BEENUP WIND FARM

Shadow Flicker and Blade Glint Assessment

Urbis Ltd

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Urbis Sub Consultancy Agreement "Beenup Wind Farm Project: Provision of services by DNV Australia Pty Ltd", dated 11 October 2024

Objective: Beenup Wind Farm Shadow Flicker and Blade Glint Assessment

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EXECUTIVE SUMMARY

DNV has been commissioned by Urbis Ltd ("Urbis" or "the Customer") to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Beenup Wind Farm ("the Project") in Western Australia. The results of the shadow flicker 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 20 wind turbines with a maximum rotor diameter of 172 m and a hub height of 164 m has been considered in this assessment. The locations of 34 potentially sensitive shadow receptors in the vicinity of the Project have been provided by the Customer. For clarity, note that all potentially sensitive shadow receptors in this report will be referred to as dwellings, even though this list also includes a commercial premises ("dwelling" 12). The Customer has advised that 13 of these dwellings are "involved" dwellings, either as landowners or by commercial agreement, including four dwellings where it is agreed they won't be used for residential or accommodation purposes.

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.

Outcomes of the assessment

Based on this assessment, two dwellings are expected to experience shadow flicker above a moderate level of intensity within 50 m of the dwelling. For the purposes of this assessment, shadow flicker above a moderate level of intensity is assumed to occur up to a distance of 10 rotor diameters from the wind turbines. Both of these dwellings are not involved with the Project.

Of these dwellings, one of them (dwelling number "12") is predicted to experience theoretical shadow flicker above a moderate level of intensity for durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction in this shadow flicker due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of this dwelling reduce below the recommended limit of 10 hours per year. For the other dwelling (number "32"), the durations of theoretical and actual shadow flicker above a moderate level of intensity are predicted to be below the recommended limits.

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.

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.

The effects of blade glint have not been quantified in this study as the Draft National Guidelines [1] do not provide any quantification methodology. The guidelines, however, recommend that the Customer ensures that the turbine blades used have a surface finish with a low reflectivity to avoid occurrences of blade glint.

1 INTRODUCTION

Urbis Ltd ("Urbis" or "the Customer") has commissioned DNV to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Beenup Wind Farm ("the Project") in Western Australia. The results of this work are reported here. This document has been prepared in accordance with Urbis Sub Consultancy Agreement "Beenup Wind Farm Project: Provision of services by DNV Australia Pty Ltd", dated 11 October 2024, 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 approximately 58 km south of Busselton and 12 km northeast of Augusta.

The terrain at the site is relatively simple with elevations ranging from approximately 10 m to 40 m above sea level. The site is comprised of mainly agricultural land with sparse pockets of shrubs throughout. A digital elevation model of the Project terrain was provided by the Customer [2] and was supplemented by a digital elevation model of the surrounding terrain, extending approximately 10 km from the site, 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 20 wind turbines [4]. A map of the site showing the turbine layout and terrain elevations considered in this assessment is shown in Figure 3, 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 rotor diameter of 172 m and hub height of 164 m.

2.2.2 Dwelling locations

The locations of 34 dwellings in the vicinity of the Project have been provided by the Customer [5]. For clarity, all potentially sensitive shadow receptors will be referred to as dwellings in this report, even though this list includes a commercial premises ("dwelling" 12). The Customer has advised that 13 of these dwellings are "involved" dwellings, either as landowners or by commercial agreement, including a number of dwellings where it is agreed they won't be used for residential or accommodation purposes.

For the purposes of this assessment, 25 dwellings have been identified as having the potential to experience shadow flicker, based on their distances from the proposed turbine locations. Of those 25 dwellings, nine have been identified by the Customer as involved dwellings, including four where it is agreed they won't be used for residential or accommodation purposes.

The remaining nine dwellings are at locations that are considered unlikely to be impacted by shadow flicker at intensities typically considered sufficient to cause annoyance, as discussed further in Sections 3.1 and 4.1.2, and have not been considered further in this assessment.

The 25 dwellings considered in this assessment are shown in Figure 3 and presented in Table 2.

It should be noted that the scope of the work reported here does not include a comprehensive survey of dwellings in the vicinity of the Project, and so DNV is relying on dwelling 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 [6]. 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 Environment Protection and Heritage Council (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 at any dwelling should not exceed 30 hours per year at any dwelling, and that the actual or measured shadow flicker duration should not exceed 10 hours per year. 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 [7, 8] 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

Blade glint involves the regular reflection of the 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 [1].

A methodology for the quantification of blade glint impacts as well as a regulatory limit are not provided by the Draft National Guidelines [9]. However, the Draft National Guidelines suggest that the Customer ensures the blades of the wind turbines have a finish with low reflectivity.

In relation to blade glint, guidance from the Draft National Guidelines [1] states that:

> *"Blade glint can be produced when the sun's light is reflected from the surface of wind turbine blades. Blade glint has potential to annoy people.*
>
> *All major wind turbine blade 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.*
>
> *Proponents should ensure that blades from their supplier are of low reflectivity."*

DNV

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.

In the absence of detailed dwelling height information, shadow flicker has been calculated at the 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 [7, 8] 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 1720 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 calculated the shadow flicker to a distance of up to 15 times the rotor diameter (15D), or 2580 m, which should include shadow flicker below a "moderate level of intensity".

In this assessment, shadow flicker of a moderate level of intensity or above is assumed to occur up to a distance of approximately 10D from the wind farm. Conversely, shadow flicker below a moderate level of intensity, described as "low intensity" shadow flicker in this report, 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 4. 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 overestimation of the 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 dwelling.

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:

- Cape Leeuwin (9518), located approximately 22 km southwest of the centre of the Project site [10]
- Jarrahwood (9842), located approximately 58 km northeast of the centre of the Project site [11]
- Pemberton (9592), located approximately 74 km southwest of the centre of the Project site [12]
- Manjimup (9573), located approximately 78 km east of the centre of the Project site [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 50% and 71%, and the average annual cloud cover is approximately 63%. This implies that on an average day, 63% 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 at the site was derived from publicly available wind direction data [14] [15] [16] and used to estimate the reduction in shadow flicker duration due to rotor orientation. The resulting wind rose is shown overlaid on the indicative shadow flicker map in Figure 4. The 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, and the results are summarised in Table 4.

The results of the theoretical and predicted actual shadow flicker modelling are also shown in the form of shadow flicker maps in Figure 5 and Figure 6 respectively. The shadow flicker values presented in these maps represent the worst case between the results calculated at 2 m and 6 m above ground level for each modelled grid point.

Based on this assessment, two dwellings are expected to experience shadow flicker above a moderate level of intensity within 50 m of the dwelling. For the purposes of this assessment, shadow flicker above a moderate level of intensity is assumed to occur up to a distance of 10 rotor diameters from the wind turbines. Both of these dwellings are not involved with the Project.

Of these dwellings, one of them (dwelling 12) is predicted to experience theoretical shadow flicker above a moderate level of intensity for durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction in this shadow flicker due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of this dwelling reduce below the recommended limit of 10 hours per year. For the other dwelling (number "32"), the durations of theoretical and actual shadow flicker above a moderate level of intensity are predicted to be below the recommended limits.

Beyond the 10D distance limit, it is assumed that any shadow flicker experienced will be below a moderate level of intensity and unlikely to cause annoyance. However, as discussed in Section 4.1.2, 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, although not part of the methodology outlined in the Draft National Guidelines, DNV has also calculated the theoretical shadow flicker impacts for the Project for an increased distance limit of 15D that is intended to include shadow flicker of low intensity. The results of this additional assessment are also included in the map presented in Figure 5. These results indicate that, in addition to the dwellings expected to be affected by shadow flicker above a moderate level of intensity, 12 dwellings may have the potential to be exposed to low intensity shadow flicker. These dwellings are noted in Table 2.

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 20 turbines with a rotor diameter of 172 m and a hub height of 164 m. These dimensions represent the maximum turbine dimensions currently under consideration for the Project.

Based on this assessment, two dwellings are expected to experience shadow flicker above a moderate level of intensity within 50 m of the dwelling. For the purposes of this assessment, shadow flicker above a moderate level of intensity is assumed to occur up to a distance of 10 rotor diameters from the wind turbines. Both of these dwellings are not involved with the Project.

Of these dwellings, one of them (dwelling number "12") is predicted to experience theoretical shadow flicker above a moderate level of intensity for durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction in this shadow flicker due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of this dwelling reduce below the recommended limit of 10 hours per year. For the other dwelling (number "32"), the durations of theoretical and actual shadow flicker above a moderate level of intensity are predicted to be below the recommended limits.

It is recommended that the Customer ensures the turbine blades are coated with a non-reflective paint to avoid the occurrence of blade glint from the wind farm.

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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]
T1	341140	6216362	35	T11	340893	6210691	24
T2	340789	6215512	32	T12	342468	6210422	32
T3	341919	6215415	37	T13	345296	6209961	27
T4	345089	6214694	35	T14	340963	6209853	22
T5	343989	6214377	36	T15	344918	6209443	28
T6	343100	6213973	35	T16	343579	6209172	31
T7	343658	6211892	35	T17	341749	6209112	19
T8	345139	6211672	32	T18	343609	6208448	30
T9	341439	6211432	28	T19	342822	6208140	28
T10	343229	6211314	34	T20	343193	6207619	28

1. 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.

Table 2 Locations of dwellings considered in this assessment [5]

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Nearest turbine Distance [m][2]	Nearest turbine Turbine ID
1	339933	6218621	2560	T1
2	340681	6218532	2216	T1
3	340855	6218801	2454	T1
6	341069	6218432	2069	T1
7	*341528*	*6217917*	*1600*	*T1*
9	342689	6218169	2378	T1
11 [3]	*343529*	*6214483*	*473*	*T5*
12	340601	6214584	949	T2
13	338389	6215122	2433	T2
14	*338449*	*6214374*	*2604*	*T2*
17	*340918*	*6213803*	*1715*	*T2*
18	*341404*	*6213392*	*1794*	*T6*
19	*338804*	*6211699*	*2319*	*T11*
20	340479	6207562	2006	T17
21	340818	6207345	2000	T17
22	341298	6207232	1775	T19
23	341567	6206855	1798	T19
24	341486	6206578	2000	T20
25 [3]	*342442*	*6208726*	*698*	*T19*
26 [3]	*344715*	*6209164*	*346*	*T15*
27 [3]	*345037*	*6210146*	*318*	*T13*
28	347594	6209196	2421	T13
32	341223	6207695	1513	T13
33	341234	6207287	1804	T19
34	339819	6217839	1981	T1

1. 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.
2. The shadow flicker assessment has considered dwellings up to a maximum distance of 15D + 50 m from the Project wind turbines.
3. Involved dwelling where there is a commercial agreement such that the dwelling will not be used for residential or accomodation purposes.
4. Involved dwellings are indicated by *underlined italic text*.

Table 3 Shadow flicker model settings for theoretical shadow flicker calculation

Model setting	
Shadow distance limit (10D)	1720 m
Year of calculation	2037
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 dwelling	8 points evenly spaced (every 45°) on 25 m and 50 m radius circles centred on the provided dwelling location

Table 4 Theoretical and predicted actual annual shadow flicker duration

Dwelling ID	Easting[1] [m]	Northing[1] [m]	Landowner status	Contributing turbines[2]	Theoretical annual				Predicted actual annual[3]			
					At dwelling [hr/yr]		Max within 50 m [hr/yr]		At dwelling [hr/yr]		Max within 50 m [hr/yr]	
					2 m	6 m	2 m	6 m	2 m	6 m	2 m	6 m
12	340601	6214584	Non-involved	T3 T6	**33.0**	**32.6**	**35.1**	**34.4**	5.9	5.8	6.1	6.0
13[4]	338389	6215122	Non-involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14[4]	338449	6214374	Involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17[4]	340918	6213803	Involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18[4]	341404	6213392	Involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19[4]	338804	6211699	Involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20[4]	340479	6207562	Non-involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21[4]	340818	6207345	Non-involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22[4]	341567	6206855	Non-involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23[4]	341486	6206578	Non-involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24[4]	338804	6211699	Non-involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30[4]	347593	6209195	Non-involved	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	341223	6207695	Non-involved	T18 T19 T20	12.1	12.0	12.8	12.8	2.5	2.4	2.6	2.6
33[4]	341234	6207287	Non-involved	-	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. 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.
2. Contributing turbines shown are for the theoretical shadow flicker calculated at 2 m above ground level.
3. Considering likely reductions in shadow flicker duration due to cloud cover and turbine orientation.
4. Dwelling is not predicted to experience any shadow flicker above a moderate level of intensity, but may experience low intensity shadow flicker.

LIST OF FIGURES

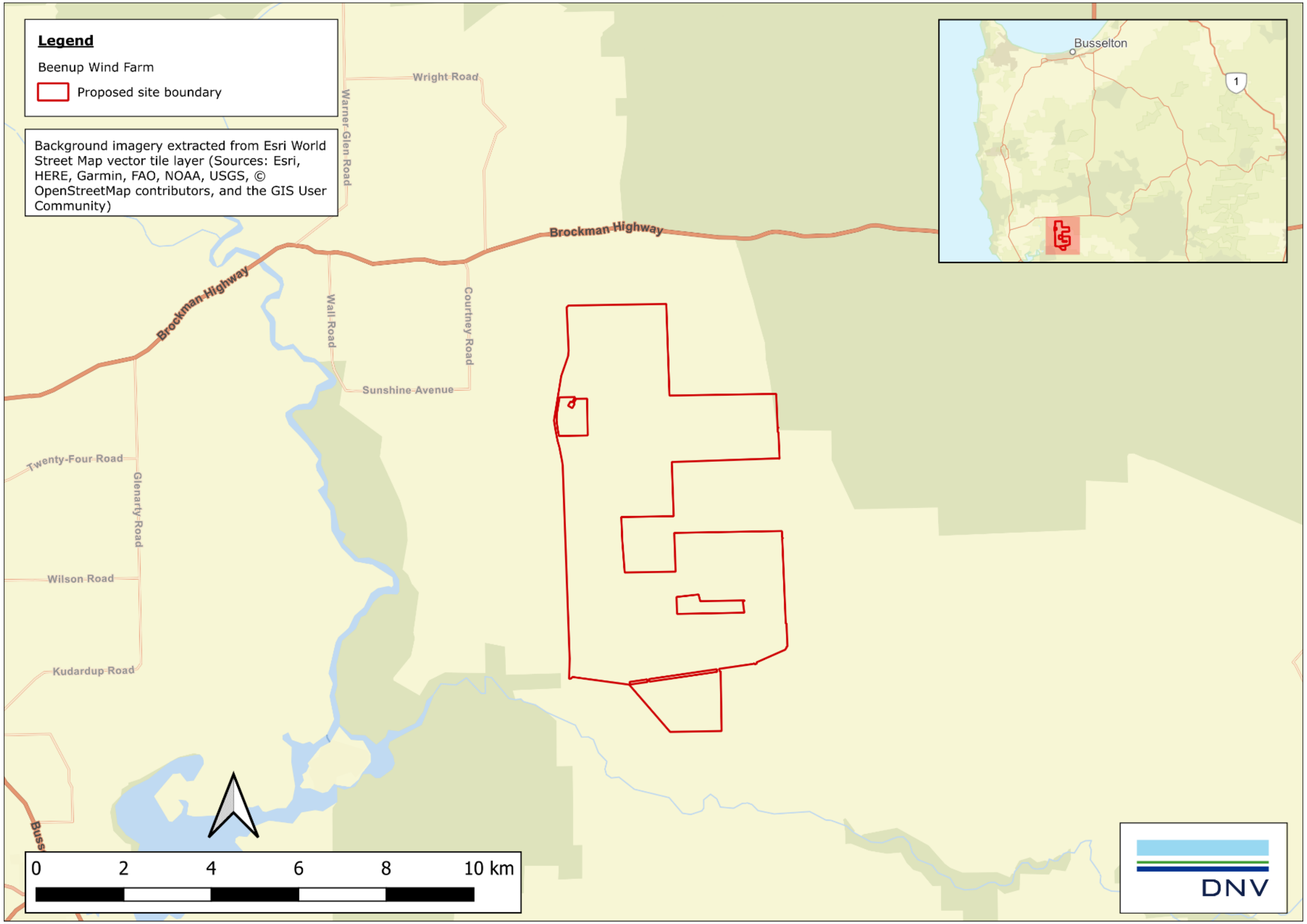

Figure 2 Location of the Project

DNV

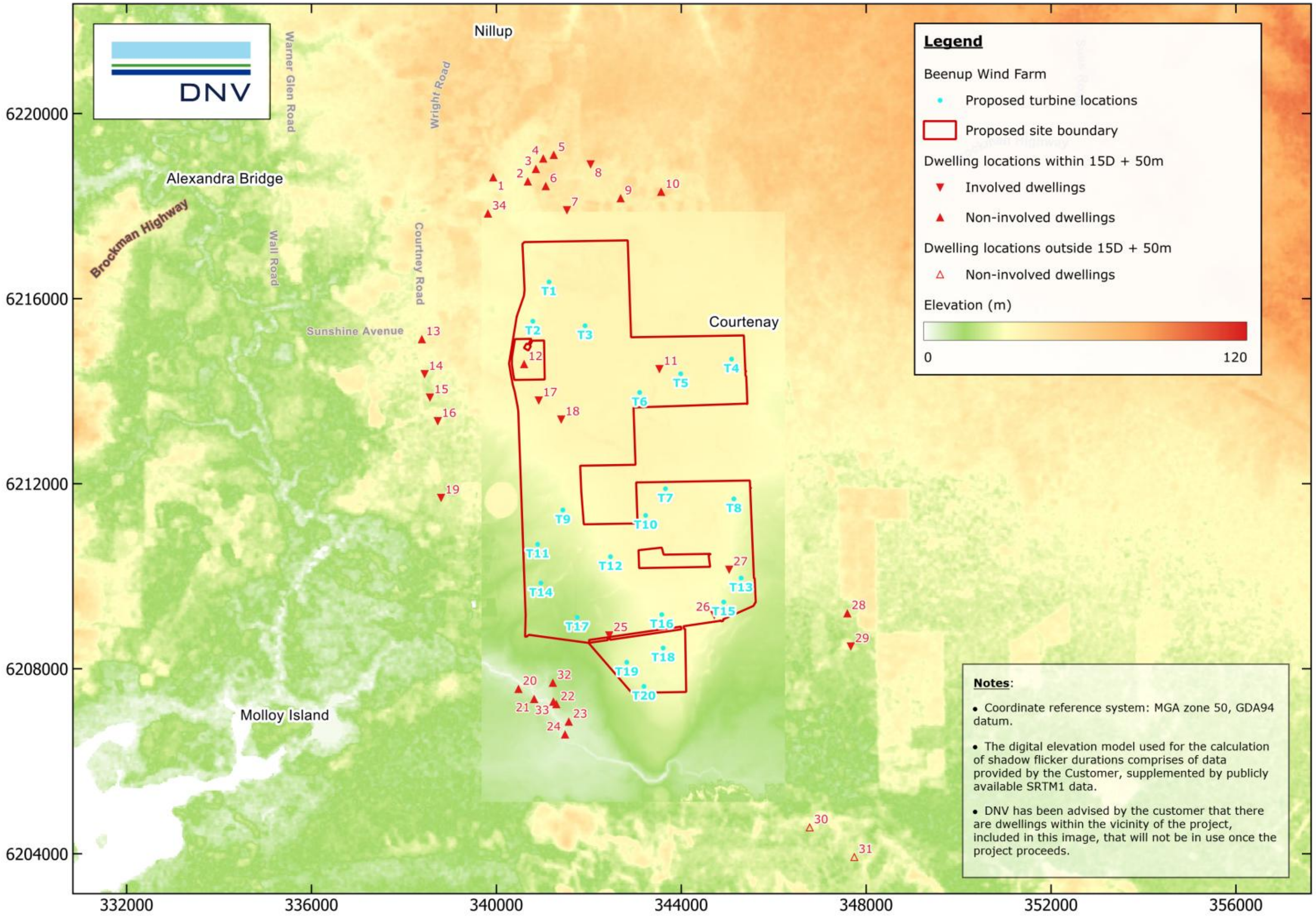

Figure 3 Map of the proposed Project, showing proposed turbine locations, nearby dwellings, and terrain elevation

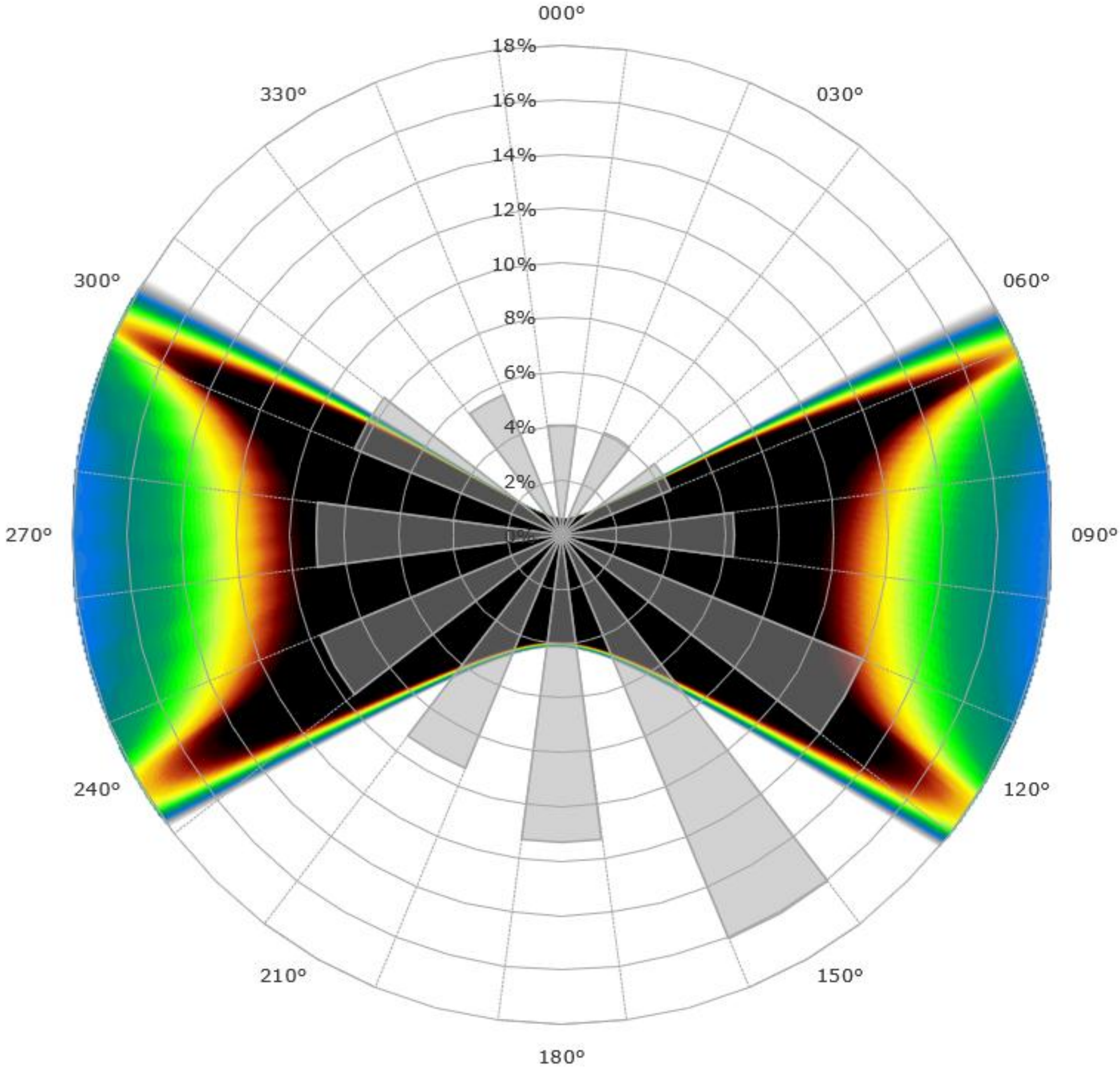

Figure 4 Indicative shadow flicker map and wind direction frequency distribution

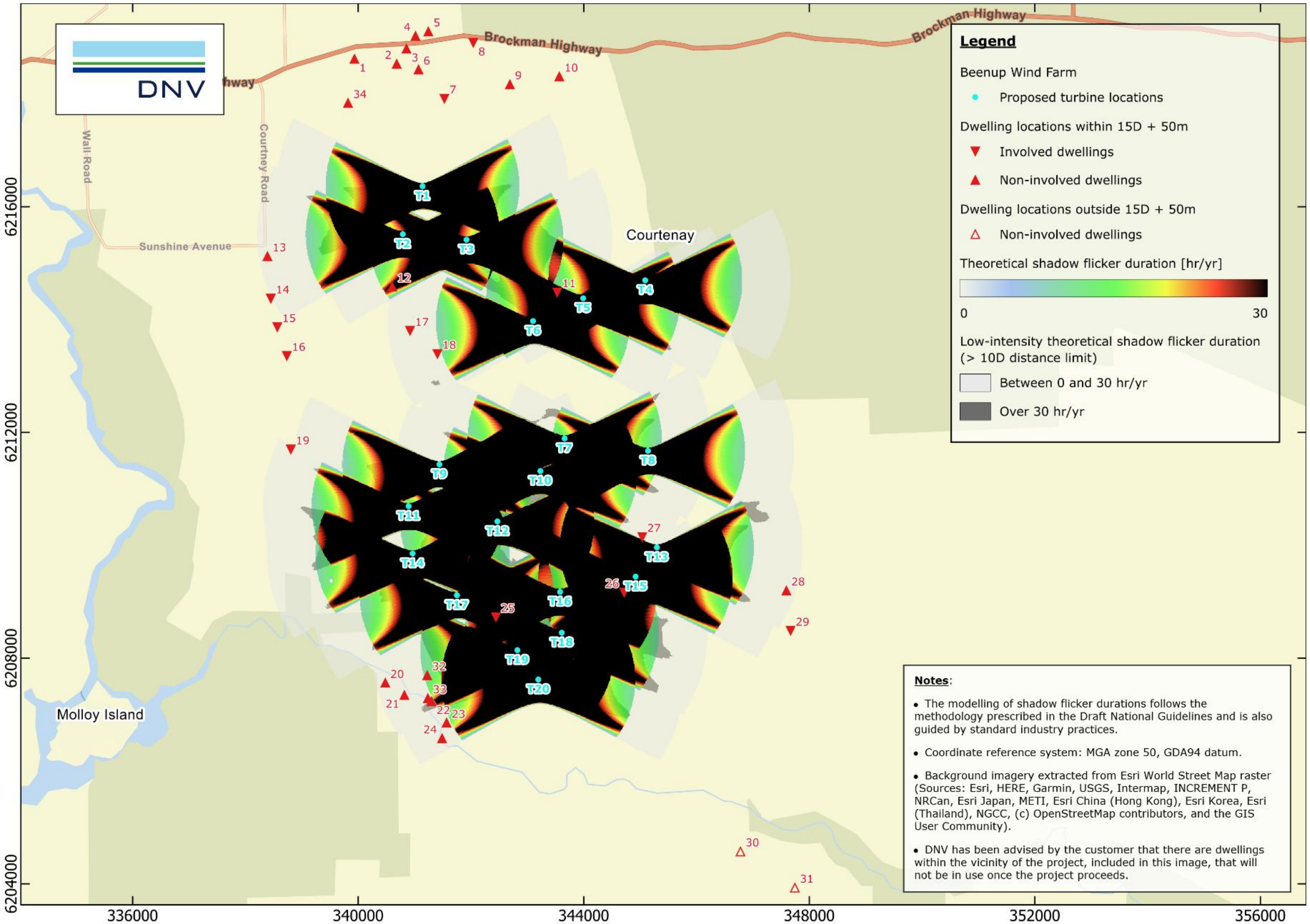

Figure 5 Theoretical annual shadow flicker duration map for the Project

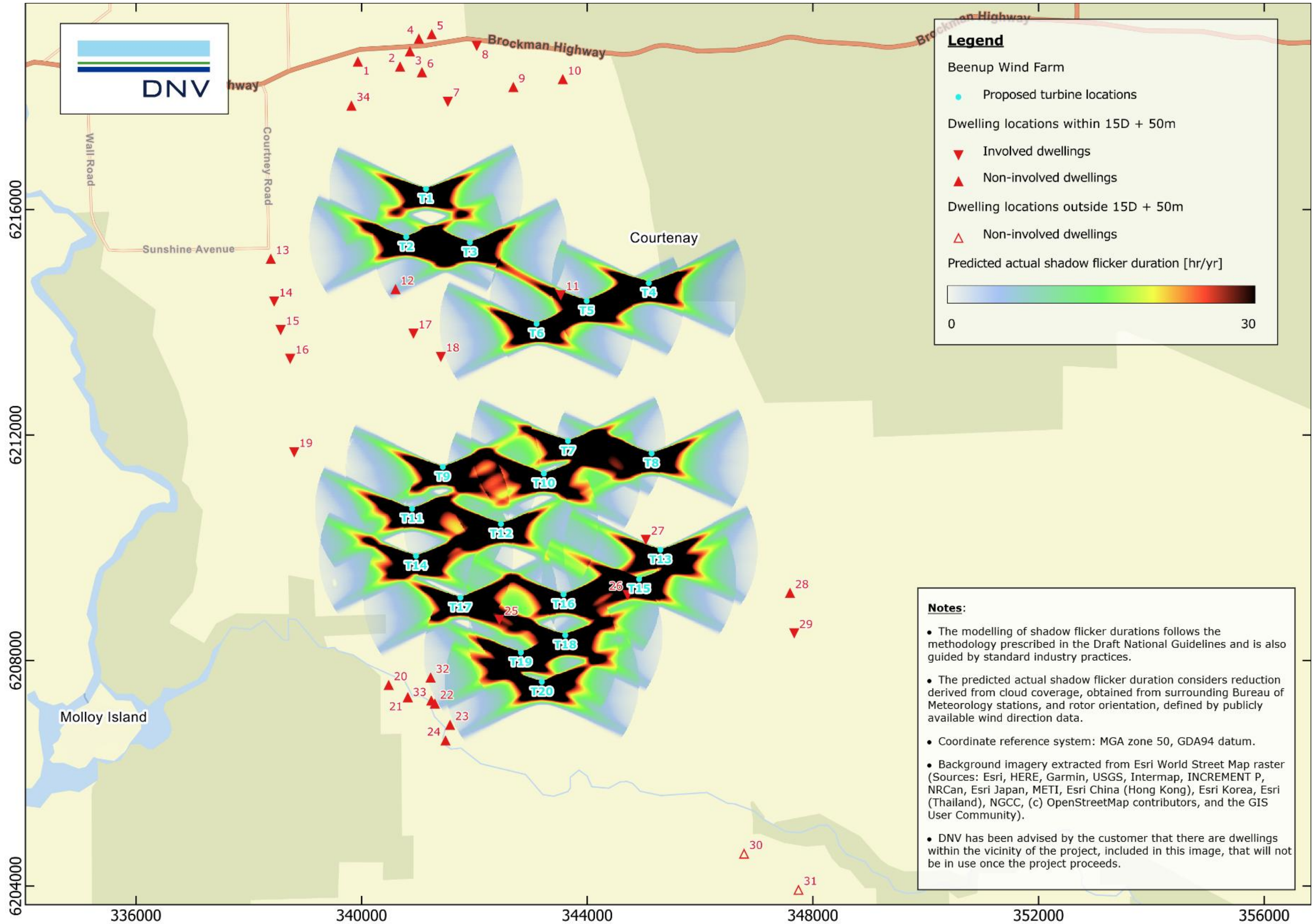

Figure 6 Predicted actual annual shadow flicker duration map for the Project

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