DNV·GL

COOPERS GAP WIND FARM

Shadow Flicker and Blade Glint Assessment

AECOM Australia Pty Ltd

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1 EXECUTIVE SUMMARY

DNV GL has been commissioned by AECOM Australia Pty Ltd ("the Customer" or "AECOM") to independently assess the expected annual shadow flicker duration in the vicinity of the proposed Coopers Gap Wind Farm ("the Project"). The results of the work are reported here. This document has been prepared pursuant to the "Offer for Professional Services – Letter of Engagement" received from the Customer and executed on 21 April 2016, as well as subsequent email exchange with the Customer.

Shadow flicker involves the modulation of light levels resulting from the periodic passage of a rotating wind turbine blade between the sun and an observer. The duration of shadow flicker experienced at a specific location can be determined using a purely geometric analysis which takes into account the relative position of the sun throughout the year, the wind turbines at the site, local topography and the viewer. This method has been used to determine the shadow flicker duration at sensitive locations neighbouring the proposed Coopers Gap Wind Farm.

However, this analysis method tends to be conservative and typically results in over-estimation of the number of hours of shadow flicker experienced at a dwelling [1]. Therefore, an attempt has been made to quantify the likely reduction in shadow flicker duration due to cloud cover, and hence produce a prediction of the actual shadow flicker duration likely to be experienced at a dwelling.

The Customer has commissioned DNV GL to assess the shadow flicker based upon a layout provided for the Coopers Gap Wind Farm consisting of 102 turbines [2]. A hypothetical turbine model with a hub height of 110 m and a rotor diameter of 140 m has been considered, as requested by the Customer [3]. The Customer has also provided the locations of 85 sensitive receptors (defined in Section 3 as any habitable building sited on a sensitive land use area) in the vicinity of the wind farm [5, 6], 18 of which have been identified as belonging to financial landowners [4, 5]. Elevation contours for the site and surrounds were provided for a previous assessment [7]. These have been used to determine the theoretical duration of shadow flicker caused by the Coopers Gap Wind Farm at each sensitive receptor.

The Queensland State Code [8] and Planning Guidelines [9] recommend limits of 30 hours per year and 30 minutes per day on the theoretical shadow flicker duration at existing sensitive land uses in the vicinity of the wind farm. In the event that an assessment of the reduction in shadow flicker duration due to cloud cover is completed, the Queensland Planning Guidelines also recommend a reduced limit of 10 hours per year.

This assessment was based on the methodology for assessing shadow flicker durations recommended in the Queensland Planning Guidelines, under the assumption that shadow flicker durations evaluated at sensitive receptors are representative of the shadow flicker durations at the centre of the sensitive land use on which each receptor is located. Calculations were carried out assuming buildings had either one or two stories with window heights of either 2 m or 6 m, respectively. The relevant shadow flicker duration at a sensitive receptor was taken as the maximum calculated duration occurring within 50 m of the receptor.

The results indicate that, of the sensitive receptors identified by the Customer for study, there are locations within 50 m of seven receptors which are predicted to experience some shadow flicker from the turbine locations proposed for the Coopers Gap Wind Farm. Six of these receptors are predicted to experience theoretical shadow flicker durations in excess of the recommended limits of 30 hours per year or 30 minutes per day within 50m of the receptor location. However, DNV GL has been informed that these are all located on land belonging to financial landowners. When considering the predicted actual shadow flicker duration, which takes into account the reduction in shadow flicker due to cloud cover, five of these sensitive receptors are expected to experience actual shadow flicker durations in excess of 10 hours per year, within 50 m of the receptor location.

The prediction of the actual shadow flicker duration presented here does not take into account any reduction due to turbine orientation, low wind speed, vegetation, or other shielding effects around each sensitive receptor in calculating the number of shadow flicker hours. Therefore, the values presented may still be regarded as conservative. The effects of shadow flicker can also be reduced through a number of mitigation measures such as the installation of screening structures or planting of trees to block shadows cast by the turbines, the use of turbine control strategies which shut down turbines when shadow flicker is likely to occur, or the relocation of turbines.

It should be noted that the results presented here have been generated based on a hypothetical turbine with a 110 m hub height and 140 m rotor diameter, as discussed in Section 2.2. If the turbine selected for the site has dimensions smaller than those considered here, but still within the turbine envelope, then shadow flicker durations in the vicinity of the site are likely to be lower than those predicted here.

Blade glint involves the reflection of light from a turbine blade, and can be seen by an observer as a periodic flash of light coming from the wind turbine. Blade glint is not generally a problem for modern turbines provided non-reflective coatings are used for the surface of the blades.

2 DESCRIPTION OF THE PROPOSED WIND FARM SITE

2.1 The Project

The Coopers Gap Wind Farm is being developed by AGL Energy Ltd ("AGL") and AECOM is undertaking the environmental and planning assessment on behalf of AGL in order to obtain planning approval.

The Coopers Gap Wind Farm site is located approximately 175 km northwest of Brisbane, 45 km southwest of Kingaroy and 55 km north-northeast of Dalby in the Cooranga North region of inland Queensland, as shown in Figure 1. The site consists of predominantly cleared land used for farming, scattered vegetation, and small areas of dense forestry. The Bunya Mountains National Park is located approximately 8 km southeast of the proposed site. Topography of the site is characterised by moderate slopes and rolling hills that vary in elevation between approximately 530 m and 840 m with more rugged terrain to the south.

Elevation data for the site area and immediate surrounds was provided to DNV GL for the purpose of a previous assessment of the site [7]. The elevation contours for the Coopers Gap Wind Farm are displayed in Figure 3.

2.2 Proposed Wind Farm Layout

A proposed turbine layout for the Coopers Gap Wind Farm consisting of 102 wind turbine generators was supplied to DNV GL by the Customer [2]. The turbines are proposed to be located upon the local hilltops across the site with base elevations ranging from approximately 530 m to 840 m above sea level.

DNV GL has modelled the shadow flicker using a hypothetical turbine with a 110 m hub height and 140 m rotor diameter configuration, as requested by the Customer [3]. These turbine dimensions are intended to encapsulate the turbine configurations under consideration for the site. The results generated based on these dimensions will be conservative for turbine configurations with dimensions that remain inside the turbine envelope by satisfying all of the following criteria:

- a rotor diameter of 140 m or less;
- a maximum blade chord of 5.3 m (as discussed in Section 4.2);
- an upper blade tip height of 180 m or less; and
- a lower tip height of 40 m or greater.

A list of coordinates of the proposed turbine locations are given in Table 2.

2.3 Sensitive Locations

A list of sensitive locations or receptors neighbouring the wind farm was supplied to DNV GL by the Customer [5, 6].

The coordinates of sensitive receptors within 1.5 km of the proposed turbine locations are presented in Table 1. DNV GL has assumed that all listed sensitive receptors are habitable building structures sited on sensitive land use areas, as defined in Section 3. Sensitive receptors situated more than 1.5 km from turbine locations will have predicted annual shadow flicker durations of zero hours due to the shadow flicker distance limit assumed for the analysis, as discussed further in Sections 3 and 4.2. It should be noted that DNV GL 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 PLANNING GUIDELINES

The Queensland State Development Assessment Provisions for wind farm developments [8] state that a requirement that the proposed wind farm *"Development avoids or minimises shadow flicker impacts on existing or approved sensitive land uses"* by ensuring that

> *"The modelled blade shadow flicker impact on any existing or approved sensitive land use(s) does not exceed 30 hours per annum and 30 minutes per day… [and] wind turbine blades have a low reflectivity finish/treatment"*.

The associated Queensland Wind Farm State Code - Planning Guidelines [9] provides background information, a proposed methodology, and a suite of assumptions for assessing shadow flicker durations in the vicinity of a wind farm in order to demonstrate compliance with the Queensland State Code.

As an alternative to the requirement that the modelled theoretical shadow flicker at an existing sensitive land use should not exceed 30 hours per year or 30 minutes per day, the Queensland Planning Guidelines recommend that the actual shadow flicker duration; determined by taking into account only reductions due to cloud cover and the use of turbine control strategies, should not exceed 10 hours per year. The guidelines also recommend that the shadow flicker duration should be assessed by calculating the maximum shadow flicker occurring within 50 m of the centre of a sensitive land use.

A sensitive land use is defined by the Queensland State Development Assessment Provisions as a child or community care centre, community residence, dual occupancy, dwelling house, educational establishment, health care service, hospital, multiple dwelling, office, re-locatable home park, residential care facility, retirement facility, rooming accommodation, short-term accommodation, or tourist park. This definition includes private land where the owners have negotiated commercial agreements with the wind farm operator, except in the case where a signed Deed of Release has been provided to the relevant regulatory authority. The Queensland Planning Guideline also does not explicitly refer to sensitive receptors when describing the method for assessing shadow flicker, but notes a requirement to assess and report the maximum value of shadow flicker duration within 50m of the centre of a sensitive land use. For the purposes of this report the centre of a sensitive land use will be taken to be the location of the nominated sensitive receptors.

The impact of shadow flicker is typically only significant up to a distance of around 10 rotor diameters from a turbine [10] or approximately 800 to 1400 m for modern wind turbines (which typically have rotor diameters of 80 to 140 m). 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 is acknowledged in the Queensland Planning Guidelines, which state that the first step in performing a shadow flicker assessment is to *"determine the extent of shadows from turbines"* and suggest a distance equivalent to 265 maximum blade chords[1] as an appropriate limit. This limit corresponds to approximately 800 to 1325 m for modern wind turbines, which typically have maximum blade chord lengths of 3 to 5 m.

The Queensland State Code and Planning Guidelines do not provide any specific guidance on blade glint, except to note that wind turbine blades should have a low reflectivity finish/treatment.

[1] The maximum blade chord is the thickest part of the blade.

4 SHADOW FLICKER AND BLADE GLINT ASSESSMENT

4.1 Shadow Flicker 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:

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

4.2 Theoretical Modelled Shadow Flicker 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 wind farm site, 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.

Based on the methodology proposed in the Queensland Planning Guidelines, DNV GL has assessed the shadow flicker at sensitive receptors in the vicinity of the proposed wind farm and also nominated a grid of locations surrounding this point to determine the highest shadow flicker duration within 50 m of the centre of each receptor location. As information about sensitive land use areas in the vicinity of the proposed wind farm was not available, it has been assumed that the shadow flicker duration within 50 m of each sensitive receptor is representative of the shadow flicker that would be experienced within 50 m of the centre of the sensitive land use on which the receptor is located.

Shadow flicker has been calculated at sensitive receptors at heights of 2 m, to represent ground floor windows, and 6 m, to represent second floor windows. The receptors are simulated as fixed points, representing the worst case scenario, as real windows would be facing a particular direction. The shadow flicker calculations for sensitive receptors have been carried out with a temporal resolution of 1 minute; if shadow flicker is predicted to occur in any 1-minute period, the model records this as 1 minute of shadow flicker. The shadow flicker map was generated using a temporal resolution of 5 minutes 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. The UK wind industry considers that 10 rotor diameters is appropriate [10], while the Queensland Planning Guidelines suggest a distance equivalent to 265 maximum blade chords as an appropriate limit.

The Customer has nominated a hypothetical turbine rotor diameter of 140 m for this study. Without any details on the turbine blade chord available, DNV GL has implemented a maximum shadow length of 10 rotor diameters or 1400 m. Under the Queensland Planning Guidelines, this will be conservative for any turbine with a maximum blade chord of less than 5.3 m.

The model also makes the following assumptions and simplifications:

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

These simplifications mean that the results generated by the model are likely to be conservative.

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 relatively flat area is shown in Figure 2. 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 solstice and conversely the lobes to the south result from the winter solstice. 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.

4.3 Factors Affecting Shadow Flicker 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.

1. The wind turbine will not always be yawed such that its rotor is in the worst case orientation (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.

   As recommended in [9], 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 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.

4.4 Predicted Actual Shadow Flicker Duration

As discussed above in Section 4.3, 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. Exclusion of these factors means that the theoretical calculation is likely to be conservative. An attempt has been made to quantify the likely reduction in shadow flicker duration due cloud cover and, therefore, produce a prediction of the actual shadow flicker duration likely to be experienced at a sensitive receptor.

Cloud cover is typically measured in 'oktas' or effectively eighths of the sky covered with cloud. DNV GL has obtained data from five Bureau of Meteorology (BoM) stations, namely Kingaroy, Nanango, Dalby, Oakey Aero, and Dalby Airport, located a distance of approximately 40 km to 71 km from the site [11, 12, 13, 14, 15]. 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 33% and 58%, and the average annual cloud cover is approximately 45%. This means that on an average day, 45% 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 a reasonable assumption. An assessment of the likely reduction in shadow flicker duration due to cloud cover was conducted on a monthly basis, which indicated that a reduction of 40% to 52% is expected at the affected sensitive receptors.

It should be noted that the methodology used in this assessment deviates somewhat from the method recommended by the Queensland Planning Guidelines for assessing the reduction in shadow flicker due to cloud cover as the guidelines recommend considering the 9 am and 3 pm cloud cover separately, and also recommend using the "number of cloudy days" parameter provided by the BoM, rather than the number of oktas. However the approach described above is deemed to provide a reasonable estimate of the likely impact of cloud cover on the shadow flicker duration.

No attempt has been made to account for rotor orientation and vegetation or other shielding effects around each shadow receptor in calculating the shadow flicker duration. Similarly, turbine shutdown has not been considered. It is therefore likely that the adjusted shadow flicker durations presented here can still be regarded as a conservative assessment.

4.5 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. As discussed, 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 RESULTS OF THE ANALYSIS

A shadow flicker assessment was carried out at all sensitive receptors located within 1.5 km of the proposed Coopers Gap Wind Farm, as outlined in Table 1. The theoretical predicted shadow flicker durations at all sensitive receptors identified to be affected by shadow flicker are presented in Table 4. The maximum predicted theoretical shadow flicker durations within 50 m of these receptors are also presented in this table. The results are presented in the form of shadow flicker maps at 2 m and 6 m above ground in Figure 4 and Figure 5, respectively. Additionally, the results are presented in the form of shadow flicker duration contours in Figure 6 and Figure 7.

These results indicate that seven sensitive receptors in the vicinity of the Coopers Gap Wind Farm are predicted to experience some shadow flicker based on the methodology recommended in the Queensland Planning Guidelines. Of these sensitive receptors, six are predicted to be affected by theoretical shadow flicker durations of greater than the recommended limits of 30 hours per year or 30 minutes per day, within 50 m of the receptor locations. However, DNV GL has been informed that all of these sensitive receptors are located on land belonging to financial landowners.

An assessment of the level of conservatism associated with the theoretical results has been conducted by calculating the possible reduction in shadow flicker duration due to cloud cover. These adjusted results are presented as predicted actual shadow flicker durations in Table 4. Consideration of cloud cover reduces the predicted shadow flicker duration by approximately 40% to 52% at the sensitive receptors affected by shadow flicker.

After reduction due to cloud cover is taken into account, five of the sensitive receptors that are expected to exceed theoretical shadow flicker limits are predicted to be subject to actual shadow flicker duration above 10 hours, within 50 m of the receptor location.

It should be noted that the method prescribed by the Queensland Planning Guidelines for assessing actual shadow flicker duration recommends that only reductions due to cloud cover and/or turbine operation scheduling be included. As a result, no other potential sources of reduction, such as turbine orientation, were considered.

Furthermore, it should also be noted that shadow flicker durations have been calculated within 50 m of sensitive receptors, rather than within 50 m of the centre of sensitive land use(s).

Finally, there are some minor deviations between the methodologies employed to calculate the reduction in shadow flicker duration due to cloud cover compared to that outlined in the Queensland Planning Guidelines. However the approach described in Section 4.4 is deemed to provide a reasonable estimate of the likely impact of cloud cover on the shadow flicker duration.

5.1 Mitigation Options

If shadow flicker presents a problem, its effects can be reduced through a number of measures. These include the installation of screening structures or planting of trees to block shadows cast by the turbines, or the use of turbine control strategies which shut down turbines when shadow flicker is likely to occur.

It should be noted that the results presented here have been generated based on a hypothetical turbine model with a 110 m hub height and 140 m blade diameter configuration, as discussed in Section 2.2. If the turbine eventually selected for the site has dimensions smaller than those considered here, but still within the hypothetical turbine envelope, then shadow flicker durations in the vicinity of the site are likely to be lower than those predicted here.

6 CONCLUSION

An analysis has been conducted to determine the annual duration of shadow flicker experienced at sensitive receptors in the vicinity of the proposed Coopers Gap Wind Farm, based on the methodology proposed in the Queensland Planning Guidelines. The results of the assessment are presented in the form of shadow flicker maps, in Figure 4 to Figure 7. The shadow flicker results for each sensitive receptor predicted to be affected by shadow flicker are also listed in Table 4.

The assessment of theoretical shadow flicker duration shows that seven of the sensitive receptors identified are predicted to experience some level of theoretical shadow flicker within 50 m of the receptor location. Six sensitive receptors are predicted to be affected by theoretical shadow flicker durations of greater than the State Development Assessment Provisions and Planning Guidelines recommended limits of 30 hours per year or 30 minutes per day, within 50 m of the receptor location. However, all of these receptors are understood to be located on land belonging to financial landowners.

Approximation of the degree of conservatism associated with the worst-case results has been conducted by calculating the possible reduction in shadow flicker duration due to cloud cover. The results of this analysis, also presented in Table 4, show that five of the seven sensitive receptors are predicted to experience actual annual shadow flicker durations within 50 m of the house location that are in excess of 10 hours. It should be noted that the method prescribed by the Queensland Planning Guidelines for assessing actual shadow flicker duration recommends that only reductions due to cloud cover and/or turbine operation scheduling, be included. As a result, no other potential source of reduction, such as turbine orientation, was considered.

The calculation of the predicted actual shadow flicker duration does not take into account any reduction due to turbine orientation, low wind speed, vegetation, or other shielding effects around each building in calculating the number of shadow flicker hours. Therefore, the values presented may still be regarded as a conservative assessment.

If shadow flicker presents a problem, mitigation strategies to reduce the duration of shadow flicker experienced at a sensitive receptor can include: the installation of screening structures or planting of trees to block shadows cast by the turbines, or the use of turbine control strategies which shut down turbines when shadow flicker is likely to occur, or relocation of turbines.

Blade glint is not likely to cause a problem for observers in the vicinity of the wind farm provided non-reflective coatings are used on the blades of the turbines.

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Table 1 Sensitive receptor locations within 1.5 km of turbines at the Coopers Gap Wind Farm

Sensitive Receptor ID	Easting[1] [m]	Northing[1] [m]	Landowner Status	Distance to nearest turbine [km]
A	340084	7046384	Financial landowner	0.9
B	336940	7045735	Financial landowner	1.2
C	336840	7049667	Financial landowner	0.9
D	336677	7050047	Financial landowner	1.2
E	341658	7047168	Financial landowner	0.8
F	341691	7047075	Financial landowner	0.8
G	346234	7042890	Financial landowner	0.8
H	346168	7042875	Financial landowner	0.8
J	341073	7045511	Financial landowner	1.0
P	340106	7040162	Financial landowner	1.4
W	344403	7038525	Financial landowner	1.0
X	344326	7038446	Financial landowner	1.0
Y	345841	7038503	Financial landowner	1.1
AB	348510	7038356	Financial landowner	1.4

[1] Coordinate system: MGA zone 56, GDA94 datum.

Table 2 Proposed turbine layout for the Coopers Gap Wind Farm

WTG ID	Easting[1] [m]	Northing[1] [m]	WTG ID	Easting[1] [m]	Northing[1] [m]	WTG ID	Easting[1] [m]	Northing[1] [m]
1	349148	7042520	35	346783	7041658	69	339639	7048085
2	349002	7043594	36	346770	7039862	70	339448	7047066
3	348926	7044989	37	346608	7040806	71	339245	7047675
4	348830	7045393	38	346510	7043641	72	339183	7046185
5	348798	7040208	39	346233	7044187	73	338942	7046537
6	348770	7044491	40	346094	7040140	74	338647	7048552
7	348579	7043255	41	346071	7041912	75	338450	7047551
8	348340	7045141	42	345775	7041073	76	338415	7049965
9	348280	7039704	43	345666	7041515	77	338152	7048978
10	348179	7042391	44	345526	7040398	78	338130	7050310
11	348154	7043726	45	345493	7042072	79	337879	7047850
12	348065	7042000	46	345407	7044436	80	337841	7050656
13	348044	7047214	47	345290	7039473	81	337703	7049304
14	348023	7044302	48	345141	7040996	82	337642	7048301
15	347917	7046742	49	345085	7039912	83	337423	7046809
16	347917	7041062	50	345034	7041609	84	337175	7047738
17	347895	7044714	51	344861	7040272	85	336885	7048398
18	347836	7045795	52	344675	7039622	86	336760	7048806
19	347801	7047571	53	344499	7040652	87	336394	7047841
20	347737	7045280	54	344229	7039950	88	336306	7048248
21	347677	7040015	55	344097	7039451	89	336280	7047376
22	347655	7043090	56	343749	7040230	90	336196	7048633
23	347506	7040582	57	343476	7039307	91	336056	7049008
24	347386	7041794	58	342549	7046344	92	335880	7047025
25	347354	7046555	59	341783	7041003	93	335639	7047975
26	347341	7043449	60	341592	7042529	94	335501	7048513
27	347287	7042186	61	341456	7041942	95	335494	7046696
28	347235	7040950	62	341237	7044039	96	335366	7047470
29	347205	7046015	63	341167	7041147	97	334913	7046863
30	347110	7042888	64	341021	7044562	98	334908	7047980
31	347108	7045546	65	341013	7046624	99	334840	7046485
32	347009	7044548	66	340484	7047219	100	334713	7048739
33	346834	7040451	67	340267	7044337	101	334582	7048339
34	346821	7044015	68	340208	7044806	102	334509	7047439

[1] Coordinate system: MGA zone 56, GDA94 datum.

Table 3 Shadow flicker model settings for theoretical shadow flicker calculation

Model Parameter	Setting
Maximum shadow length	1400 m
Year of calculation	2029
Minimum angle to the sun	3°
Time step	1 min (5 min for map)
Rotor modelled as	Sphere
Sun modelled as	Disk
Offset between rotor and tower	Not required
Receptor height (single storey)	2 m
Receptor height (double storey)	6 m
Locations used for determining maximum shadow flicker within 50 m of each sensitive receptor	25 m grid centred on sensitive receptor location[1]

[1] In addition to the 25 m resolution grid points, points were added every 45° on a 50 m radius circle centred on the sensitive receptor location.

Table 4 **Theoretical and predicted actual annual shadow flicker durations for sensitive receptors affected by shadow flicker**

Sensitive Receptor ID[1]	Easting[2] [m]	Northing[2] [m]	Contributing Turbines	Theoretical Maximum Daily Shadow Flicker				Theoretical Annual Shadow Flicker				Predicted Actual Annual Shadow Flicker[4]			
				At Receptor[3] [min/day]		Max Within 50 m[3] [min/day]		At Receptor[3] [hr/yr]		Max Within 50 m[3] [hr/yr]		At Receptor[3] [hr/yr]		Max Within 50 m[3] [hr/yr]	
				2 m	6 m	2 m	6 m	2 m	6 m	2 m	6 m	2 m	6 m	2m	6 m
A	340084	7046384	65, 72, 73	45	51	60	59	53.5	56.0	61.2	60.6	29.6	31.2	34.3	34.1
C	336840	7049667	78, 81	38	38	42	42	27.5	28.3	36.6	37.4	13.1	13.5	17.5	17.9
D	336677	7050047	80	28	29	30	30	31.6	31.2	34.0	33.8	18.9	18.7	20.4	20.2
E	341659	7047168	66	30	30	32	31	14.1	14.2	15.4	15.4	8.0	8.1	8.8	8.8
F	341691	7047075	66	29	29	30	30	13.3	13.3	14.5	14.3	7.7	7.8	8.4	8.3
G	346234	7042890	22, 26, 30	40	39	42	42	48.0	48.3	64.5	64.9	27.2	27.5	36.7	37.0
H	346168	7042875	26, 30	36	37	39	39	41.7	41.9	47.0	47.4	24.0	24.1	26.9	27.2
Limits				30		30		30		30		10		10	

[1] All sensitive receptors affected by shadow flicker belong to financial landowners.
[2] Coordinate system: MGA zone 56, GDA94 datum.
[3] Sensitive receptors predicted to experience zero hours of shadow flicker within 50 m of the receptor have been omitted from this table.
Shadow flicker durations above the recommended limits are highlighted in red.
[4] Considering likely reductions in shadow flicker duration due to cloud cover only.

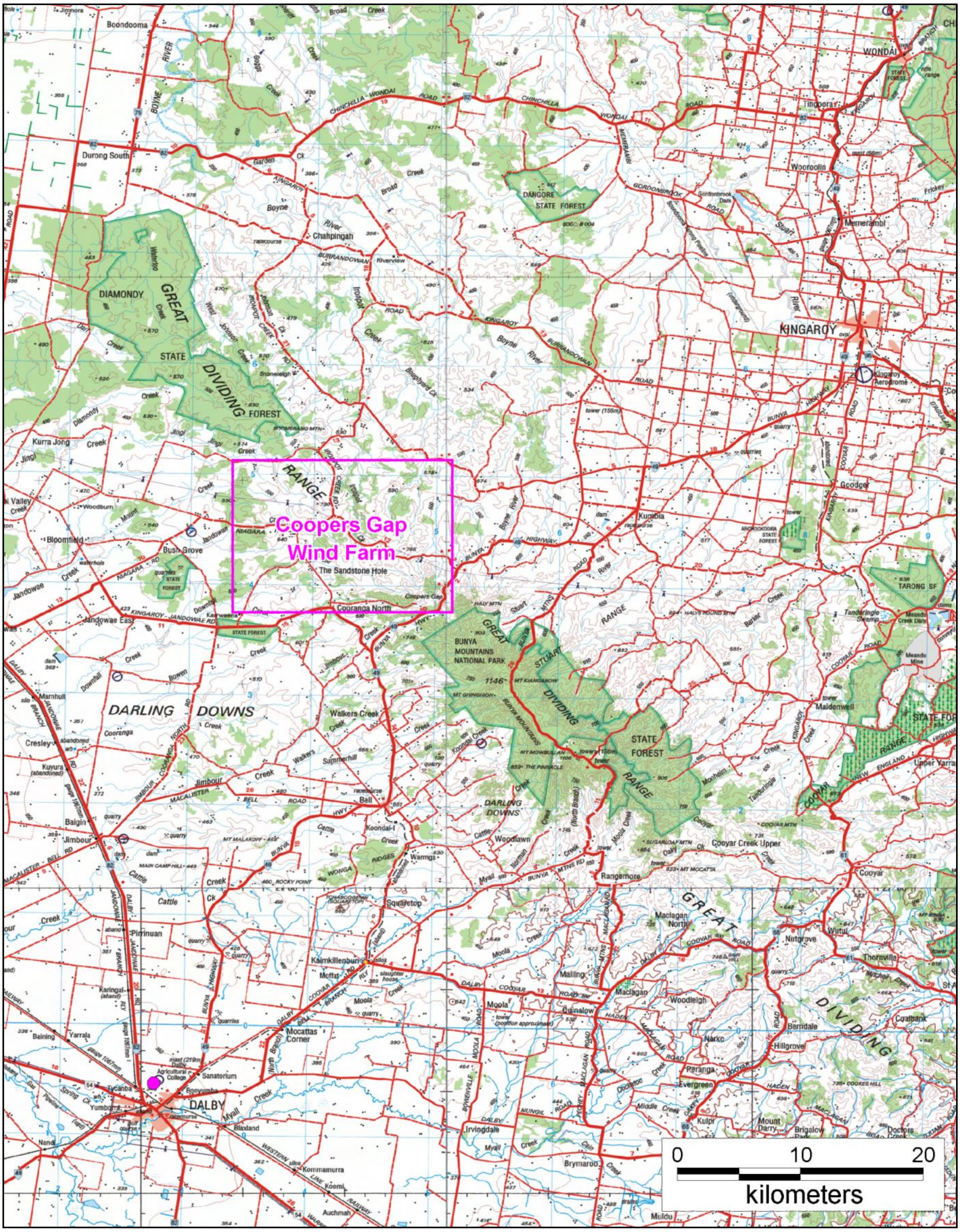

Figure 1 **Location of the proposed Coopers Gap Wind Farm.**

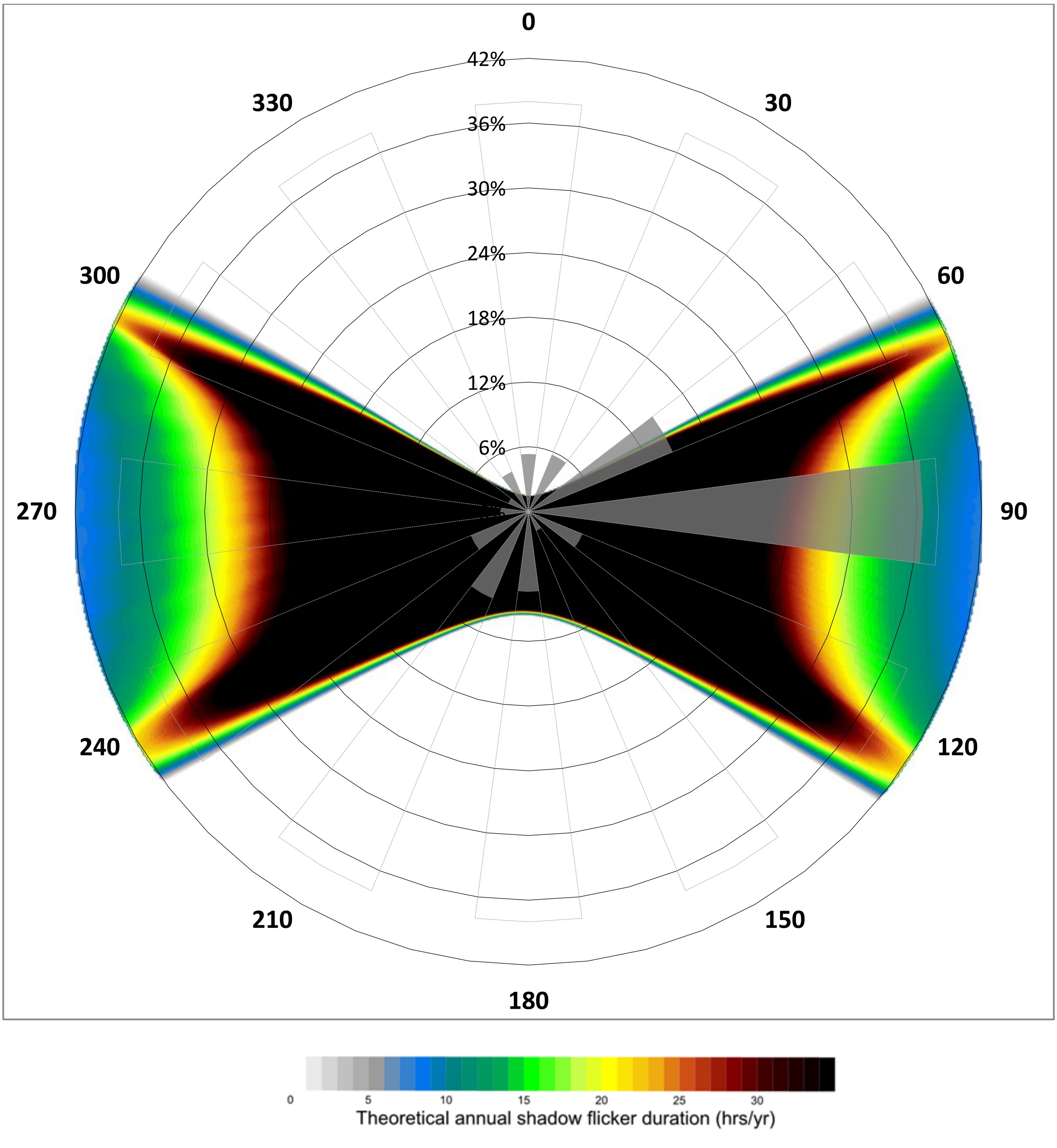

Figure 2 Indicative shadow flicker map and wind direction frequency distribution

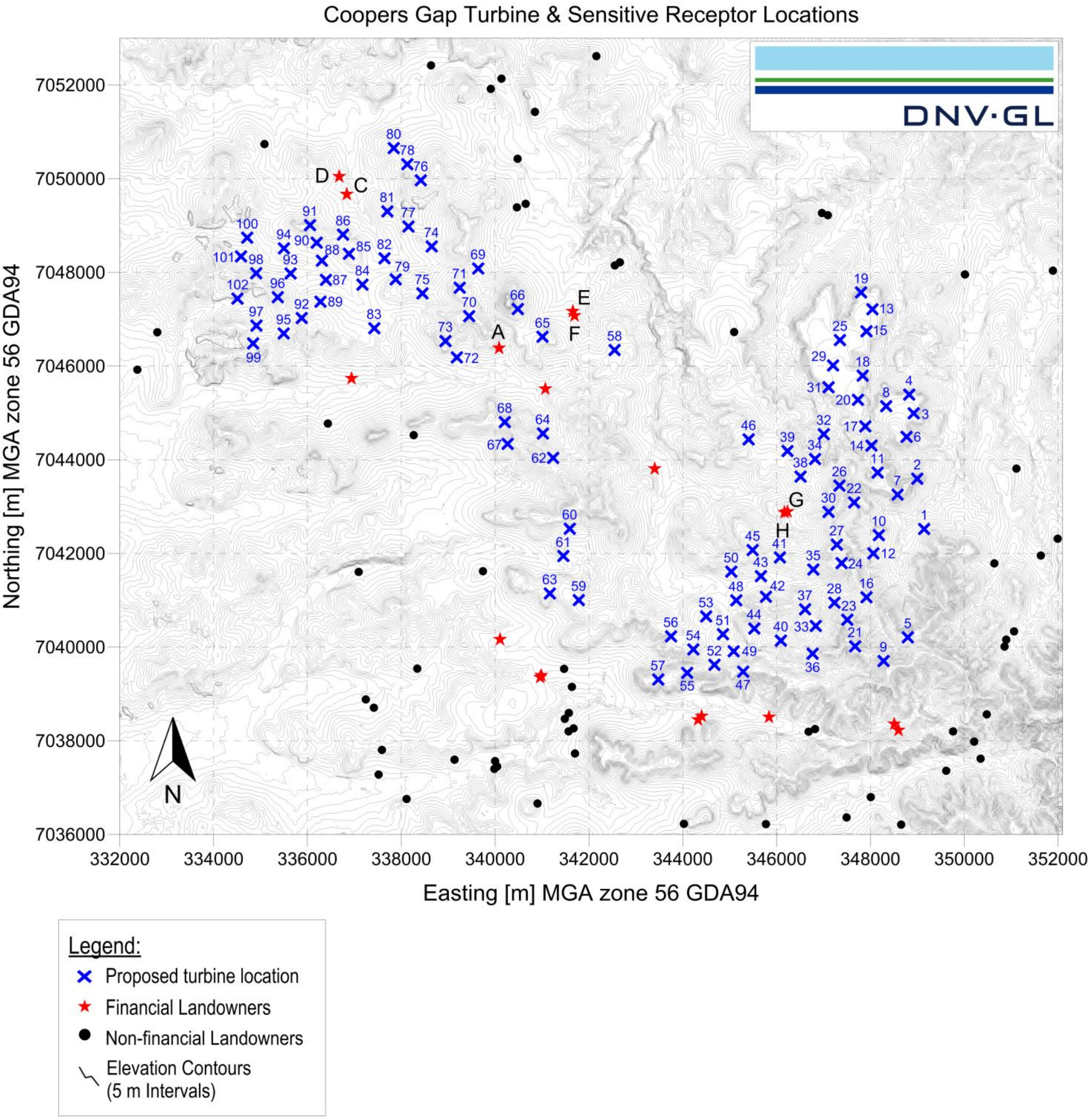

Figure 3 Map of the proposed Coopers Gap Wind Farm with turbines and sensitive receptor locations.

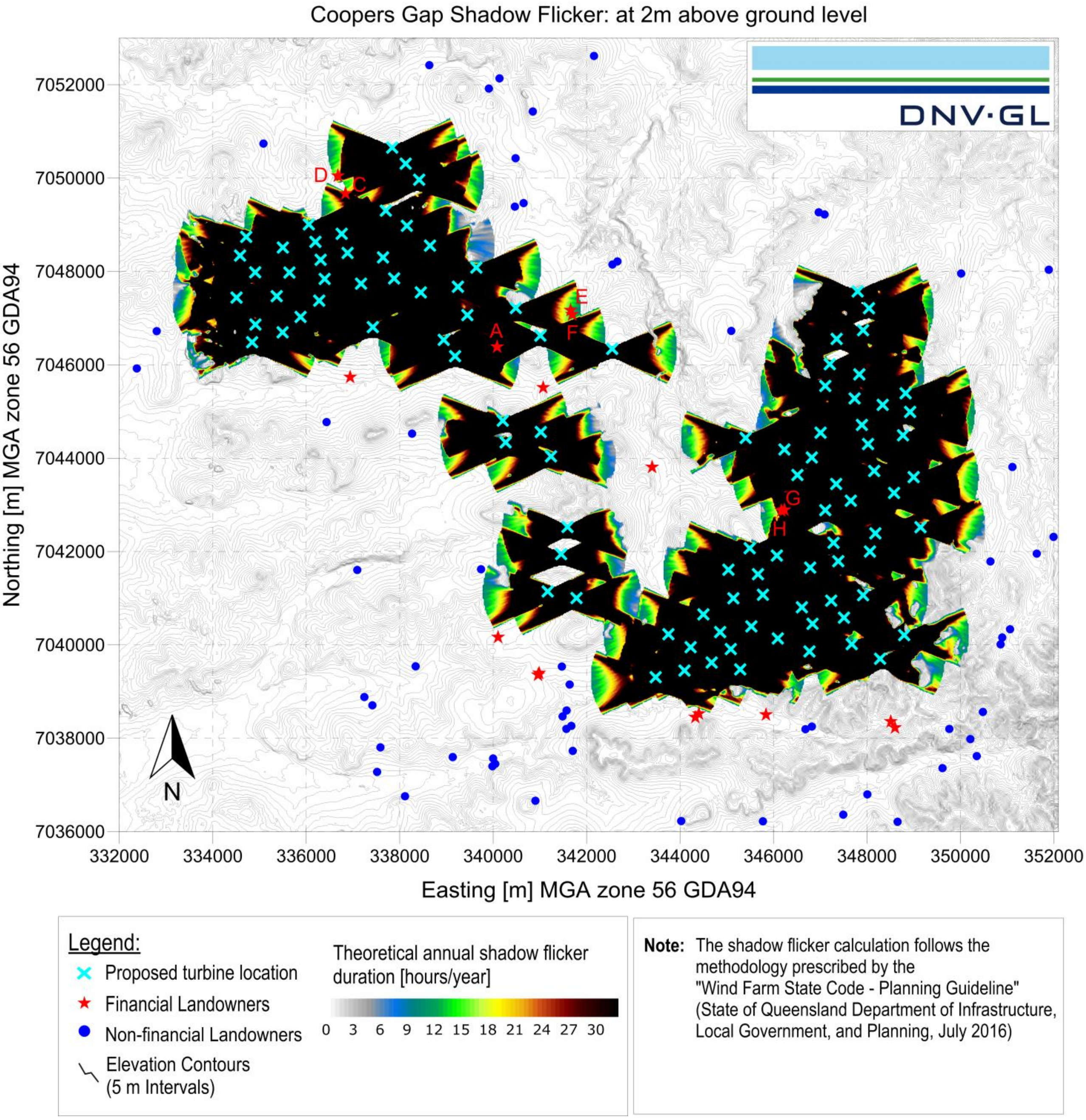

Figure 4 Map of the proposed Coopers Gap Wind Farm with turbines, sensitive receptor locations, and theoretical annual shadow flicker duration at 2 m above ground level

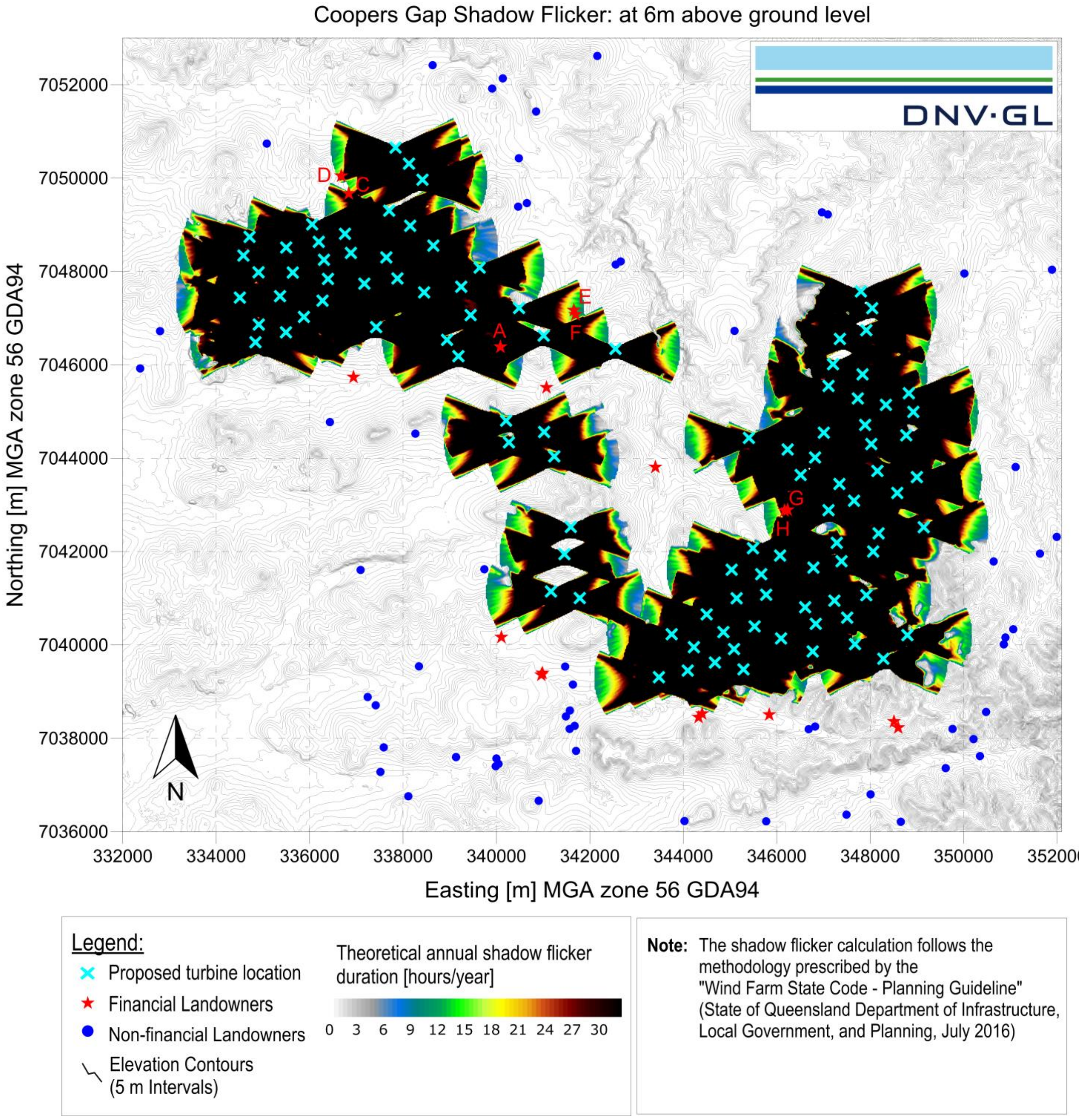

Figure 5 Map of the proposed Coopers Gap Wind Farm with turbines, sensitive receptor locations, and theoretical annual shadow flicker duration at 6 m above ground level

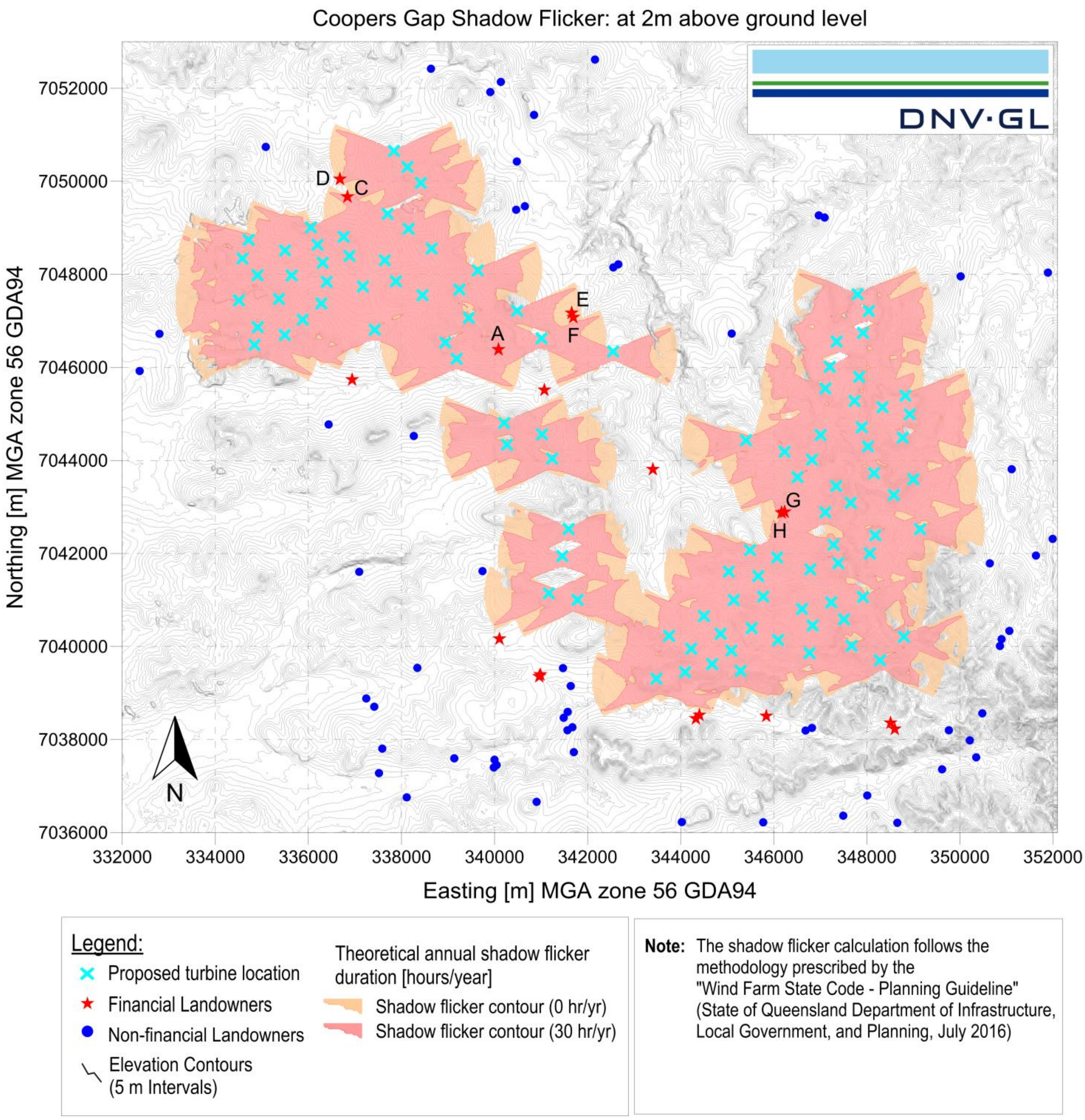

Figure 6 Map of the proposed Coopers Gap Wind Farm with turbines, sensitive receptor locations, and theoretical annual shadow flicker duration at 2 m above ground level

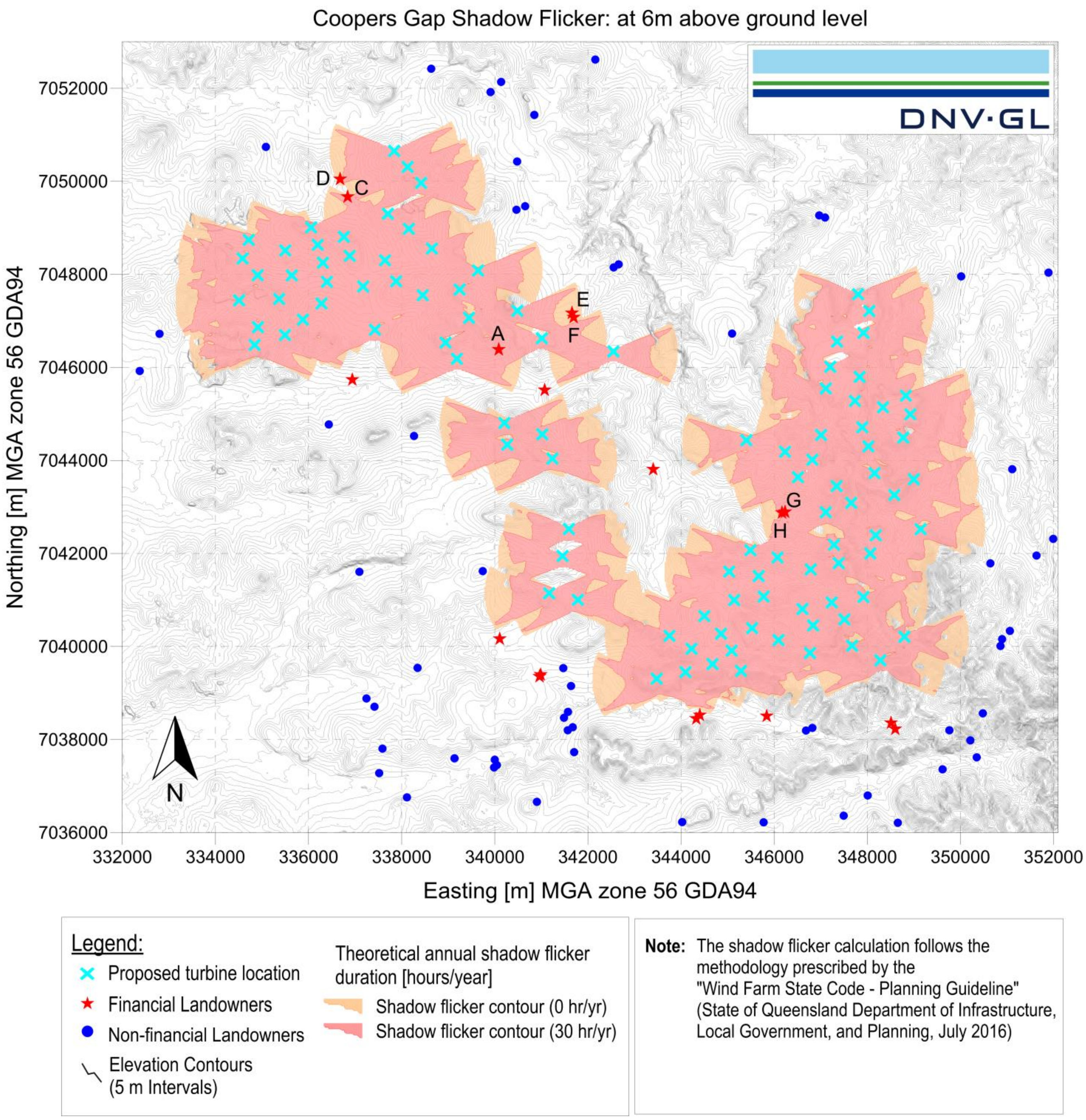

Figure 7 Map of the proposed Coopers Gap Wind Farm with turbines, sensitive receptor locations, and theoretical annual shadow flicker duration at 6 m above ground level

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