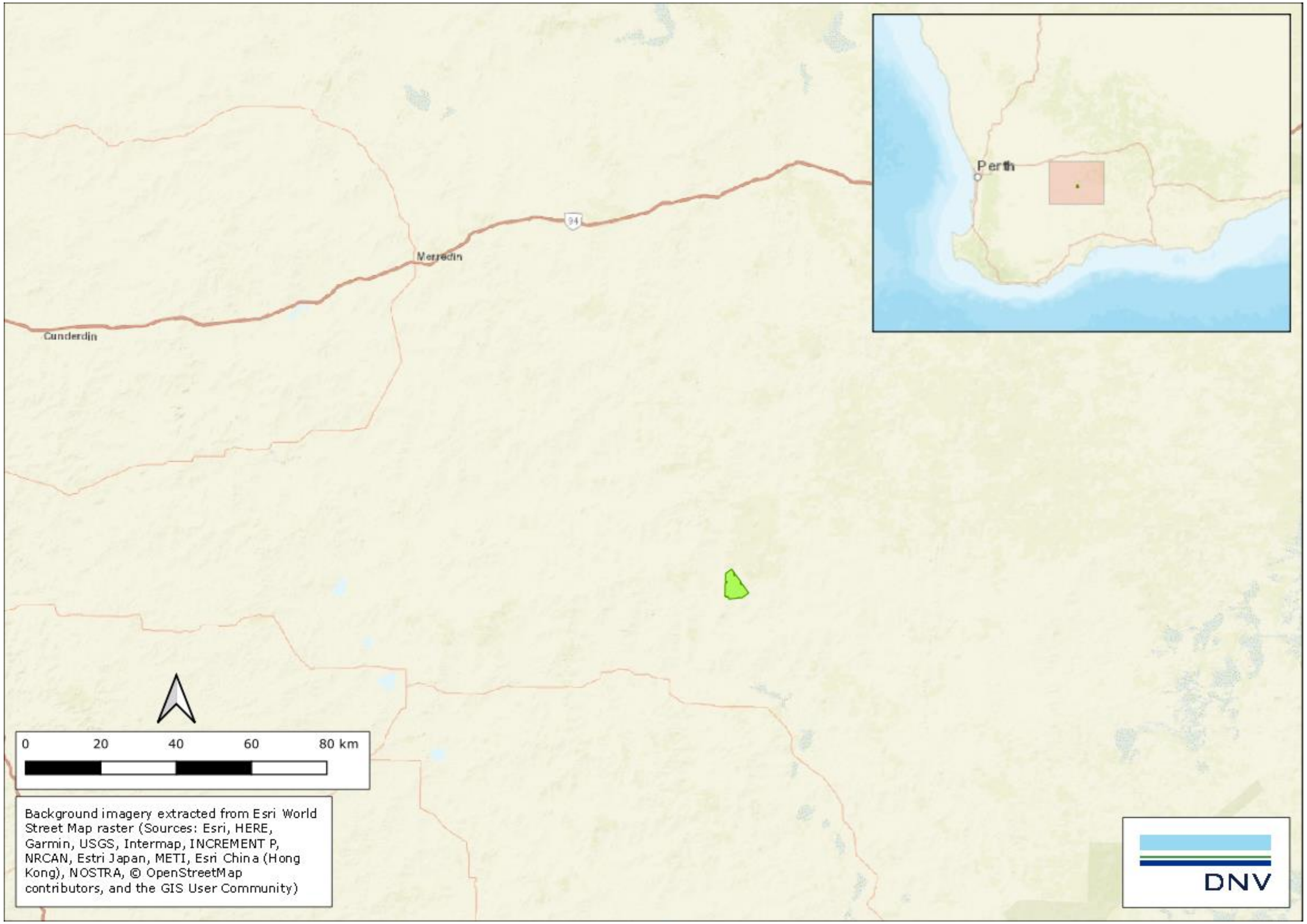

Figure 2 Location of the Project

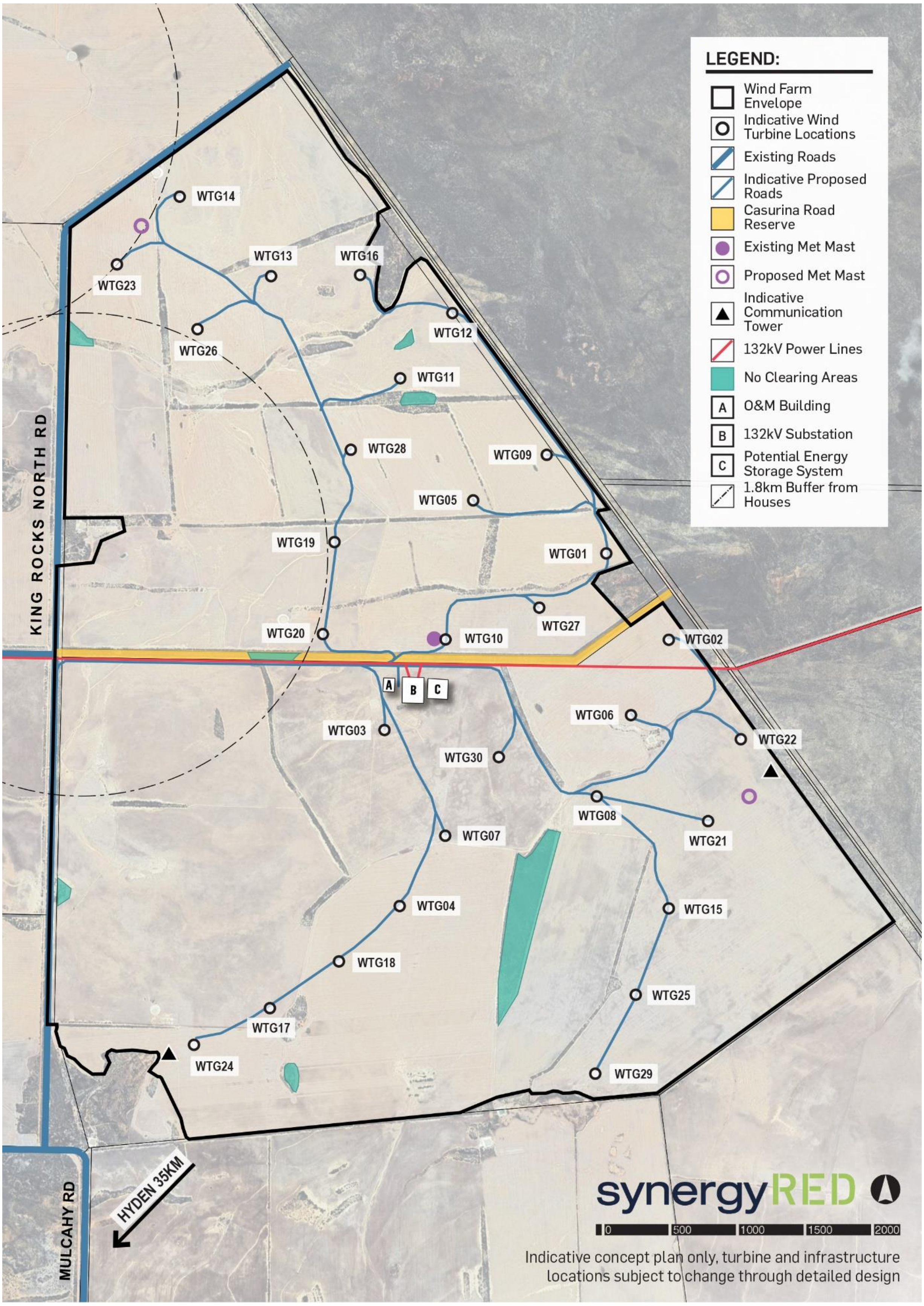

Figure 3 Site plan, showing wind farm envelope and indicative turbine and infrastructure locations, as provided by the Customer [2]

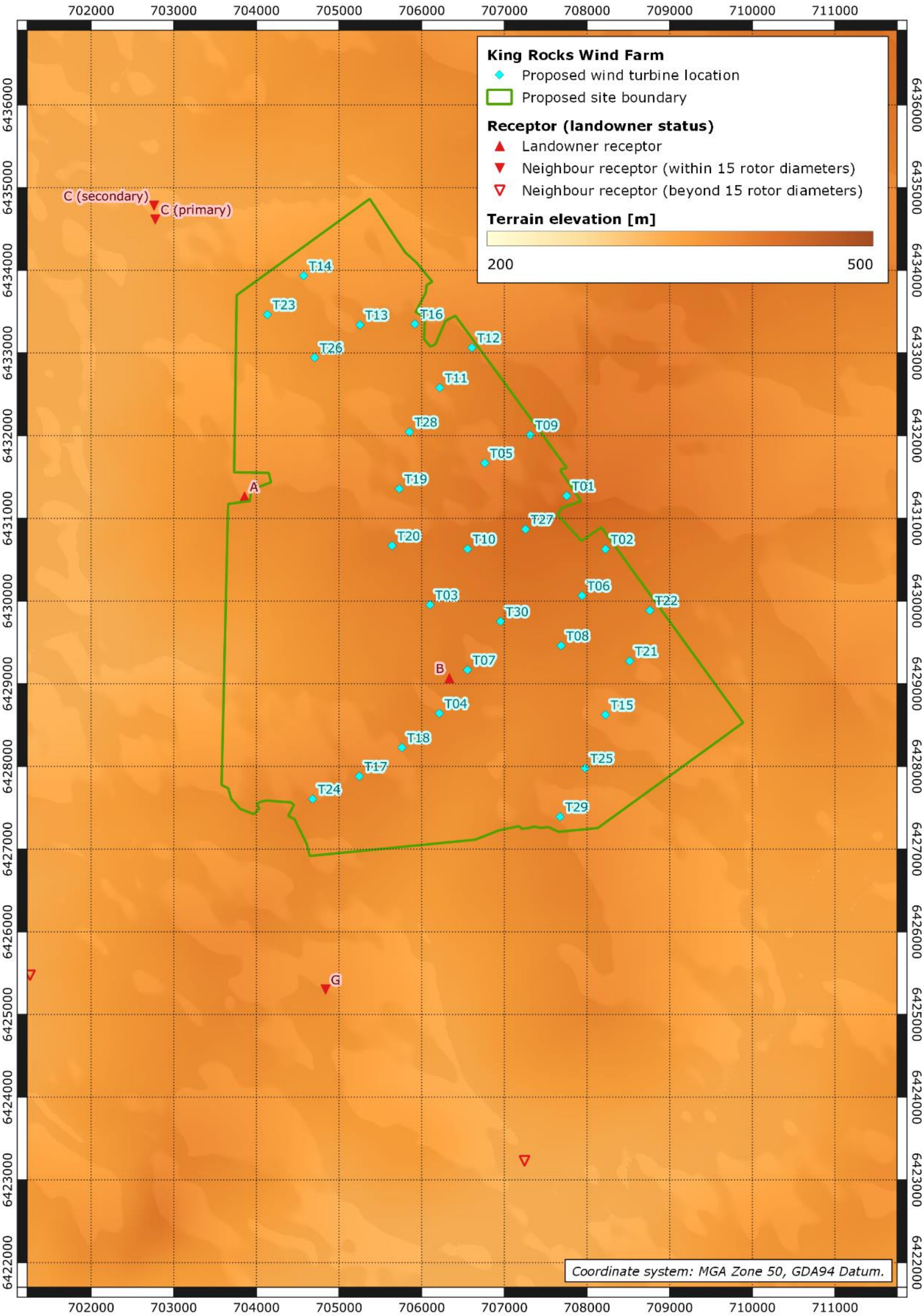

Figure 4 Site layout, showing wind turbines, receptors and elevations

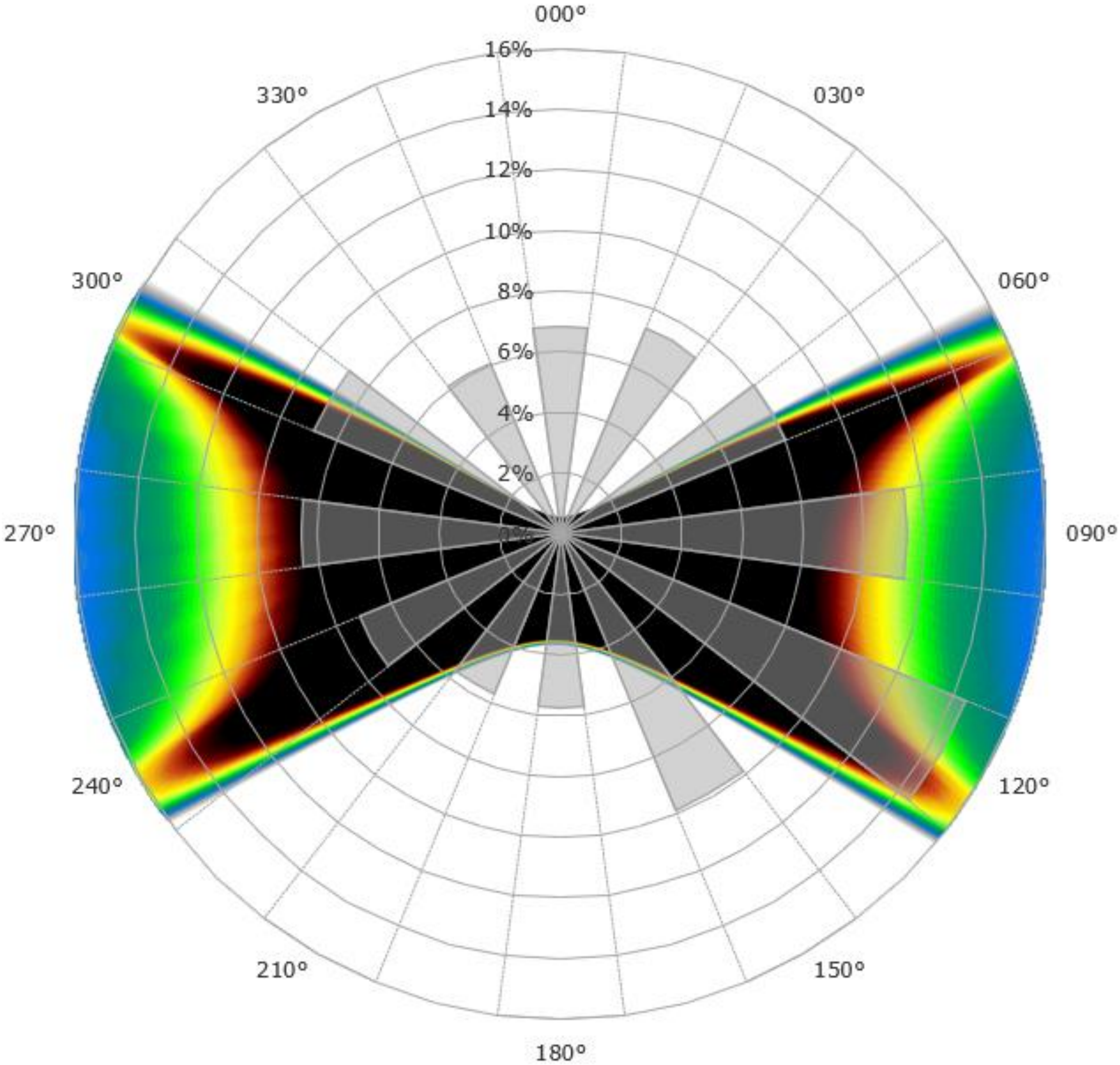

Figure 5 Indicative shadow flicker map and wind direction frequency distribution

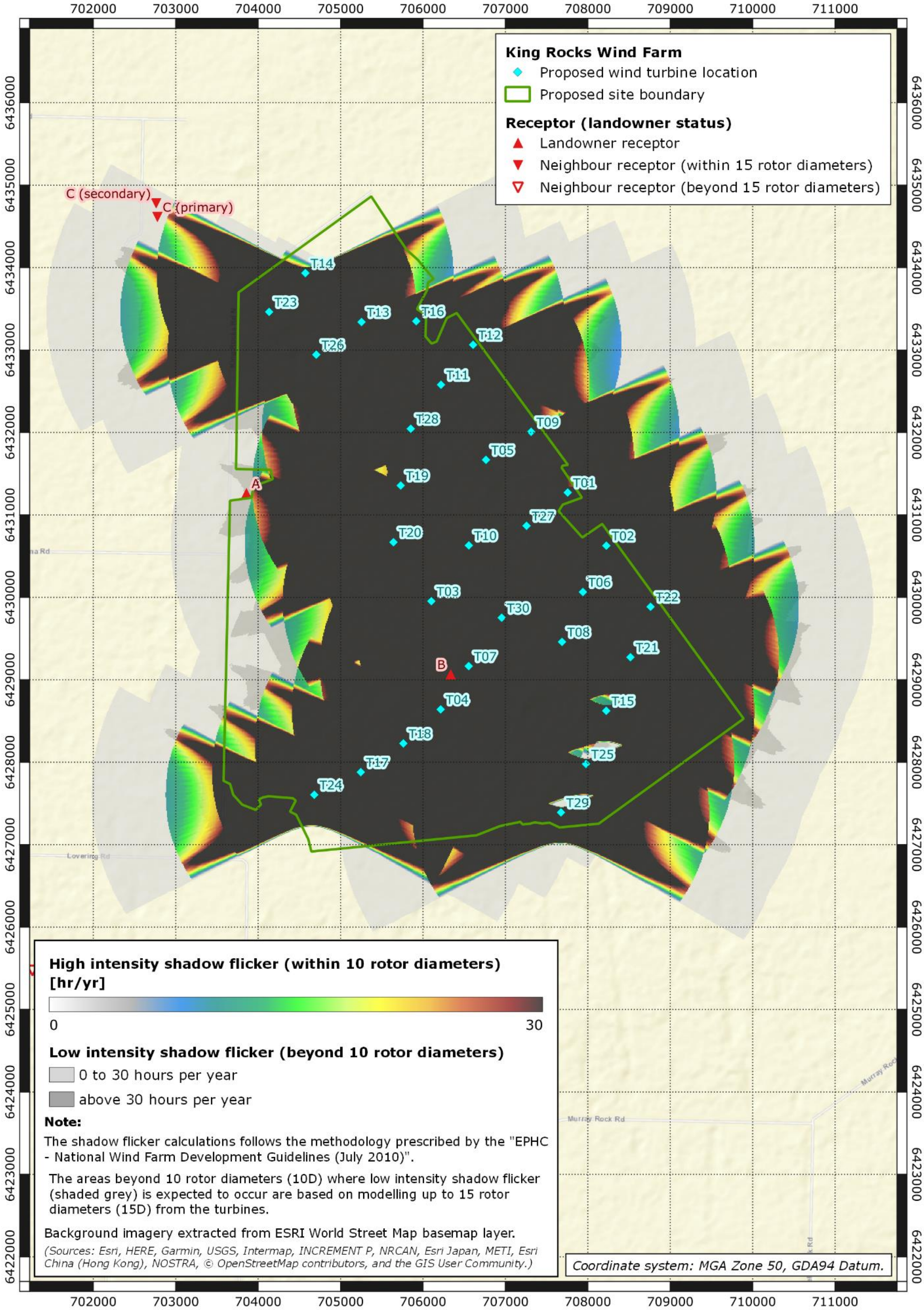

Figure 6 Theoretical annual shadow flicker duration map

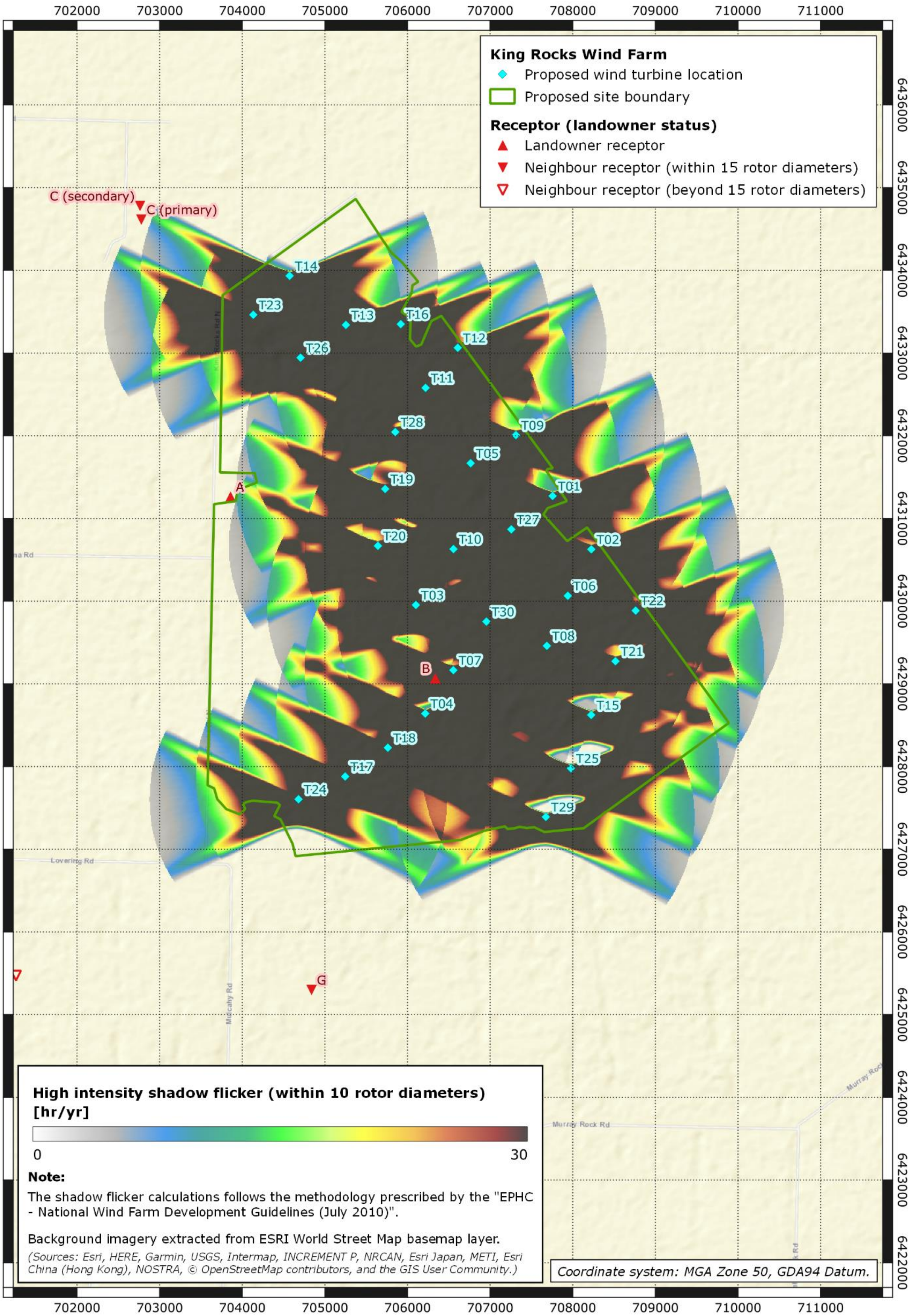

Figure 7 Predicted actual annual shadow flicker duration map

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