CLEVE WIND FARM

Shadow Flicker and Blade Glint Assessment

AECOM Australia Pty Ltd

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Project name:	Cleve Wind Farm	DNV Energy Systems
Report title:	Shadow Flicker and Blade Glint Assessment	Level 12, 350 Queen Street
Customer:	AECOM Australia Pty Ltd	Melbourne Vic 3000
	Level 28, 91 King William Street	Australia
	Adelaide SA 5000	Tel: +61 3 8615 1515
Customer contact:	Jeff Tomlian	ABN 19 094 520 760
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Prepared by:	Verified by:	Approved by:
P Degorski *Consultant* *Energy Analytics*	**E Tomlinson** *Engineer* *Energy Analytics*	**N Brammer** *Senior Engineer* *Team Lead – Technical Planning* *Energy Analytics*

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EXECUTIVE SUMMARY

DNV has been commissioned by AECOM Australia Pty Ltd ("the Customer") to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Cleve Wind Farm ("the Project") in South 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 80 wind turbines with a maximum rotor diameter of 172 m and a hub height of 150 m has been considered in this assessment [2]. The locations of 663 receptors in the vicinity of the Project have been provided by the Customer [3]. The Customer has advised that 23 of these receptors are associated with the Project.

The theoretical shadow flicker durations at receptors 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 receptor 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, 9 receptors are expected to experience shadow flicker above a moderate level of intensity within 50 m of the receptor. For the purposes of this assessment, shadow flicker above a moderate level of intensity is assumed to occur up to a distance of around 10 rotor diameters from the wind turbines. All these receptors are associated with the Project.

Out of the 9 receptors predicted to experience shadow flicker above a moderate level of intensity, 2 are predicted to experience theoretical shadow flicker durations above the recommended limit of 30 hours per year within 50 m of the receptor. When considering the likely reduction in shadow flicker duration due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of both these receptors remain above the recommended limit of 10 hours per year. The predicted shadow flicker durations at Receptor 16 significantly exceed the recommended theoretical and actual 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 receptor.

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

AECOM Australia Pty Ltd ("the Customer") has commissioned DNV to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Cleve Wind Farm ("the Project") in South Australia. The results of this work are reported here. This document has been prepared in accordance with the AECOM subconsultancy agreement dated 9 July 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 13 km north-west of Cleve and 125 km south-west of Whyalla.

The terrain at the site is relatively simple with elevations above sea level ranging from approximately 410 m in the north-east decreasing to 150 m in the south-west. The site is comprised of agricultural land with pockets of forest and shrubs throughout. A digital elevation model of the surrounding terrain was derived from publicly available SRTM1 data [4].

2.2 The Project

2.2.1 Proposed wind farm layout

The Project is proposed to consist of 80 wind turbines [5]. 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 150 m [6].

2.2.2 Receptor locations

The locations of 663 receptors in the vicinity of the Project were provided to DNV by the Customer [3], of which 23 have been identified by the Customer as associated with the Project [7].

For the purposes of this assessment, 30 receptors have been identified as having the potential to experience shadow flicker, based on their distances from the proposed turbine locations, and these have been considered in this assessment. The remaining 633 receptors are at locations that are considered unlikely to be impacted by shadow flicker of an intensity typically considered sufficient to cause annoyance, as discussed further in Sections 3.1 and 4.1.

The locations of the 30 receptors considered in this assessment are shown in Figure 3 and presented in Table 2.

Out of those 30 receptors:

- 20 are associated with the Project
- 10 are not associated.

It should be noted that the scope of the current work has not included a comprehensive survey of sensitive land uses and building locations in the area, and so DNV is relying on the information provided by the Customer.

3 REGULATORY REQUIREMENTS

3.1 Shadow flicker

The South Australian Planning and Design Code (SA Planning Code) published by the Government of South Australia [8] includes the following requirement (Performance Outcome 3.4 – Interface between Land Uses, Overshadowing):

> *"Development that incorporates moving parts, including windmills and wind farms, are located and operated to not cause unreasonable nuisance to nearby dwellings and tourist accommodation caused by shadow flicker."*

However, the SA Planning Code does not discuss a methodology for assessing shadow flicker or guidance on allowable shadow flicker durations. 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 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 [9, 10] 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 [11]. 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."*

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 receptors and has determined the highest shadow flicker duration within 50 m of each of these locations.

Shadow flicker has been calculated at receptors 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 receptor 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 [9, 10] 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 assessed 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 turbines. 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 turbines.

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 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:

- Kimba (18040), located approximately 50 km north of the centre of the site [12]
- Polda (18139), located approximately 100 km west of the centre of the site [13]
- Whyalla AERO (18120), located approximately 120 km northeast of the centre of the site [14]
- Port Lincoln (18070), located approximately 130 km southwest of the centre of the site [15].
- Cleve (18014), located approximately 15 km southeast of the centre of the site [16].

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 44.0% and 60.6%, and the average annual cloud cover is approximately 53.7%. This implies that on an average day, 53.7% 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 publicly available wind direction data at the site was obtained [17] and used to estimate the reduction in shadow flicker duration due to rotor orientation. The site wind rose is shown overlaid on the indicative shadow flicker map in Figure 4. 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 receptor. 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 receptor.

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 receptor locations, as summarised in Table 2.

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, 9 receptors are predicted to experience shadow flicker of 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 expected to occur up to a distance of around 10 rotor diameters from the wind farm. All of these receptors are associated with the Project.

Out of the 9 receptors predicted to experience shadow flicker above a moderate level of intensity, 2 are predicted to experience theoretical shadow flicker durations within 50 m of the receptor that exceed the limit of 30 hours per year recommended by the Draft National Guidelines (Receptor ID 11 and 16). When considering the likely reduction due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of the 2 affected receptors remain above the recommended limit of 10 hours per year. The predicted shadow flicker durations at Receptor 16 significantly exceed the recommended theoretical and actual 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 3.1, 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 assessed the 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 receptors expected to be affected by shadow flicker above a moderate level of intensity, 12 receptors may have the potential to be exposed to low intensity shadow flicker. These receptors 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 receptor locations in the vicinity of the Project.

For the purpose of this assessment, DNV has considered a layout consisting of 80turbines with a rotor diameter of 172 m and a hub height of 150 m.

Based on this assessment, 9 receptors are predicted to experience some shadow flicker above a moderate level of intensity witin 50 m of the dwelling, all of which are associated with the Project. 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.

Out of the 9 receptors predicted to experience shadow flicker above a moderate level of intensity, 2 are predicted to experience theoretical shadow flicker durations above the recommended limit of 30 hours per year within 50 m of the receptor. When considering the likely reduction in shadow flicker duration due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of the 2 receptors remain above the recommended limit of 10 hours per year. The predicted shadow flicker durations at Receptor 16 significantly exceed the recommended theoretical and actual limits.

It is recommended that the Customer ensures the turbine blades are coated with a non-reflective paint in order 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 [5]

Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]	Turbine ID	Easting[1] [m]	Northing[1] [m]	Base elevation [m]
T01	619952	6284424	215	T02	620419	6284649	227
T03	620876	6284863	240	T04	621343	6285099	257
T05	621791	6285325	232	T06	622267	6285538	225
T07	622725	6285798	224	T08	623172	6286012	225
T09	623639	6286248	235	T10	624073	6286520	253
T11	624522	6286784	284	T12	624465	6287675	246
T15	625724	6288898	275	T13	624892	6288135	242
T14	625361	6288487	249	T16	625522	6285998	299
T17	626027	6286145	299	T18	628776	6287818	311
T19	625365	6284402	274	T20	626008	6283951	298
T21	626676	6284103	310	T22	627550	6284463	315
T23	628134	6284741	316	T24	629902	6285999	361
T25	630306	6286372	360	T26	630658	6286800	374
T27	631120	6287050	376	T28	622821	6276682	214
T29	623211	6276919	222	T30	623737	6277465	239
T31	624055	6277791	240	T32	624223	6278232	273
T33	624429	6279006	252	T34	625116	6279105	294
T35	625135	6279797	310	T36	625549	6280121	321
T37	625891	6281033	315	T38	626302	6281397	298
T39	631772	6283010	314	T40	632216	6283336	341
T41	632660	6283679	346	T42	633076	6284041	348
T43	633507	6284427	357	T44	633917	6284745	372
T45	628447	6281244	335	T46	629167	6281249	329
T47	629734	6281324	345	T48	630168	6281375	345
T49	630683	6281564	342	T50	631114	6281610	346
T51	631601	6281575	335	T52	632100	6281600	331
T53	632589	6281711	347	T54	633069	6281817	353
T55	633541	6282033	363	T56	633955	6282297	368
T57	634337	6282718	384	T58	634875	6282771	388
T59	628450	6278620	285	T60	628717	6279051	291
T61	629079	6279404	294	T62	629875	6279284	277
T63	630341	6279649	276	T64	631015	6279616	267
T65	631914	6279035	283	T66	632315	6279365	292
T67	632677	6279739	320	T68	635540	6280349	366
T69	635951	6280607	368	T70	636347	6280876	363
T71	629362	6275255	217	T72	635641	6277837	313
T73	636021	6278230	345	T74	630464	6273289	229
T75	630978	6273446	215	T76	631444	6273625	231
T77	631844	6273960	255	T82	636515	6276345	328
T83	636991	6276540	343	T84	637407	6276861	353

1. Coordinate system: MGA zone 53, GDA 94 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 receptors assessed for potential shadow flicker in this report [3]

Receptor ID	Landowner status	Easting[1] [m]	Northing[1] [m]	Nearest turbine	
				Distance [m]	Turbine ID
1	Associated	627769	6286335	1635	T23
2	Associated	623327	6284128	1764	T06
3	Associated	627498	6282847	1501	T21
4	Associated	630040	6283665	1851	T39
5	Associated	621871	6282621	2453	T03
6	Associated	622990	6281148	2535	T35
7	Associated	627265	6279944	1705	T60
8	Associated	634288	6279281	1646	T68
9	Associated	637757	6278441	1619	T84
10	Associated	621114	6277485	1886	T28
11	Associated	625532	6277477	1510	T31
12	Associated	629090	6276992	1750	T59
13	Associated	630845	6277349	1997	T65
14	Associated	635178	6276281	1338	T82
16	Associated	629889	6275416	551	T71
17	Associated	630815	6276139	1701	T71
18	Associated	633574	6274884	1962	T77
21	Associated	627881	6274623	1610	T71
22	Associated	628677	6272963	1816	T74
23	Associated	628788	6272986	1701	T74
94	Non-associated	620668	6275406	2502	T28
95	Non-associated	621838	6287496	1916	T07
96	Non-associated	620849	6287691	2547	T05
97	Non-associated	618446	6285819	2053	T01
103	Non-associated	624741	6290353	1756	T15
104	Non-associated	627251	6289861	1805	T15
108	Non-associated	636804	6282428	1618	T70
632	Non-associated	638746	6281522	2484	T70
642	Non-associated	618903	6282646	2064	T01
661	Non-associated	632908	6286931	1792	T27

1. Coordinate system: MGA zone 53 , 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 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 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

Receptor ID	Easting[1] [m]	Northing[1] [m]	Landowner status	Contributing turbines	Theoretical annual				Pr
					At receptor [hr/yr]		Max within 50 m [hr/yr]		At rec [hr/
					2 m	6 m	2 m	6 m	2 m
1	627769	6286335	Associated	T17	0.0	0.0	7.8	7.4	0.0
2[3]	623327	6284128	Associated	-	0.0	0.0	0.0	0.0	0.0
3[3]	627498	6282847	Associated	-	0.0	0.0	0.0	0.0	0.0
4[3]	630040	6283665	Associated	-	0.0	0.0	0.0	0.0	0.0
7	627265	6279944	Associated	T36	0.0	0.0	10.9	10.7	0.0
8	634288	6279281	Associated	T67	9.8	9.6	10.7	10.4	2.8
9	637757	6278441	Associated	T73	0.0	0.0	8.5	8.2	0.0
10[3]	621114	6277485	Associated	-	0.0	0.0	0.0	0.0	0.0
11	625532	6277477	Associated	T31 T32	**40.8**	**41.1**	**50.5**	**50.3**	**10.9**
14	635178	6276281	Associated	T82	16.5	16.5	17.8	17.7	4.6
16	629889	6275416	Associated	T71	**120.4**	**122.2**	**145.1**	**146.0**	**39.6**
18[3]	633574	6274884	Associated	-	0.0	0.0	0.0	0.0	0.0
21	627881	6274623	Associated	T71	16.9	16.7	18.9	18.8	4.1
22[3]	628677	6272963	Associated	-	0.0	0.0	0.0	0.0	0.0
23	628788	6272986	Associated	T74	10.8	10.9	11.7	11.6	2.9
94[3]	620668	6275406	Non-associated	-	0.0	0.0	0.0	0.0	0.0
95[3]	621838	6287496	Non-associated	-	0.0	0.0	0.0	0.0	0.0
97[3]	618446	6285819	Non-associated	-	0.0	0.0	0.0	0.0	0.0
108[3]	636804	6282428	Non-associated	-	0.0	0.0	0.0	0.0	0.0
632[3]	638746	6281522	Non-associated	-	0.0	0.0	0.0	0.0	0.0
661[3]	632908	6286931	Non-associated	-	0.0	0.0	0.0	0.0	0.0
Recommended duration limits (hr/yr)					**30 hr/yr**				

1. Coordinate system: MGA zone 53, GDA94 datum. Coordinates were provided by the Customer in a different coordinate system and/or datum and h software, which may result in small discrepancies depending on the software and transformation approach used.
2. Considering likely reductions in shadow flicker duration due to cloud cover and turbine orientation.
3. Receptor is not predicted to experience any *shadow flicker above a moderate level of intensity, but may experience some low-intensity shadow flic*

LIST OF FIGURES

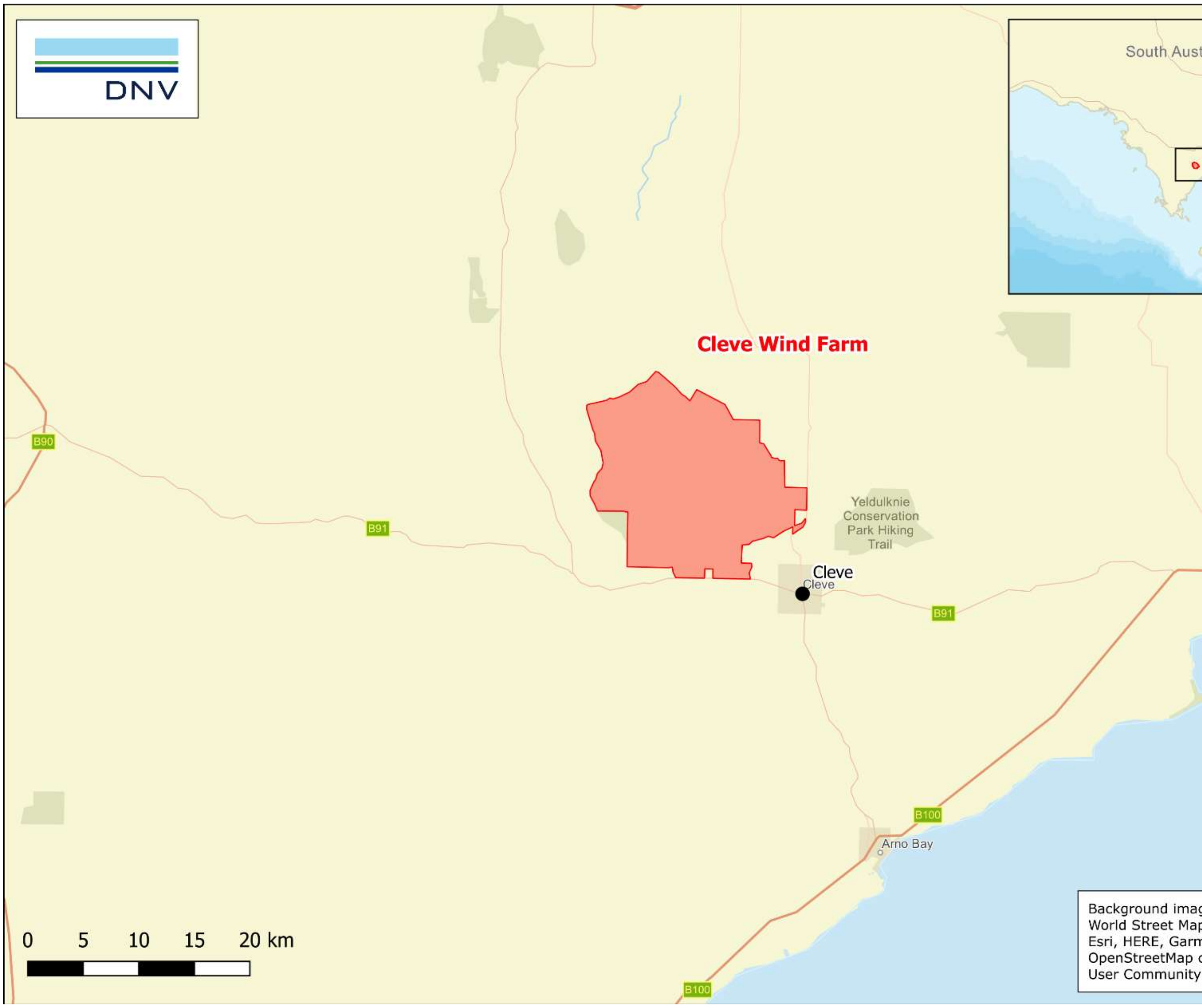

Figure 2 Location of the Project

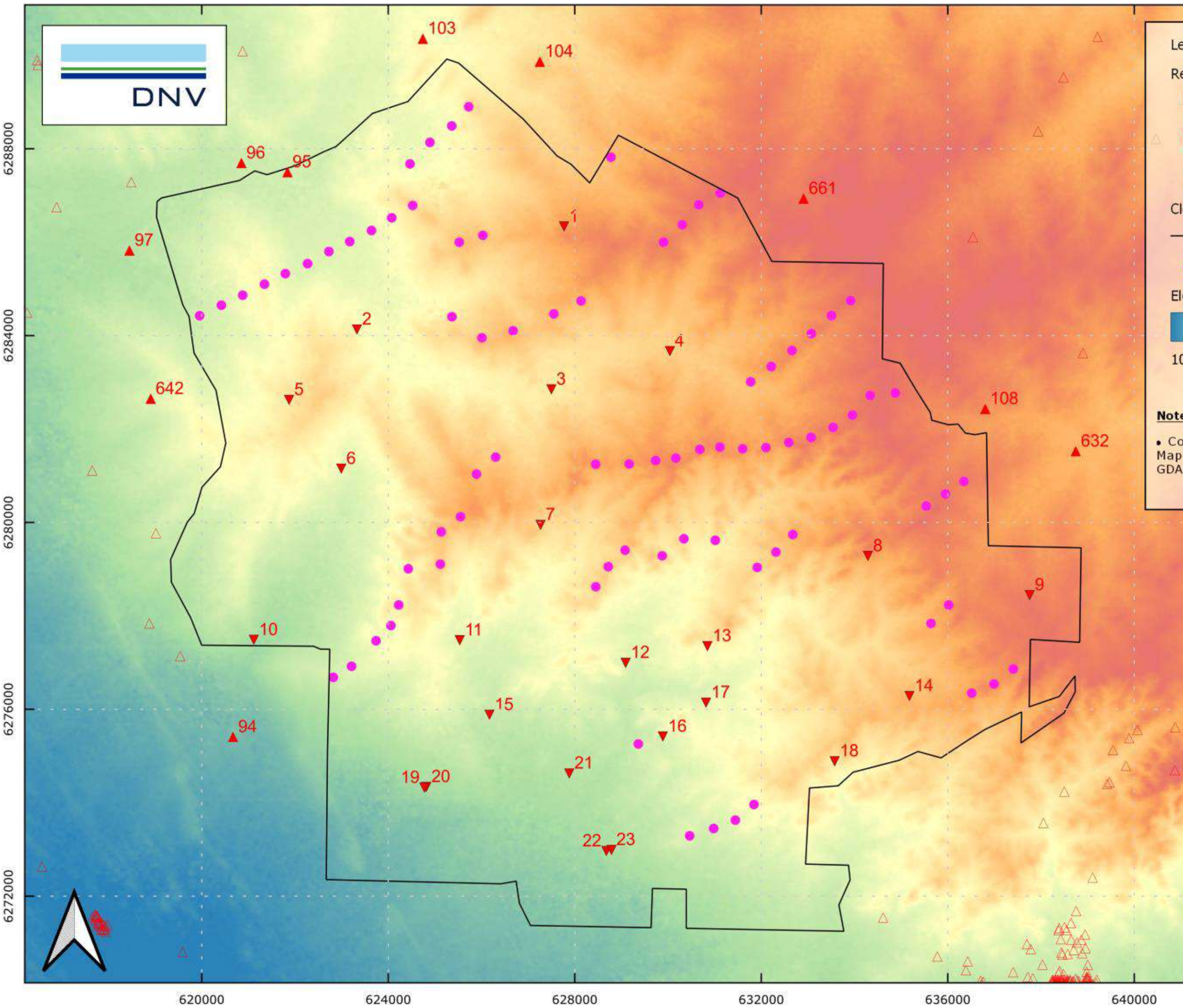

Figure 3 Site layout, showing wind turbines, receptors and elevations

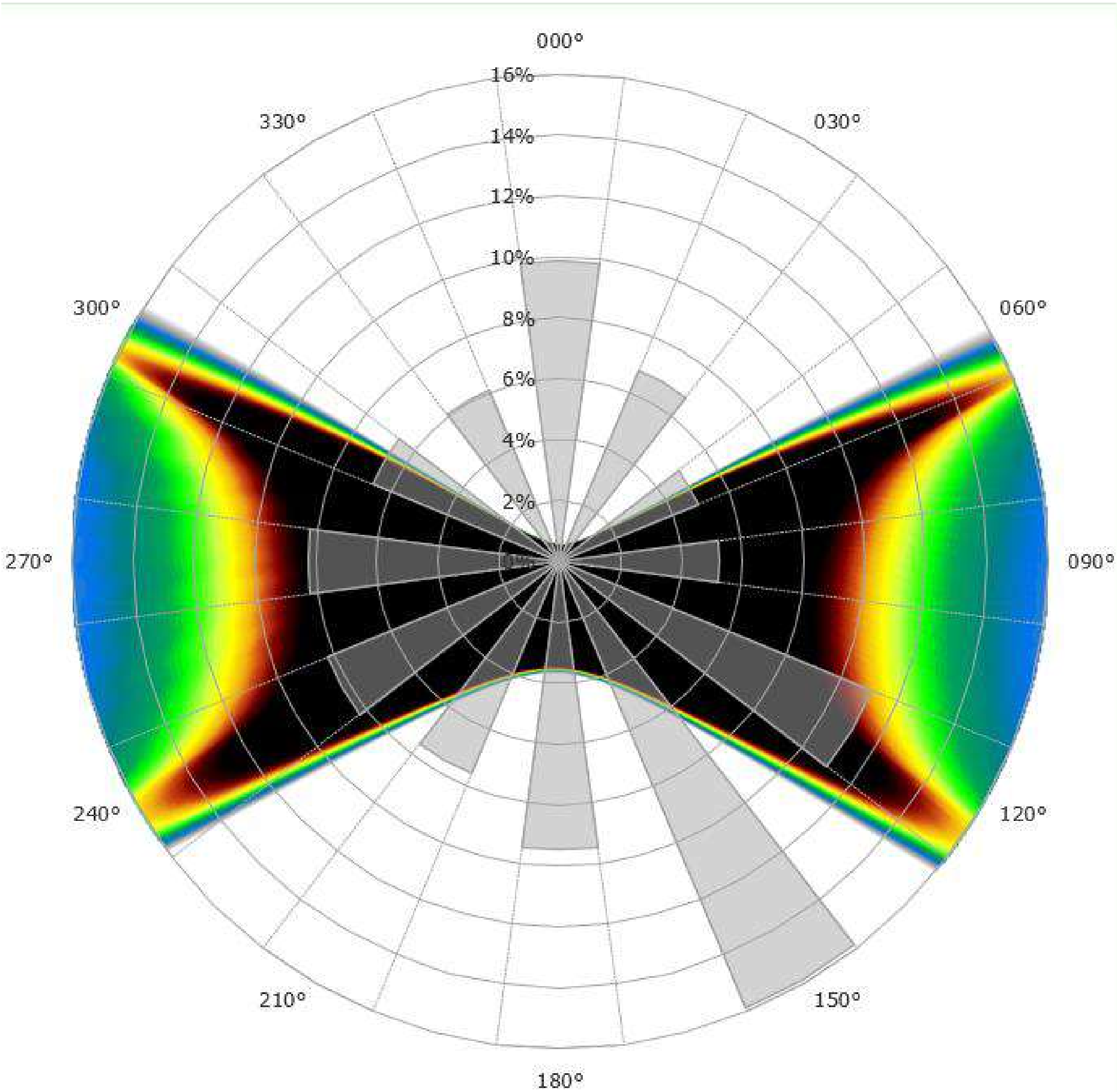

Figure 4 Indicative shadow flicker map and wind direction frequency distribution

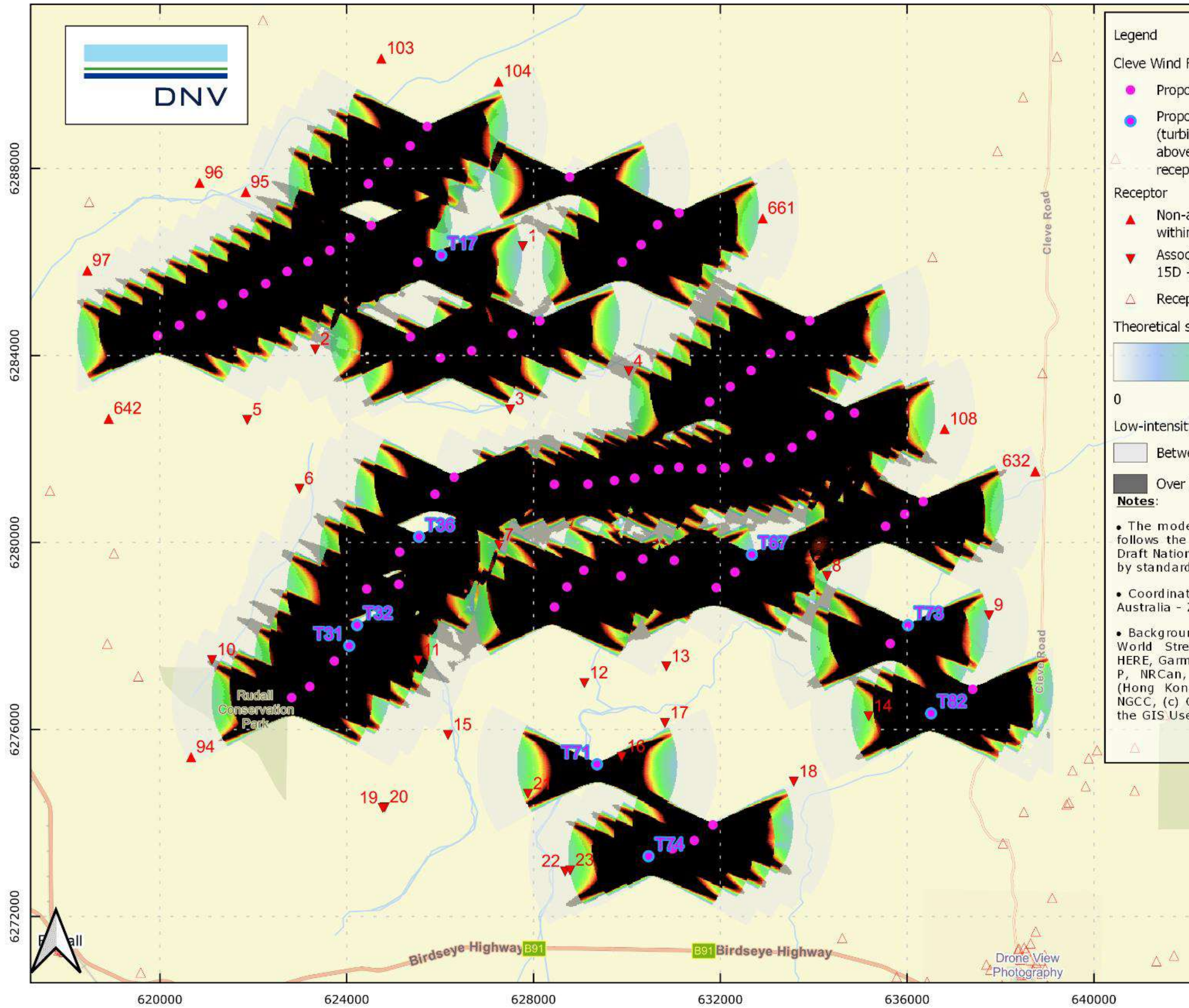

Figure 5 Theoretical annual shadow flicker duration map

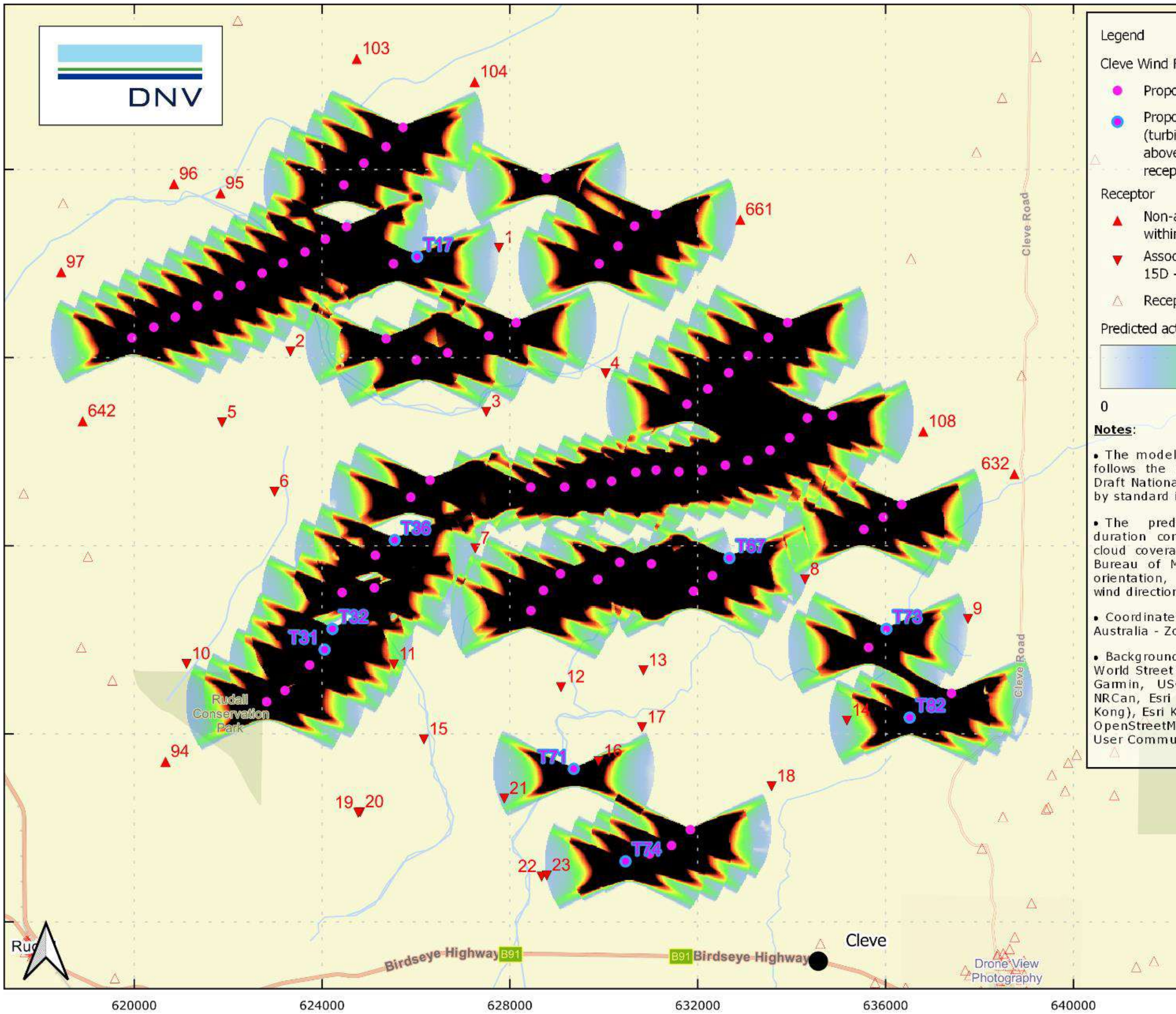

Figure 6 Predicted actual annual shadow flicker duration map

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