Marri Wind Farm

Shadow Flicker Assessment

Alinta Energy

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Executive Summary

Aurecon Australasia Pty Ltd has performed a Shadow Flicker assessment for the proposed Marri Wind Farm (the Project) in Western Australia. The Project is located approximately ~20 kilometres (km) south of the township of Dandaragan in Western Australia's Wheatbelt region. The Project encompasses around 12,400 hectares (ha) of land to the east of Namming Nature Reserve and Brand Highway.

Shadow flicker occurs due to the interaction of the sun with the spinning turbine blades and can affect viewers if the moving shadow of the turbine blades passes over a window that provides natural light.

Shadow flicker has been assessed for the largest proposed turbine size, for a distance of 2.2 km from the turbines.

Shadow flicker has been predicted to affect four non-involved residences with the current proposed turbine layout, but for durations within the allowable limits of 30 hours per year (theoretical) and 30 minutes per day. Eight turbines were identified which if moved within their micro-siting zones, may result in the allowable limits being exceeded for three of these dwellings and mitigation may be required. One additional non-involved residence may also be affected by shadow flicker if the closest turbine to this residence is moved within its micro-siting zone, but the predicted duration in this case is within the allowable limit.

Shadow flicker has been predicted to affect most of the involved (host) residences. Aurecon recommends that the Proponent consult with all relevant landowners in order to assess and implement potential mitigation options.

Other nearby residences are beyond the distance threshold for shadow flicker to occur. It is recommended for the assessment to be redone when the turbine model, layout and hub height is finalised. Mitigation if required can be achieved with the use of "flicker timers" that turn off turbines when they would be causing shadow flicker for residents.

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1 Introduction

Aurecon Australasia Pty Ltd (Aurecon) has been engaged by Marri WF Pty Ltd as trustee for the Marri WF Unit Trust (the Proponent) to carry out a shadow flicker assessment for the proposed Marri Wind Farm (the Project), located approximately ~20 km south of the township of Dandaragan in Western Australia's Wheatbelt region.

The purpose of this report is to provide an assessment of the actual and potential shadow flicker effects anticipated once the wind farm is operational.

In further detail, this report contains:

- A description of the Project location and environment
- A description of shadow flicker causes and potential effects
- A description of the relevant legislation, policies and guidelines that were taken into consideration during the assessment
- An overview of the methodology undertaken to inform the assessment
- An assessment of actual and potential effects
- Conclusion and recommendations.

All maps are shown with north pointing to the top of the page, unless otherwise indicated.

2 Site Description

The Project is located approximately 1 km north of Regans Ford and 110 km north of Perth in Western Australia. The area is within a rural environment, consisting of areas of pasture, plantation blocks, working farms and lifestyle blocks with residential development. The site location and proposed maximum 82-turbine layout is shown in Figure 2-1. A micro-siting zone of 300 metres (m) radius is proposed around each turbine to allow for minor changes in turbine location during detailed design and construction activities. Micro-siting will only occur where the 1.1 x tip height setback of 302 m from the site boundary can be met. Aurecon notes that one turbine is currently proposed within this setback distance but understands this turbine will be micro-sited further from the site boundary prior to construction.

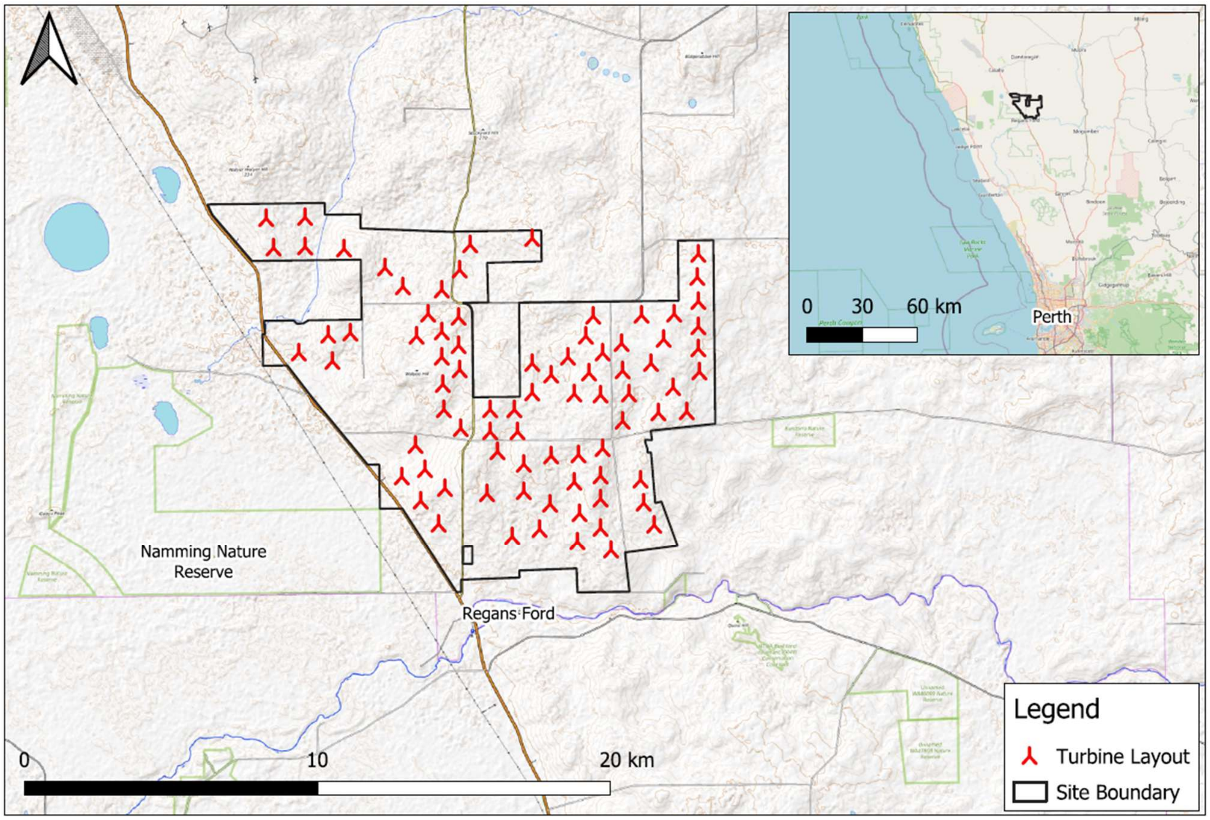

Figure 2-1 Site location and turbine layout

2.1 Turbine details

A simple schematic of the main components of wind turbines are shown in Figure 2-2. The turbine components are generic across all modern three-bladed turbines, and the dimensions are the maximum proposed for the Project.

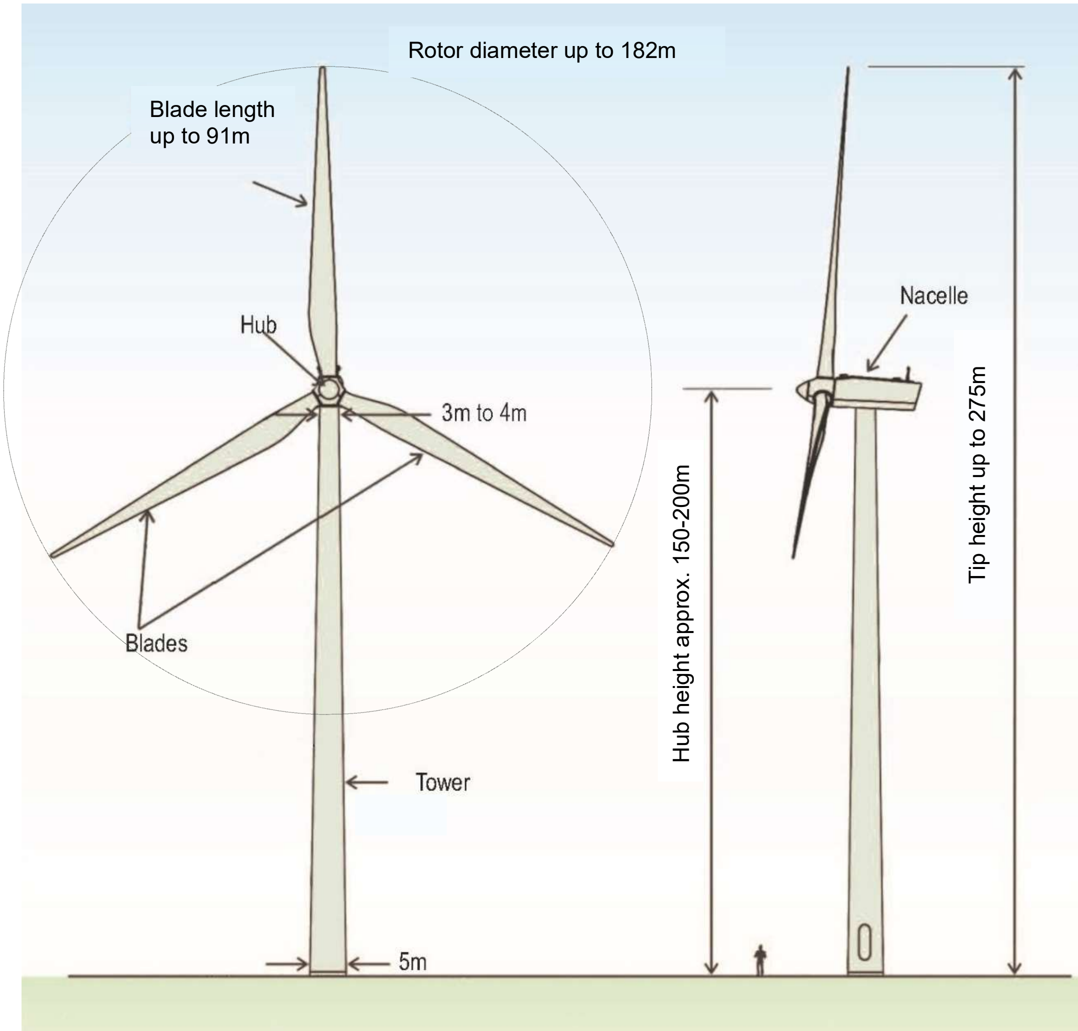

Figure 2-2 Wind turbine main components and dimensions

The main wind farm components shown in Figure 2-2 are described further below.

- **Tower**: A tapered cylindrical steel tower mounted on the foundation.
- **Nacelle**: The nacelle is the housing mounted on top of the tower that encloses a gearbox, generator, electric motors, brakes, electronic components, wiring and hydraulic and lubricating oil systems. The nacelle is typically constructed of steel and fibreglass and is able to rotate (yaw) to face toward the wind.
- **Rotor**: The assembly of the rotor blades and hub, which is mounted on the front of the nacelle and turned by the wind.
- **Blade**: Each blade is attached to the hub and the blades can be rotated (pitched) to control the speed of the rotor and the power produced.

3 Shadow Flicker

Shadow flicker is the fluctuation of light levels from the intermittent blocking of the sun, for example at a fixed ground position where the rotating blades block the sun, or when moving past objects such as closely spaced trees. In terms of a wind turbine, the shadow flicker effect will occur under circumstances where the wind turbine location and orientation are such that at certain times of the day, the sun's rays pass through the swept area of the rotating blades and cast a moving shadow. This effect is most pronounced within a building receiving natural light from outside via a window. Figure 3-1 shows an example of a wind turbine shadow on nearby land, which under the right conditions would cause shadow flicker.

Figure 3-1 Wind turbine shadow with potential to cause shadow flicker

3.1 Shadow Flicker Conditions

For a wind turbine to cause shadow flicker at a given location, the following conditions have to be satisfied. If any one of these conditions are not met, then shadow flicker will either be greatly reduced, or potentially not occur from the viewpoint location:

- The sun must be in the correct position in the sky to cast a shadow of the turbine onto a particular viewpoint location. As the position of the sun relative to the turbine is continually changing the effect is limited in duration to certain times of the day and certain days of the year for each location.
- The wind turbine must be operational (i.e., the wind must be blowing and the blades rotating).
- The sun must not be significantly obscured by cloud.
- The sun must not be diffused by the atmosphere (typically occurs at low sun angles, see Figure 3-2).
- There must be an unobstructed line-of-sight between the wind turbine and the viewpoint location (i.e., the turbine is not hidden by buildings, trees).
- The dimension of the part of the blade causing the shadow must be large enough to cast significant shadow. The widest part of the blade (the chord near the root of the blade, which may be up to 5-6 metres (m) across) causes the most shadowing; the smallest part of the blade (the tip, which may be up to 0.5 m) is not sufficient to cast any noticeable shadow.

Once all the above factors are met, and shadow flicker is present, the intensity of its effect can vary. This is dependent on the positioning and orientation between the sun, the wind turbine and the receptor, in terms of position and intensity of the sun, distance between the turbine and viewpoint location and the angle of the turbine relative to the sun and the receptor.

When the receptor is close to the turbine, direct sunlight is blocked by the blade and the receptor experiences alternate full sunlight and full shade. As the distance between the receptor and wind turbine increases, the apparent size (angle) of the sun remains effectively constant, but the apparent size of the blade decreases, so less of the sun is blocked and the shadow is less strong.

Figure 3-2 Diffuse sunlight at low sun elevation angle, resulting in insignificant shadow flicker effects

3.2 Shadow flicker potential effects

The effects of shadow flicker can generally be classified as an annoyance or general discomfort to the affected residents living near the Project.

A perceived concern with shadow flicker is the potential to cause epileptic seizures. However, the evidence on shadow flicker does not support a health concern. According to the Australian National Wind Farm Development Guidelines - Draft[1] (Section E.2.2 p 149), conventional three-bladed horizontal axis wind turbines with a rotor speed of 20 revolutions per minute cause shadow flicker at frequencies of around 1 Hz or less. This is considered well below the flicker frequency ranges identified for potential human health effects that may trigger epileptic seizures. Seizures are generally triggered by flashing lights between the frequencies of 5 to 30 Hz (flashes per second)[2]. Additionally, 20 revolutions per minute was appropriate for typical wind turbines of the time (15 years ago), but modern larger turbines like the ones proposed at the Project rotate slower, at less than 10 revolutions per minute.

The primary effect of shadow flicker is annoyance or discomfort with no serious negative health effects anticipated or proven.

[1] Commonwealth of Australia Environment Protection and Heritage Council (EPHC), "National Wind Farm Development Guidelines – Draft", dated July 2010, , https://www.nepc.gov.au/sites/default/files/2022-09/draft-national-wind-farm-development-guidelines-july-2010.pdf

[2] Epilepsy Foundation of America, https://www.epilepsy.com/article/2014/3/shedding-light-photosensitivity-one-epilepsys-most-complex-conditions-0#:~:text=Generally%2C%20flashing%20lights%20between%20the,greater%20than%20three%20per%20second.

4 Guidelines and limits

Shadow flicker can be classified in terms of having two potential limits. Firstly, the distance from which shadow flicker is noticeable, secondly the duration in which shadow flicker is felt. These limits are applicable to any residence other than residences owned by landowners hosting wind turbines, and are discussed in the following sections.

The most relevant Australian guidelines (based on international guidelines) appropriate for shadow flicker assessment and setting limits are the Australian Draft National Guidelines[1]. These Guidelines are 15 years old and were never progressed past "draft" stage as individual states were beginning to develop their own planning guidelines[3], but they remain the most detailed and thorough set of recommendations in Australia and are still generally held in industry as the basis for assessment. Aurecon is not aware of any specific Western Australia guidelines.

The Draft National Guidelines recommend assessing shadow flicker as the maximum value within 50 m of the nominal residence location to account for outdoor residential areas (gardens) and uncertainty in the modelling and extent and location of the residence.

4.1 Duration

The accepted shadow flicker duration limits within the Australian Draft National Guidelines are:

- Limit of **30** hours per year and 30 minutes per day **theoretical** (modelled) duration

If the theoretical duration limit is exceeded:

- Limit of **10** hours per year and 30 minutes per day **realistic** (modelled) or **actual** (measured) duration.

Aurecon considers these to be appropriate and in accordance with other international guidelines. A more in-depth explanation of theoretical, realistic and actual duration is outlined below. If the limit based on theoretical duration is exceeded, then the realistic duration should be considered. If the realistic duration is exceeded at a residence, then the effect must be mitigated ensuring that the limit on actual duration is met.

Theoretical Duration

Limit of 30 hours per year and 30 minutes per day **theoretical** (modelled) duration, based on:

- Turbine rotor assumed to be orientated towards the sun at all times
- Minimum sun elevation angle 3° (see Figure 3-2 which shows diffuse sunlight resulting in poorly defined shadows and therefore minimal shadow flicker impact at low sun elevation)
- Time and duration of modelling: one full non-leap year
- Receptor height of between 1.5 - 2 m and window / balcony height where residences have more than one storey
- No shadow if the turbine is behind the terrain (no line of sight)

If the limit on theoretical duration is not met:

Realistic Duration

Limit of 10 hours per year and 30 minutes per day **realistic** duration, based on theoretical plus:

- Duration reduced by proportion of time that there is cloud cover (using relevant local data)
- Duration reduced by proportion of time that turbine is not operating, due to wind speed being too high or too low or turbine stopped for maintenance or fault

[3] https://www.nepc.gov.au/publications/archive/ephc-archive/ephc-archive-future-national-wind-farm-development-guidelines

- No shadow if the view of a source turbine is blocked by dense vegetation (tree, hedge) or structure[4] (fence, building)

If the limit on realistic duration is not met:

Actual Duration

Limit of 10 hours per year and 30 minutes per day **actual** duration, using a pre-programmed timer to shut down turbine(s) at times the sun is in a position that shadow flicker will occur, unless the turbine rotor is parallel to the line from residence to sun or the sun is behind cloud.

Appendix E of the Draft National Guideline provides details on how the durations are calculated. These are explained in more detail in Sections 5.1 and 5.2.

4.2 Distance

The Draft National Guidelines suggest a distance equivalent to 265 times the maximum blade width (chord) as an appropriate shadow flicker limit, beyond which shadow flicker from turbines is unlikely to cause annoyance. This corresponds to approximately 1,060 m to 1,325 m for current modern wind turbines (which typically have blade chord lengths of 4 m to 5 m). At this distance the blade covers 50% of the sun area.

The Draft National Guidelines were developed over 15 years ago when wind turbine sizes were significantly smaller and designs were less advanced. Aurecon considers that the recommended distance of 265 times maximum blade width is less appropriate for large modern wind turbines, as the ratio of blade width to length has decreased as wind turbine designs have progressed. Using this limit can cut off the modelling of shadow flicker before the extent of the 30-hour limit is reached. In other words, some locations predicted to experience over 30 hours of theoretical shadow flicker (albeit of a slightly lower intensity) are determined to have no effects when the limit of 265 times blade width is applied.

Therefore, a more conservative limit of 683 times the average blade width is used by Aurecon. At this distance only 20% of the sun is covered by the blade, so the shadows cast by the wind turbine are less pronounced and shadow flicker effects are less noticeable than at a closer distance to the turbine. The blade width used in the calculation is the average of the maximum blade width (chord) and blade width at 90% radius.

This alternative threshold was also considered in the Draft National Guidelines as it was (and still is) implemented as regulation in Germany[5], in what the Draft National Guidelines noted were "by far the most comprehensive and well researched [international] regulations" reviewed. However, this alternative threshold was not recommended in the Draft National Guidelines at the time of publication as it was more conservative than the then-current Australian approaches of approximately 1 km distance from ~2MW wind turbines. The Draft National Guidelines' recommendation of 265 times maximum blade width was more in line with the ~1 km distances typically used in Australian wind farm developments at the time. This is now significantly out of date and so the more conservative limit of 683 times the average blade width is used as the distance limit in this assessment.

The two thresholds are summarised in Table 4-1 and Figure 4-1 below.

Table 4-1 Turbine distance and proportion of sun blocked

Distance to turbine (metres)	Blade subtended angle	Proportion of the sun blocked
265 x blade width	0.216°	50%
683 x blade width	0.0844°	20%

[4] Only where the obstruction completely blocks the view, from the receptor, of a turbine that is contributing to shadow flicker.

[5] "Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen (WEA-Schattenwurf-Hinweise)" (Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines)

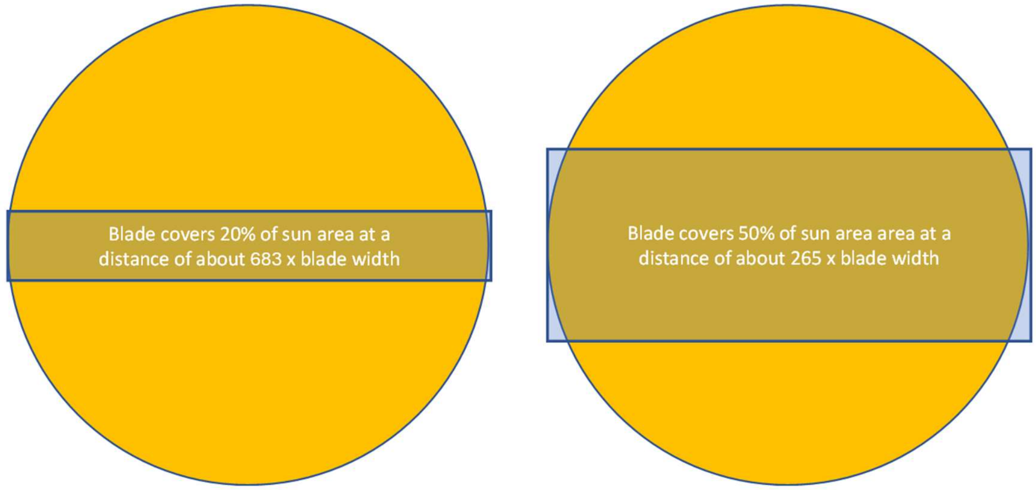

Figure 4-1 Proportion of sun blocked by blade

5 Methodology

Aurecon has undertaken a shadow flicker assessment for nearby residences of the Project, using WindPRO version 4.1 software. Terrain data used in the modelling was Copernicus Digital Surface Model (DSM) contour data (30 m resolution, 10 m contours) for the Project and surrounding area. This is relatively low resolution but sufficient for shadow flicker modelling given the simple terrain. Cumulative effects of shadow flicker have been assessed for two other wind farms close enough to the Project to cause cumulative shadow flicker: the existing Yandin Wind Farm and proposed Yathroo Wind Farm.

The nearest turbine at Yandin Wind Farm to the north is over 4 km away, and there is no overlap in shadow flicker potential area between Yandin and the Project. Yathroo Wind Farm has proposed turbines in close proximity to the Project turbines on several sides, so the cumulative effects of shadow flicker at affected residences has been assessed.

While the turbine model and hub height has not been confirmed yet, this assessment has applied a conservative approach to determine the worst-case shadow flicker effect. The analysis uses the largest possible turbine dimensions being considered (see Section 2.1). The turbine size parameters are:

- Blade tip height: 275 m
- Rotor diameter: 182 m
- Hub height: 184 m (based on maximum tip height)

The blade width at the widest point and at 90% radius have been estimated as 4.9 m and 1.7 m respectively, extrapolated from the WindPRO database of blade widths for turbines with rotor diameters of 170-175 m. This gives an average blade width of 3.3 m.

The locations and addresses of surrounding residences were provided by the Proponent which were identified from satellite imagery. These are listed in Appendix 1. The residences are divided into “involved” (host residences, within the Project site boundary) and “non-involved.”

The modelling has been carried out using the following settings:

- Calculations are performed at 1-minute time intervals and 1-day intervals with a resolution of 1 m
- The digital terrain model was used to calculate turbine/sun visibility with visibility line-of-sight calculated with a resolution of 15 m
- The viewing window for each location was assumed to be 1 x 1 m in size with viewer located at 2.0 m above ground level
- The estimated average blade width for the modelled turbine is 3.26 m. Shadow flicker is not calculated beyond 2,224 m (683 x average blade width, as discussed in Section 4.2).

The following sections outline how the theoretical and realistic duration are determined.

5.1 Theoretical duration

The WindPRO model simulates the path of the sun during the year and can calculate the relative positions of the sun, wind turbines, residences and terrain to predict the possible shadow flicker durations in the vicinity of the Project from a purely geometrical standpoint. This calculation gives the theoretical number of shadow flicker hours experienced at each nearby residence.

5.2 Realistic duration

As outlined in Section 4.1, the actual shadow flicker hours per year will be less than the theoretical as there are a number of factors the analysis does not consider, including the presence of cloud cover, vegetation screening or intervening structures, the orientation of the wind turbine and periods when the wind turbines are not operating. Aside from screening vegetation and objects, it is generally cloud cover that provides the most substantial reduction from theoretical to realistic in the amount of shadow flicker experienced by receptors.

The realistic duration reduction is only applicable for the total hours per year limitation (30 hours), as the theoretical predicted number of minutes per day may still be achieved despite all of these factors e.g. on a sunny day with the turbine operational.

The reductions applied to calculate realistic shadow flicker from theoretical are:

- Sunshine hours: approximately 69% of yearly daylight hours at the Project location, according to the Australian Bureau of Meteorology[6]
- Availability of turbines: 97% (proportion of time not operating due to maintenance, faults, or other non-operation such as cable unwinding = 3%)
- Operating time: 95% (proportion of time not operating due to high or low wind = 5%).

Combining these factors, realistic duration is assessed to be 63.7% of theoretical duration.

Some factors, outlined below, were not accounted for in this analysis, despite being mentioned in Section 4.1. If the below factors were considered it would further reduce the realistic duration percentage, making this analysis more conservative.

- Rotor orientation relative to the sun
- Orientation of residence windows
- Dense vegetation blocking sunlight

[6] Bureau of Meteorology, http://www.bom.gov.au/watl/sunshine/

6 Results

The potential shadow flicker effect at each residence location potentially affected by shadow flicker is outlined in Table 6-1 (non-involved residences) and

Almost all (8 out of 11) involved (landowner) residences are above the shadow flicker limits due to their proximity to multiple turbines. However, shadow flicker limits typically do not apply to these dwellings as acceptable shadow flicker is assumed to be agreed between the Proponent and the landowners in the wind turbine hosting agreements. The results for involved residents is shown in Table 6-2Table 6-2Table 6-2.

Table 6-2 (involved residences). Other residences are considered too far away (over 2.2 km from a turbine) or at the wrong orientation relative to the wind farm to experience any significant shadow flicker. The results are displayed in descending order of total predicted shadow flicker per year. Realistic shadow flicker duration is only displayed if the theoretical shadow flicker limit (30 hours per year) is exceeded, in accordance with the Draft National Guidelines.

The shadow flicker results presented are generally for the residence location rather than the highest value within 50m as recommended by the Draft National Guidelines because:

1. The effects are less impactful outdoors where there is more diffuse and uniform lighting, and
2. The uncertainty/extent of residence location is much smaller than 50m.

Aurecon has checked and confirmed that using the highest value within 50m of the residence location does not change whether any residences are above the shadow flicker limits.

For the provided layout, four non-involved residences are predicted to experience shadow flicker as outlined in Table 6-1 below. For all four of these, the predicted shadow flicker duration is within the Draft National Guideline limits and does not require mitigating strategies.

Table 6-1 Non-involved residences affected by shadow flicker

Dwelling ID	Turbine(s) causing shadow flicker	Distance to turbine causing most shadow flicker [km]	Theoretical shadow flicker per year [hh:mm]	Realistic shadow flicker per year [hh:mm]	Max shadow flicker per day [hh:mm]	Shadow flicker limits exceeded
42	WP69, WP11	1.9	18:58	n/a	0:23	No
22	WP81	1.5	12:00	n/a	0:28	No
8	WP65	1.9	11:30	n/a	0:22	No
40	WP71	1.9	9:14	n/a	0:23	No

Almost all (8 out of 11) involved (landowner) residences are above the shadow flicker limits due to their proximity to multiple turbines. However, shadow flicker limits typically do not apply to these dwellings as acceptable shadow flicker is assumed to be agreed between the Proponent and the landowners in the wind turbine hosting agreements. The results for involved residents is shown in Table 6-2Table 6-2Table 6-2.

Table 6-2 Involved residences affected by shadow flicker

Dwelling ID	Turbine(s) causing shadow flicker	Distance to turbine causing most shadow flicker [km]	Theoretical shadow flicker per year [hh:mm]	Realistic shadow flicker per year [hh:mm]	Max shadow flicker per day [hh:mm]	Shadow flicker limits exceeded
99	WP39, WP53, WP64	0.5	202:21	128:58	1:32	Yes, n/a
16	WP81, WP80, WP70	0.9	93:51	59:49	0:48	Yes, n/a
12	WP79, WP30, WP38, WP29, WP11	1.1	91:19	58:12	0:43	Yes, n/a
10	WP53, WP39, WP60	0.8	91:12	58:07	1:47	Yes, n/a
13	WP14, WP6, WP15, WP63, WP1, WP7	1.8	69:14	44:07	0:45	Yes, n/a
17	WP30, WP18, WP56, WP12	1.7	56:57	36:17	0:36	Yes, n/a

Dwelling ID	Turbine(s) causing shadow flicker	Distance to turbine causing most shadow flicker [km]	Theoretical shadow flicker per year [hh:mm]	Realistic shadow flicker per year [hh:mm]	Max shadow flicker per day [hh:mm]	Shadow flicker limits exceeded
21	WP43, WP29, WP25, WP52	1.3	53:39	34:11	0:32	Yes, n/a
2	WP44, WP43	1.7	39:51	25:23	0:27	Yes, n/a
5	WP25, WP24, WP52	1.7	25:54	n/a	0:24	No
43	WP27, WP15, WP7	1.8	24:08	n/a	0:29	No

The above shadow flicker results are illustrated in Figure 6-1 for the theoretical duration per year. We note that the map is produced at a lower calculation resolution than the results for each receptor shown in the table above, so the results above are more precise than the map illustration below.

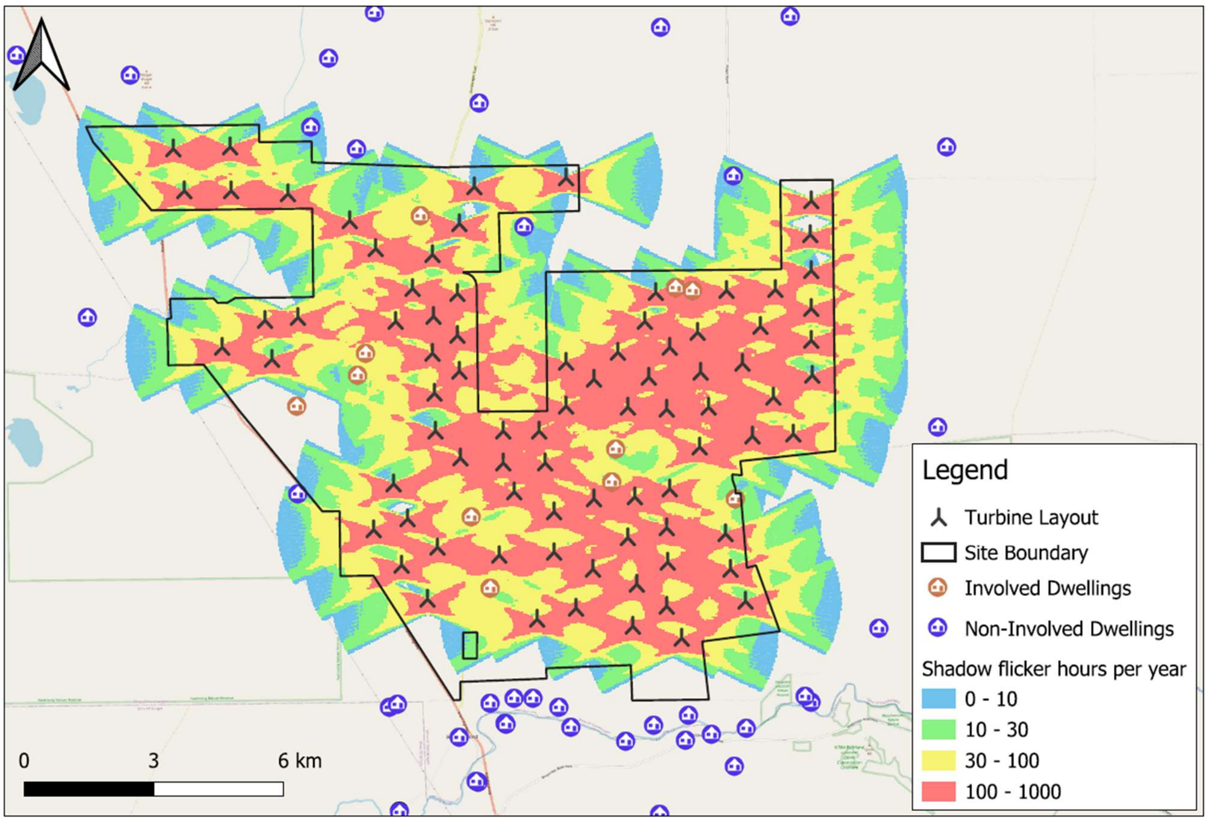

Figure 6-1 Shadow flicker map showing theoretical (worst-case) annual shadow flicker

Refer to See Appendix 2 for a graphical report showing shadow flicker effects for affected residences throughout the year. The results presented in this report are for the largest turbine rotor size, hub height and the greatest number of turbines that are proposed. If a smaller turbine is installed, then the duration will be less.

6.1 Micro-siting movements

As noted in Section 2, there is a micro-siting zone of up to 300 m radius for each turbine position. Movement of turbines within this micro-siting zone may increase or decrease shadow flicker effects, and there are eight turbines (WP11, WP65, WP69, WP80, WP81, WP71 and/or WP73) for which this can have a material impact on the shadow flicker predicted for non-involved residences. Aurecon has tested the impacts of moving these turbines closer to the non-involved residences by 300 m from the provided location, bringing them to the edge of the micro-siting zones. As a result, the shadow flicker for all four dwellings identified in Table 6-1 would increase, and one additional dwelling (#20) would be affected. Three of these dwellings (#22, #42 and #8) would exceed the shadow flicker limits, and would require mitigation. The worst-case shadow flicker results for non-involved dwellings with these turbine movements is shown in Table 6-3. Aurecon notes that moving turbines away from the residences would have the opposite effect and could reduce or eliminate the amount of shadow flicker received for all non-involved residences. This sensitivity assessment has not been undertaken for the involved (landowner) dwellings as shadow flicker limits are assumed to be managed through agreements between the Proponent and landowners. However the same principal applies: moving turbines towards or away from the residences would increase or decrease respectively the amount of shadow flicker received.

Table 6-3 Non-involved residences affected by shadow flicker - worst case

Dwelling ID	Turbine(s) causing shadow flicker	Distance to turbine causing most shadow flicker [km]	Theoretical shadow flicker per year [hh:mm]	Realistic shadow flicker per year [hh:mm]	Max shadow flicker per day [hh:mm]	Shadow flicker limits exceeded
22	WP80, WP81	1.3	58:05	36:34	0:34	Yes
42	WP69, WP11	1.6	33:27	21:03	0:29	Yes
8	WP65	1.6	32:00*	20:09	0:28	Yes*
40	WP71	1.8	22:24	n/a	0:25	No
20	WP73	1.7	16:36	n/a	0:26	No

* Highest value within 50m of the dwelling coordinate

Mitigation strategies may be required for three non-involved residences (#22, #42 and #8) if the nearest turbines to these residences are moved within the micro-siting zones. The degree of mitigation required will depend on the results of the pre-construction assessment, using the final turbine model and layout and considering visibility of the turbines from inside the residences. Mitigation options are discussed in Section 7 below.

6.2 Cumulative Impacts

A cumulative impact assessment was conducted for all dwellings identified, due to the proximity of the Yathroo Wind Farm. The approximate layout and information for 65 turbines was obtained from the Yathroo Wind Farm Development Application[7] published online; Aurecon notes that the turbine positions have been estimated based on the provided map and are not accurate. The maximum turbine size being proposed for Yathroo was assessed (blade length 91 m, tip height 261 m). Only the current proposed turbine layout for Marri Wind Farm was assessed, and not the worst-case scenario with turbines moved within their 300 m micro-siting zones.

Three non-involved dwellings (ID #8, #22, and #40) are predicted to experience cumulative shadow flicker effects from the Project and Yathroo Wind Farm. This is shown in Figure 6-2.

[7] Umwelt (Australia) Pty Limited, "Yathroo Wind Farm – Development Application – Final" (Section 1.2 - Figure 1.2 and Section 3.4.1 and Table 3.1), dated July 2025, https://www.dandaragan.wa.gov.au/Profiles/dandaragan/Assets/ClientData/Documents/Nikita/24360_R12_Neoen_Yathroo_Wind_Farm_DA_V4__1_.pdf

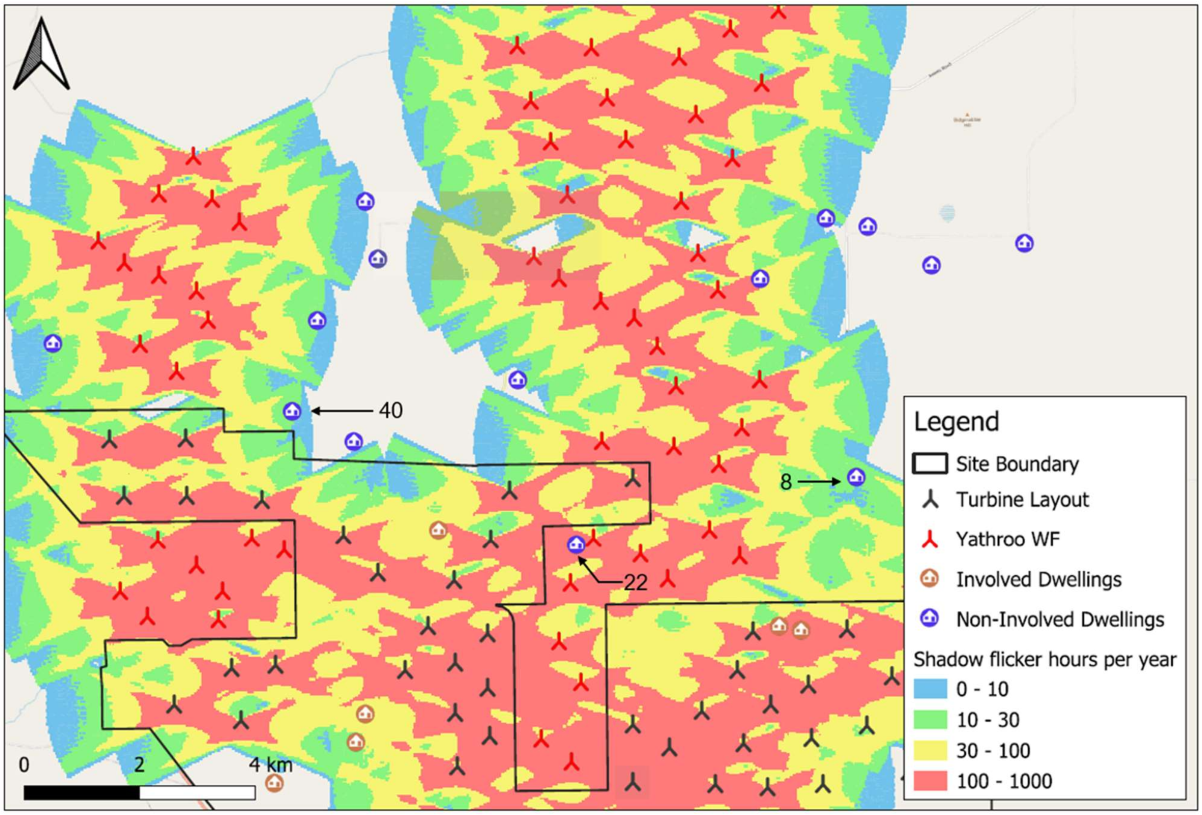

Figure 6-2 Shadow flicker map showing theoretical (worst-case) annual shadow flicker with cumulative impacts

Dwelling #22 has been assessed to be over the acceptable limit of shadow flicker according to the Draft National Guidelines. However, this dwelling is situated within the Yathroo Wind Farm site boundary area and therefore is assumed to be part of the involved dwellings for that wind farm. For this reason, Aurecon considers that cumulative shadow flicker caused by Yathroo Wind Farm for this dwelling is outside of the scope of this assessment.

The other two dwellings (ID #8 and #40) are still within the acceptable shadow flicker limits when considering the cumulative impacts of both wind farms. Additionally, dwelling #40 is situated within the Yathroo Wind Farm site boundary area and therefore is assumed to be part of the involved dwellings for that wind farm and therefore exempt from cumulative effects assessment (similar to dwelling #22 discussed above).

As noted above, this assessment has been done for the current proposed turbine layout for the Project, and movement of turbines within the micro-siting zones may cause dwelling #8 to be above the limit for cumulative shadow flicker. This would require mitigation, with options discussed in Section 7.

7 Mitigation

The most practical mitigation strategy for shadow flicker is usually a turbine shut-down protocol which will switch off the turbines causing shadow flicker so that the total actual duration at receptors is no more than the allowable limit. “Flicker timers” are standard additions to the turbine SCADA (Supervisory Control and Data Acquisition) system that can automate this process by stopping each relevant turbine at the date and time of day when the sun is in a position that would cause shadow flicker. In addition, each relevant turbine can be fitted with a light sensor so that the turbine is only stopped when there is direct sunlight, and rotor orientation can also be considered so that the turbine is not shut down if the rotor is near-parallel to the line from the residence to the sun.

Screening vegetation could also reduce the realistic shadow flicker, but this is not always practical, acceptable to the affected residents or cost-effective, particularly when the turbines are very tall as is the case for the Project.

The shadow flicker limits will only be exceeded if one or more specific turbines are moved within their micro-siting zones. Therefore, Aurecon notes that reducing the micro-siting zones for the relevant turbines to ensure that all non-involved residences will be below the shadow flicker duration hour per year limit and/or the minutes per day is an option. This would mean that no further mitigation will be required.

8 Conclusions and Recommendations

Shadow flicker is the fluctuation of light levels from the intermittent blocking of the sun due to wind turbine blades spinning and can be an annoyance for nearby residences.

Four non-involved residences are predicted to experience shadow flicker, all within the allowable limits of 30 hours per year and/or 30 minutes per day (theoretical duration). If several turbines are moved within their micro-siting zones, three non-involved residences may experience shadow flicker duration above the allowable limit(s) and require mitigation strategies.

Eight involved residences are predicted to experience shadow flicker exceeding the allowable limits.

Aurecon recommends the following process to ensure that the effects of shadow flicker are no more than minor at the relevant residences:

- Reassess realistic shadow flicker for final layout and turbine model, taking into account the visibility of the turbines from the residence due to vegetation and other screening
- After revision of the assessment, if the shadow flicker realistic modelled duration limit is exceeded, then mitigation should be applied to meet the limit for actual duration.

As discussed in Section 70, mitigation may involve a shadow flicker timer in the turbine control system (SCADA) or installing screening vegetation between the residences and the turbines to ensure that actual shadow flicker does not exceed the relevant limit. Aurecon recommends that the Proponent consult with all relevant landowners associated with the residences where shadow flicker above the allowable limits is predicted, in order to assess and implement potential mitigation options.

Appendix 1 – Turbines and Residences

Turbine ID	UTM (south) – GDA2020, zone 50		Elevation [m ASL][1]	Turbine ID	UTM (south) – GDA2020, zone 50		Elevation [m ASL][1]
	Easting	Southing			Easting	Southing	
WP1	375880	6580830	194	WP42	380725	6579115	230
WP2	369318	6585145	160	WP43	380793	6577286	199
WP3	369571	6584167	147	WP44	380729	6576378	210
WP4	382071	6576236	190	WP45	380739	6575571	186
WP5	371429	6581177	158	WP46	380017	6575059	180
WP6	372190	6581235	160	WP47	380720	6574560	180
WP7	371590	6580277	129	WP48	376944	6577877	215
WP8	381069	6573822	180	WP49	381438	6580899	231
WP9	374443	6581143	183	WP50	381491	6579970	229
WP10	383184	6579392	215	WP51	381690	6579167	214
WP11	374398	6577395	139	WP52	381486	6578240	203
WP12	374591	6575505	152	WP53	382104	6581861	220
WP13	375872	6581788	201	WP54	382699	6578510	210
WP14	375318	6581269	200	WP55	380790	6580552	234
WP15	375308	6580411	220	WP56	378630	6574526	140
WP16	375360	6578625	190	WP57	382459	6580188	229
WP17	375426	6575920	180	WP58	379946	6574111	162
WP18	375197	6574728	136	WP59	384063	6581455	230
WP19	375938	6577998	193	WP60	383225	6581889	232
WP20	370445	6580551	101	WP61	384071	6580723	208
WP21	382184	6575424	187	WP62	379031	6579815	192
WP22	376942	6578616	223	WP63	375919	6580007	220
WP23	370657	6584180	120	WP64	382886	6581033	240
WP24	377779	6578618	220	WP65	384067	6583946	204
WP25	377896	6577888	200	WP66	384036	6583156	227
WP26	376839	6575745	181	WP67	384050	6582336	238
WP27	375350	6579488	220	WP68	374844	6581909	184
WP28	378385	6580198	200	WP69	373947	6576339	124
WP29	378113	6576753	218	WP70	373379	6583479	138
WP30	378114	6575812	173	WP71	370629	6585176	127
WP31	377718	6574271	135	WP72	382537	6574670	161
WP32	378396	6579204	217	WP73	371968	6584100	149
WP33	379813	6576163	190	WP74	384080	6579907	206
WP34	379013	6575410	168	WP75	375293	6582707	181
WP35	379597	6580436	213	WP76	373981	6582835	150
WP36	379821	6579173	210	WP77	383648	6578547	207
WP37	379971	6577090	212	WP78	379037	6577047	200
WP38	374720	6576594	149	WP79	377192	6577209	190
WP39	380471	6581820	216	WP80	376260	6584272	160
WP40	380209	6581156	210	WP81	375923	6583406	150
WP41	380314	6579872	222	AE82	378394	6584473	210

1. Above sea level

Dwelling ID	UTM (south) - GDA2020, zone 50		Elevation [m ASL]	Dwelling ID	UTM (south) – GDA2020, zone 50		Elevation [m ASL]
	Easting	Southing			Easting	Southing	
Involved							
2	382327	6577021	200	17	376669	6574936	163
5	379576	6578153	230	21	379471	6577410	224
10	381332	6581817	240	41	372198	6579160	140
12	376223	6576594	210	43	373604	6579875	202
13	373779	6580367	220	99	380956	6581887	233
16	375040	6583550	163	-	-	-	-
Non-Involved							
1	385214	6588528	180	40	372506	6585618	129
3	377644	6572395	90	42	372218	6577118	100
4	378252	6572190	93	44	380614	6587923	210
6	385643	6574016	160	45	387224	6585140	190
7	383596	6588159	200	46	374339	6572206	86
8	382289	6584483	230	47	374525	6572253	88
9	380445	6571791	105	48	375956	6571494	90
11	387001	6578660	140	49	376390	6570457	85
14	376420	6586166	161	50	376342	6570493	85
15	384387	6594496	200	51	375741	6568755	89
18	382305	6570840	130	52	375757	6568729	89
19	381768	6588973	180	53	375773	6568707	88
20	373581	6585096	130	54	375832	6568618	87
22	377438	6583297	180	55	378631	6569357	140
23	376661	6572288	90	56	374445	6569326	90
24	368347	6586800	190	57	374501	6569364	90
25	365711	6587277	93	58	380571	6569722	160
26	364157	6581457	80	59	381773	6571563	108
27	367354	6581201	94	60	384088	6572308	110
28	360359	6594055	110	61	383941	6572439	112
29	366662	6590268	189	62	381258	6572005	100
30	373996	6588260	154	63	379803	6571411	100
31	372940	6587199	150	64	382488	6588824	170
32	373771	6589264	190	65	377206	6572393	90
33	375112	6595187	180	66	374559	6569790	80
34	375103	6595256	180	67	378522	6571740	100
35	375236	6594718	173	68	381184	6571433	102
36	375433	6594612	170	69	382588	6571721	103
37	370004	6597071	260	70	377014	6571831	92
38	374930	6597953	200	71	377023	6571805	92
39	374154	6597572	217	40	372506	6585618	129

Appendix 2 - Shadow flicker reports

The following attached results from the WindPRO software outline the shadow flicker calculation inputs, settings and outputs. They also illustrate the times at which shadow flicker will occur and turbines causing shadow flicker for each residence.

Sunrise and sunset are shown as solid lines on the graphs, and the time is given as local time so sunrise and sunset shift by an hour in April and September due to daylight savings.

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