WIND PROSPECT

ENERGY FORMS

WILLATOOK WIND FARM

# Planning Application Report

# Appendix L Shadow Flicker

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WILLATOOK WIND FARM

# Shadow Flicker and Blade Glint Assessment

Willatook Wind Farm Pty Ltd

**Report No.:** 10286402-AUME-R-01-F
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# EXECUTIVE SUMMARY

DNV has been commissioned by Willatook Wind Farm Pty Ltd ("the Proponent") to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Willatook Wind Farm ("the Project") in Victoria. 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 in accordance with the Victorian Planning Guidelines [1], which are referenced in clauses 19.01-2S and 52.32-5 of the Victoria Planning Provisions [2]. For the purposes of this assessment, DNV has also considered the guidance and recommendations given in the Draft National Guidelines [3]. The methodology used in this study has been informed by these guidelines and various standard industry practices.

The Victorian Planning Guidelines recommend a shadow flicker limit of 30 hours per year in the area immediately surrounding a dwelling. In addition, 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 59 wind turbines with a maximum proposed rotor diameter of 190 m and tip height of 250 m has been considered. 59 dwellings have been identified within 2900 m of the Project. 21 of these dwellings are stakeholder dwellings belonging to wind farm host landowners or landowners who have entered into a formal agreement with the Proponent, of which 6 are dilapidated dwellings. The remaining 38 dwellings are non-stakeholder dwellings, of which 2 are dilapidated dwellings.

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

## Assessment results

The results of the shadow flicker assessment are summarised in Table 4.

Based on this assessment, a number of dwellings are expected to experience some high intensity shadow flicker, meaning shadow flicker of at least a moderate level of intensity or above, which is expected to occur up to a distance of around 10 rotor diameters from the wind farm.

A total of 24 dwellings are predicted to experience some high intensity shadow flicker, of which 13 are stakeholder dwellings and 11 are non-stakeholder dwellings.

Out of the 13 stakeholder dwellings predicted to experience some high intensity shadow flicker, 11 are predicted to experience theoretical shadow flicker durations above the recommended limit of 30 hours per year within 50 m of the dwelling. When considering the likely reduction in duration due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of the same 11 dwellings are predicted to be above the recommended limit of 10 hours per year.

Out of the 11 non-stakeholder dwellings predicted to experience some high intensity shadow flicker, none are predicted to experience theoretical or actual shadow flicker durations above the recommended limits of 30 and 10 hours per year respectively within 50 m of the dwelling.

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

However, it should be noted that the 50 m area surrounding some stakeholder dwellings is expected to experience very high theoretical shadow flicker durations, with several cases of high intensity shadow flicker of more than 100 hours per year and, in two cases, over 700 hours per year.

The Proponent has advised that *"commercial arrangements have been entered into with stakeholders recognising impacts from the wind farm (including shadow flicker)"* and that they are *"committed to conducting further work with stakeholders to develop specific measures to limit shadow flicker"*.

It is understood that the Proponent is committed to meeting an *actual* shadow flicker limit of 30 hours per year for stakeholder dwellings and that this is specified in the legal agreement between those landowners and the Proponent [4, 5]. This commitment may reduce shadow flicker durations for at least one of the stakeholder dwellings, however the shadow flicker durations at some dwellings may remain high.

It is likely that some form of mitigation, potentially involving turbine curtailment, will be required to limit shadow flicker durations so that the Project adheres to contractual limits.

The effects of shadow flicker may be reduced through a number of mitigation options 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 which shut down turbines when shadow flicker is likely to occur. It should be noted that if implementing turbine curtailments as a component of the shadow flicker mitigation strategy, this will likely result in a reduction in the energy output of the wind farm.

It should be noted the turbine configuration parameters (namely hub height and rotor diameter) used in the modelling, as advised by the Proponent, are representative of a worst-case scenario and the actual hub height and rotor diameter may be smaller. In the event that a turbine with smaller dimensions is selected, the shadow flicker durations at some dwellings are also likely to be lower than reported. DNV understands that the Proponent plans to prepare an updated shadow flicker assessment once turbine selection and detailed design (including micro-siting) have been conducted [5].

In order that blade glint is not an issue for the wind farm, it is recommended that the turbine blades are coated with a non-reflective paint.

# 1 INTRODUCTION

Willatook Wind Farm Pty Ltd ("the Proponent") has commissioned DNV to independently assess the expected annual shadow flicker durations in the vicinity of the proposed Willatook Wind Farm ("the Project") in western Victoria. The results of this work are reported here. This document has been prepared in accordance with DNV proposal L2C-212273-AUME-P-01 Issue A, dated 10 February 2021, 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 [6] and configuration in general accordance with the Policy and Planning Guidelines for Development of Wind Energy Facilities in Victoria (Victorian Planning Guidelines) prepared by the Victorian Department of Environment, Land, Water and Planning in July 2021 [1]. For the purpose of this assessment, DNV has also considered the guidance and recommendations given in the National Wind Farm Development Guidelines – Draft (Draft National Guidelines) prepared by the Environment Protection and Heritage Council (EPHC) in July 2010 [3].

# 2 DESCRIPTION OF THE SITE AND PROJECT

## 2.1 The site

The proposed Willatook Wind Farm ("the Project") is located approximately 35 km north-west of Warrnambool and 190 km west of Geelong. An overview of the site location is presented in Figure 2.

The terrain on and around the site is relatively flat, and consists mostly of farmland, with significant plantation areas south-west of the site. A digital elevation model (DEM), extending approximately 10 km from the site, was derived from publicly available SRTM1 data [7].

## 2.2 The project

### 2.2.1 Proposed wind farm layout

The Project is proposed to consist of 59 wind turbines [6]. A map of the site with the proposed turbine layout is shown in Figure 3, and the coordinates of the proposed turbine locations are given in Table 1.

As requested by the Proponent, DNV has modelled the shadow flicker based on a hypothetical turbine model with a rotor diameter of 190 m and a maximum upper tip height of 250 m [8]. The maximum blade chord length for the hypothetical turbine, defined as the dimension through the thickest part of the blade, is 5 m [8].

### 2.2.2 Shadow receptor locations

A list of dwellings neighbouring the wind farm was provided to DNV by the Proponent [9]. The coordinates of those 59 dwellings within 2900 m of proposed turbine locations (which corresponds to 15 times the maximum proposed rotor diameter plus 50 m) are presented in Table 2.

Out of the 59 dwellings which have been identified within 2900 m of the Project:

- 21 are stakeholder dwellings belonging to wind farm host landowners or landowners who have entered into a formal agreement with the Proponent, of which 6 are dilapidated dwellings [1]; and
- 38 are non-stakeholder dwellings, of which 2 are dilapidated dwellings [1].

It is understood from the Proponent that commercial arrangements have been entered into with stakeholders recognising impacts from the wind farm (including shadow flicker) [10].

DNV has modelled all listed dwellings including dilapidated dwellings, as advised by the Proponent[1] [11]. However, DNV has assumed that the dilapidated dwellings will not be inhabited following construction of the wind farm. Dwellings situated more than 2900 m from turbine locations are considered unlikely to be impacted by shadow flicker, as discussed further in Sections 3.1 and 4.1. It should be noted that the scope of the current work did not include a comprehensive survey of sensitive land uses and building locations in the area, and so DNV is relying on information provided by the Proponent.



[1] Dwellings were identified by the Proponent by reviewing aerial imagery and cadastral information, combined with ground truthing.

# 3 REGULATORY REQUIREMENTS

## 3.1 Shadow flicker

The Victoria Planning Provisions [9], particularly clause 52.32, and the Victorian Planning Guidelines [1], which are referenced in clauses 19.01-2S and 52.32-5 of the Victoria Planning Provisions, guide the development of wind energy facilities in Victoria. In relation to shadow flicker, the Victorian Planning Guidelines currently state:

> *"The shadow flicker experienced immediately surrounding the area of a dwelling (garden fenced area) must not exceed 30 hours per year as a result of the operation of the wind energy facility."*

The Victorian Planning Guidelines also include the following example permit condition:

> *"Shadow flicker from the wind energy facility must not exceed 30 hours per annum at any pre-existing dwelling (insert date), unless an agreement has been entered into with the relevant landowner waiving this requirement. The agreement must be in a form that applies to the land comprising a pre-existing dwelling for the life of the wind energy facility, to the satisfaction of the responsible authority, and must be provided to the responsible authority upon request."*

Although the Victorian Planning Guidelines state that *"[t]he seasonal duration of [shadow flicker] can be calculated from the geometry of the machine and the latitude of the site [and] modelled in advance"*, they do not provide detailed methodologies for these calculations.

Given that the Victorian Planning Guidelines do not provide a methodology for modelling shadow flicker impacts, DNV considers that the Draft National Guidelines [3] are also relevant. In relation to shadow flicker, the Draft National Guidelines include recommendations for shadow flicker limits relevant to wind farms in Australia and advice and methodologies for assessing shadow flicker durations.

The Draft National Guidelines recommend that the modelled theoretical shadow flicker duration should not exceed 30 hours per year, and that the actual or measured shadow flicker duration should not exceed 10 hours per year. The 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 a dwelling.

As details of the 'garden fenced area' for a dwelling are not readily available, DNV assumes that the evaluation of the maximum shadow flicker duration within 50 m of a dwelling (as required by the Draft National Guidelines) is similar to assessing shadow flicker durations within the 'garden fenced area'. In most cases this approach is expected to be adequate, however it is acknowledged that, in rural areas, the 'garden fenced area' may extend beyond 50 m from a dwelling.

These limits are assumed to apply to a single dwelling, and it is noted that there is no requirement under either the Victorian Planning Guidelines or the Draft National Guidelines to assess shadow flicker durations at locations other than in the vicinity of dwellings.

The Draft National Guidelines also provide background information, a proposed methodology, and a suite of assumptions for assessing shadow flicker durations in the vicinity of a wind farm.

The impact of shadow flicker is typically only significant up to a distance of around 10 rotor diameters from a turbine [12] or approximately 1200 m to 1900 m for modern wind turbines (which typically have rotor diameters of 120 m to 190 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 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 therefore suggest a distance equivalent to 265 times the maximum blade chord as an appropriate limit, which corresponds to approximately 1000 m to 1600 m for modern wind turbines (which typically have maximum blade chord lengths of 4 m to 6 m).

For the purposes of this assessment, DNV has considered the guidance and recommendations given in both the Victorian Planning Guidelines and the Draft National Guidelines in relation to shadow flicker.

## 3.2 Blade glint

The Draft National Guidelines provide guidance on blade glint and state that:

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

# 4 ASSESSMENT METHODOLOGY

## 4.1 Shadow flicker

### 4.1.1 Overview

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

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

- the direction of the property relative to the turbine
- the distance from the turbine (the further the observer is from the turbine, the less pronounced the effect will be)
- 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)
- 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).

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 surveyed house locations and has determined the highest shadow flicker duration within 50 m of each of the provided house location.

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

As part of the shadow flicker assessment, it is necessary to make an assumption regarding the maximum length of a shadow cast by a wind turbine that is likely to cause annoyance due to shadow flicker. The UK wind industry considers that 10 rotor diameters is appropriate [12], while the Draft National Guidelines suggest a distance equivalent to 265 times the maximum blade chord as an appropriate limit.

For the current assessment, DNV has applied a maximum shadow length of 10 times the rotor diameter (10D), which corresponds to a distance limit of 1900 m. Under the Draft National Guidelines, this will be conservative for any turbine with a maximum blade chord of less than 7.2 m. Beyond this distance limit, it is assumed that any shadow flicker experienced will be below a "moderate level of intensity" and unlikely to cause annoyance. However, it is recognised that different people have different levels of sensitivity to shadow flicker and may therefore be affected by shadow flicker intensities below the "moderate level of intensity" assumed by this distance limit. To account for this possibility, DNV has also assessed the shadow flicker for an increased distance limit of 15 times the rotor diameter (15D), or 2850 m, which should include shadow flicker below a "moderate level of intensity".

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

The model also makes the following assumptions and simplifications:

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

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

To illustrate typical results, an indicative shadow flicker map for a turbine located in a flat area is shown in Figure 4. The geometry of the shadow flicker map can be characterised as a butterfly shape, with the four protruding lobes corresponding to slowing of solar north-south travel around the summer and winter solstices for morning and evening. The lobes to the north of the indicative turbine location result from the summer months and conversely the lobes to the south result from the winter months. The lobes to the west result from morning sun while the lobes to the east result from evening sun. When the sun is low in the sky, the length of shadows cast by the turbine increases, increasing the area around the turbine affected by shadow flicker.

### 4.1.3 Factors affecting duration

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

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

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

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

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

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

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

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

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

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

6. The presence of vegetation or other physical barriers around a shadow receptor location may shield the view of the wind turbine, and therefore reduce the incidence of shadow flicker.

7. Periods where the wind turbine is not in operation due to low winds, high winds, or for operational and maintenance reasons will also reduce the annual shadow flicker duration.

### 4.1.4 Predicted actual duration

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

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

- Hamilton Airport (090173), located approximately 55 km from the site [13]
- Portland (Cashmore Airport) (090171), located approximately 60 km from the site [14].

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 54% and 69%, and the average annual cloud cover is approximately 64%. This means that on an average day, 64% 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.

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. Wind direction frequency distributions derived from wind measurements at the site were provided by the Proponent [11] and used to estimate the reduction in shadow flicker duration due to rotor orientation. The measured wind rose is shown overlaid on the indicative shadow flicker map in Figure 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 dwelling. Due to limitations in the availability of suitable cloud cover data, the methodology used in this assessment also deviates somewhat from the method recommended by the Draft National Guidelines for assessing the reduction in shadow flicker due to cloud cover. However, considering the available cloud cover data, the approach described above is deemed to provide a reasonable estimate of the likely impact of cloud cover on the shadow flicker duration.

No attempt has been made to account for vegetation or other shielding effects around each shadow receptor in calculating the shadow flicker duration. Similarly, turbine shutdown has not been considered.

## 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.

In order for blade glint not to be an issue for the wind farm, it is recommended that the turbine blades are coated with a non-reflective paint.

# 5 ASSESSMENT RESULTS

## 5.1 Shadow flicker

Shadow flicker assessments were carried out at all provided dwelling locations, or 'receptors', as outlined in Table 2.

The theoretical and predicted actual shadow flicker durations at all dwellings identified to be affected by shadow flicker are presented in Table 4. The maximum predicted shadow flicker durations within 50 m of these receptors are also presented in this table. Furthermore, the results are shown in the form of shadow flicker maps in Figure 5 and Figure 6. The shadow flicker values presented in these maps represent the worst case between the results at 2 m and 6 m above ground for each modelled grid point.

Based on DNV's modelling, a number of dwellings are predicted to experience some high intensity shadow flicker, meaning generally shadow flicker of at least a moderate level of intensity or above, which is expected to occur up to a distance of around 10 rotor diameters from the wind farm. A total of 24 dwellings are predicted to experience some high intensity shadow flicker, 13 of which are stakeholder dwellings and 11 of which are non-stakeholder dwellings.

Out of the 13 stakeholder dwellings, 11 are predicted to experience theoretical shadow flicker durations within 50 m of the dwelling that exceed the limit recommended by the current guidelines. When considering the likely reduction due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of the same 11 stakeholder dwellings are predicted to be above the recommended limit of 10 hours per year.

Out of the 11 non-stakeholder dwellings, none are predicted to experience theoretical or actual shadow flicker durations above the recommended limits of 30 and 10 hours per year respectively within 50 m of the dwelling.

However, it should be noted that the 50 m area surrounding some stakeholder dwellings is expected to experience very high theoretical shadow flicker durations, in several cases high intensity shadow flicker of more than 100 hours per year, and in two cases over 700 hours per year.

The Proponent has advised that *"commercial arrangements have been entered into with stakeholders recognising impacts from the wind farm (including shadow flicker)"* and that they are *"committed to conducting further work with stakeholders to develop specific measures to limit shadow flicker"*.

It is understood that the Proponent is committed to meeting an *actual* shadow flicker limit of 30 hours per year for stakeholder dwellings and that this is specified in the legal agreement between those landowners and the Proponent [4, 5]. This commitment may reduce shadow flicker durations for at least one of the stakeholder dwellings, however the shadow flicker durations at some dwellings may remain high.

It is likely that some form of mitigation, including turbine curtailments, will likely be required to limit shadow flicker durations so that the Project adheres to contractual limits. Mitigation options are discussed further in Section 5.1.1. It should be noted that if implementing turbine curtailments as a component of the shadow flicker mitigation strategy, this will likely result in a reduction in the energy output of the wind farm.

Beyond the 10D distance limit, it is assumed that any shadow flicker experienced will be of a low intensity and unlikely to cause annoyance. However, it is recognised that different people have different levels of sensitivity to shadow flicker and may therefore be affected by shadow flicker intensities of low intensity assumed to occur beyond this distance limit. To account for this possibility, and although not part of the methodology outlined in the Draft National Guidelines, DNV has also assessed the shadow flicker impacts for the Project for an increased distance limit that is intended to include shadow flicker of low intensity. For the purpose of this assessment, to account for low intensity shadow flicker the distance limit has been increased by 50% (to 15D), and the results of this additional assessment are illustrated in the map presented in Figure 5. These results indicate that 15 additional dwellings have the potential to be exposed to low intensity shadow flicker. These dwellings are noted in Table 4.

It should be noted the turbine configuration parameters (namely hub height and rotor diameter) used in the modelling, as advised by the Proponent, are representative of a worst-case scenario and the actual hub height and rotor diameter may be smaller. In the event that a turbine with smaller dimensions is selected, the shadow flicker durations at some dwellings are also likely to be lower than reported. DNV understands that the Proponent plans to prepare an updated shadow flicker assessment once turbine selection and detailed design (including micro-siting) have been conducted [5].

### 5.1.1 Mitigation Options

The effects of shadow flicker may be reduced through a number of mitigation options 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 (or shadow flicker protection systems) which shut down turbines when shadow flicker is likely to occur.

Shadow flicker protection systems have been deployed extensively on multiple wind turbines and wind farm sites throughout Europe, however DNV understands that they have not yet been deployed within Australia. The protection system could be used to ensure that shadow flicker durations experienced at affected stakeholder dwellings remain below agreed limits.

Shadow flicker protection systems [15] typically consist of a control module that can calculate whether it is theoretically possible for shadow flicker to occur at a sensitive location, and light sensors to detect whether there is direct sunlight at the site. Examples of typical shadow flicker protection system components can be seen in Figure 7.

Once the maximum permitted shadow flicker exposure duration is exceeded, the wind turbine(s) causing the shadow flicker will be shut down for the duration of the shadow fall. During this period there will be no shadow flicker, however there may still potentially be some form of stationary shadow from the contributing wind turbine(s), depending on the sun position and blade rotation angles. All shadow flicker occurrences and shutdown periods can be recorded. The settings in the shadow flicker shutdown module that determine turbine shutdown periods are customisable depending on parameters such as the position of the sun, meteorological data, time of day and year, wind speed and temperature, etc.

## 5.2 Blade glint

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

# 6 CONCLUSIONS

A shadow flicker assessment was carried out at all dwelling locations in the vicinity of the Project. For the purpose of this assessment, DNV has considered a layout consisting of 59 turbines with a rotor diameter of 190 m and a tip height of 250 m. The results of the shadow flicker assessment based on this layout configuration are summarised in Table 4.

Based on DNV's modelling, 24 dwellings are predicted to experience some high-intensity shadow flicker, 13 of which are stakeholder dwellings and 11 of which are non-stakeholder dwellings.

Out of the 13 stakeholder dwellings, 11 are predicted to experience theoretical shadow flicker durations within 50 m of the dwelling that exceed the limit recommended by the current guidelines. When considering the predicted actual shadow flicker duration, which takes into account the reduction in shadow flicker due to cloud cover and rotor orientation, the predicted actual shadow flicker durations within 50 m of the same 11 stakeholder dwellings are expected to experience actual shadow flicker durations above the limit recommended in the guidelines.

Out of the 11 non-stakeholder dwellings predicted to experience some high intensity shadow flicker, none are predicted to experience theoretical or actual shadow flicker durations above the recommended limits of 30 and 10 hours per year respectively within 50 m of the dwelling.

However, it should be noted that the 50 m area surrounding some stakeholder dwellings is expected to experience very high theoretical shadow flicker durations; in several cases high intensity shadow flicker of more than 100 hours per year, and in two cases over 700 hours per year.

The Proponent has advised that *"commercial arrangements have been entered into with stakeholders recognising impacts from the wind farm (including shadow flicker)"* and that they are *"committed to conducting further work with stakeholders to develop specific measures to limit shadow flicker"*.

It is understood that the Proponent is committed to meeting an *actual* shadow flicker limit of 30 hours per year for stakeholder dwellings and that this is specified in the legal agreement between those landowners and the Proponent [4, 5]. This commitment may reduce shadow flicker durations for at least one of the stakeholder dwellings, however the shadow flicker durations at some dwellings may remain high.

It is likely that some form of mitigation, including turbine curtailments, will likely be required to limit shadow flicker durations so that the Project adheres to contractual limits.

The effects of shadow flicker may be reduced through a number of mitigation options 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 which shut down turbines when shadow flicker is likely to occur. It should be noted that if implementing turbine curtailments as a component of the shadow flicker mitigation strategy, this will likely result in a reduction in the energy output of the wind farm.

It should be noted the turbine configuration parameters (namely hub height and rotor diameter) used in the modelling, as advised by the Proponent, are representative of a worst-case scenario and the actual hub height and rotor diameter may be smaller. In the event that a turbine with smaller dimensions is selected, the shadow flicker durations at some dwellings are also likely to be lower than reported.

In order for blade glint not to be an issue for the wind farm, it is recommended that the turbine blades are coated with a non-reflective paint.

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[16] "210826_WIL_LVIA WTGv071.zip," provided by P. Deveney (Willatook Wind Farm Pty Ltd) to N. Brammer (DNV), 9 September 2021.

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**Table 1 Proposed turbine layout for the Project site [6]**

| Turbine ID | Easting[1] [m] | Northing[1] [m] | Base elevation [m] | Turbine ID | Easting[1] [m] | Northing[1] [m] | Base elevation [m] |
|---|---|---|---|---|---|---|---|
| T1 | 594541 | 5777512 | 117 | T31 | 601868 | 5773034 | 72 |
| T2 | 594912 | 5778008 | 120 | T32 | 601951 | 5774373 | 81 |
| T3 | 595052 | 5777437 | 118 | T33 | 602181 | 5775353 | 86 |
| T4 | 595295 | 5775292 | 86 | T34 | 602339 | 5774680 | 84 |
| T5 | 595356 | 5776399 | 99 | T35 | 602430 | 5772374 | 69 |
| T6 | 595539 | 5775736 | 89 | T36 | 602448 | 5773726 | 77 |
| T7 | 595987 | 5775116 | 88 | T37 | 602449 | 5773036 | 72 |
| T8 | 596021 | 5775883 | 90 | T38 | 602652 | 5775570 | 90 |
| T9 | 596385 | 5776184 | 90 | T39 | 602963 | 5774822 | 90 |
| T10 | 596524 | 5775138 | 91 | T40 | 602974 | 5774260 | 85 |
| T11 | 596820 | 5775529 | 93 | T41 | 602978 | 5776744 | 90 |
| T12 | 597012 | 5776114 | 90 | T42 | 602982 | 5777383 | 91 |
| T13 | 597418 | 5775401 | 91 | T43 | 602995 | 5772439 | 70 |
| T14 | 597509 | 5776428 | 91 | T44 | 603079 | 5773025 | 76 |
| T15 | 597786 | 5775729 | 93 | T45 | 603085 | 5775834 | 89 |
| T16 | 598102 | 5776261 | 92 | T46 | 603504 | 5777464 | 87 |
| T17 | 598281 | 5775070 | 96 | T47 | 604413 | 5777218 | 79 |
| T18 | 598454 | 5775587 | 95 | T48 | 604706 | 5777584 | 102 |
| T19 | 600069 | 5773733 | 85 | T49 | 605324 | 5777145 | 92 |
| T20 | 600427 | 5772376 | 67 | T50 | 605523 | 5776474 | 86 |
| T21 | 600465 | 5774158 | 82 | T51 | 606007 | 5776591 | 95 |
| T22 | 600595 | 5772972 | 68 | T52 | 606013 | 5775518 | 77 |
| T23 | 600736 | 5774616 | 86 | T53 | 606138 | 5775999 | 79 |
| T24 | 601107 | 5775130 | 93 | T54 | 606584 | 5776429 | 99 |
| T25 | 601274 | 5772373 | 65 | T55 | 606753 | 5775545 | 84 |
| T26 | 601287 | 5773051 | 69 | T56 | 606959 | 5774946 | 70 |
| T27 | 601373 | 5774416 | 82 | T57 | 606986 | 5773741 | 67 |
| T28 | 601416 | 5777791 | 94 | T58 | 607132 | 5774276 | 70 |
| T29 | 601720 | 5775145 | 86 | T59 | 607608 | 5773622 | 74 |
| T30 | 601827 | 5772400 | 71 | | | | |

1. *Coordinate system: MGA zone 54, GDA2020 datum.*

**Table 2 Shadow receptor locations within 2900 m of turbines at the Project [16]**

| Receptor ID | Landowner status | Easting[1] [m] | Northing[1] [m] | Distance to nearest turbine [m] (and nearest turbine ID) | |
|---|---|---|---|---|---|
| D1 | Stakeholder | 602338 | 5778517 | 1173 | T28 |
| D2 | Stakeholder | 602249 | 5778671 | 1212 | T28 |
| D3 | Stakeholder | 602806 | 5778870 | 1497 | T42 |
| D4 | Stakeholder | 603939 | 5778286 | 930 | T46 |
| D6 | Stakeholder | 604693 | 5776249 | 860 | T50 |
| D7[2] | Stakeholder | 604270 | 5778099 | 674 | T48 |
| D8 | Stakeholder | 604307 | 5774639 | 1356 | T39 |
| D9 | Non-stakeholder | 600298 | 5778839 | 1533 | T28 |
| D10 | Non-stakeholder | 599984 | 5778813 | 1759 | T28 |
| D11 | Non-stakeholder | 604612 | 5774248 | 1638 | T40 |
| D12 | Stakeholder | 604797 | 5779067 | 1486 | T48 |
| D14 | Stakeholder | 599057 | 5778429 | 2369 | T16 |
| D15 | Stakeholder | 606009 | 5777950 | 1057 | T49 |
| D17 | Non-stakeholder | 604805 | 5773236 | 1739 | T44 |
| D18 | Non-stakeholder | 604962 | 5773291 | 1902 | T44 |
| D19 | Stakeholder | 597861 | 5778419 | 2022 | T14 |
| D21 | Non-stakeholder | 597313 | 5778556 | 2137 | T14 |
| D22 | Non-stakeholder | 598908 | 5772235 | 1525 | T20 |
| D23 | Non-stakeholder | 597075 | 5778833 | 2315 | T2 |
| D25 | Non-stakeholder | 608204 | 5776320 | 1624 | T54 |
| D26 | Non-stakeholder | 604978 | 5771412 | 2233 | T43 |
| D28 | Stakeholder | 607967 | 5774731 | 951 | T58 |
| D29 | Non-stakeholder | 598950 | 5771721 | 1616 | T20 |
| D32 | Non-stakeholder | 596718 | 5779446 | 2308 | T2 |
| D33 | Non-stakeholder | 596404 | 5778960 | 1770 | T2 |
| D34 | Non-stakeholder | 597821 | 5772016 | 2631 | T20 |
| D36 | Non-stakeholder | 605508 | 5771178 | 2812 | T43 |
| D39[2] | Non-stakeholder | 608652 | 5775369 | 1745 | T56 |
| D40 | Non-stakeholder | 598861 | 5771212 | 1952 | T20 |
| D44 | Stakeholder | 595730 | 5778083 | 822 | T2 |
| D47 | Non-stakeholder | 601378 | 5769755 | 2620 | T25 |
| D48 | Non-stakeholder | 602014 | 5769677 | 2729 | T35 |
| D50 | Non-stakeholder | 600934 | 5769675 | 2719 | T25 |
| D51 | Non-stakeholder | 602966 | 5769562 | 2862 | T35 |
| D52 | Non-stakeholder | 602079 | 5769523 | 2873 | T35 |

| Receptor ID | Landowner status | Easting[1] [m] | Northing[1] [m] | Distance to nearest turbine [m] (and nearest turbine ID) | |
|---|---|---|---|---|---|
| D62 | Non-stakeholder | 598860 | 5769956 | 2883 | T20 |
| D78 | Non-stakeholder | 595010 | 5773129 | 2182 | T4 |
| D81 | Non-stakeholder | 595419 | 5772309 | 2864 | T7 |
| D88 | Stakeholder | 594116 | 5778220 | 823 | T2 |
| D90 | Non-stakeholder | 594390 | 5773941 | 1626 | T4 |
| D91 | Non-stakeholder | 594743 | 5773211 | 2153 | T4 |
| D97 | Non-stakeholder | 593563 | 5776282 | 1572 | T1 |
| D104 | Non-stakeholder | 609696 | 5771630 | 2886 | T59 |
| D107 | Non-stakeholder | 593478 | 5775056 | 1832 | T4 |
| D123 | Non-stakeholder | 592583 | 5777111 | 1999 | T1 |
| D124 | Non-stakeholder | 592534 | 5776194 | 2401 | T1 |
| D354 | Non-stakeholder | 594014 | 5774302 | 1619 | T4 |
| D355[2] | Stakeholder | 604198 | 5775087 | 1263 | T39 |
| D356 | Non-stakeholder | 597839 | 5771804 | 2650 | T20 |
| D357 | Non-stakeholder | 602767 | 5778969 | 1601 | T42 |
| D373 | Stakeholder | 604840 | 5779083 | 1505 | T48 |
| D374[2] | Non-stakeholder | 605063 | 5773027 | 1984 | T44 |
| D375 | Stakeholder | 599299 | 5774080 | 844 | T19 |
| D382 | Non-stakeholder | 594643 | 5773413 | 1989 | T4 |
| D383 | Non-stakeholder | 598921 | 5771659 | 1668 | T20 |
| D460[2] | Stakeholder | 600889 | 5772922 | 298 | T22 |
| D482[2] | Stakeholder | 597337 | 5775111 | 301 | T13 |
| D484[2] | Stakeholder | 603225 | 5775960 | 189 | T45 |
| D485[2] | Stakeholder | 603199 | 5775999 | 200 | T45 |

1. *Coordinate system: MGA zone 54, GDA2020 datum* [17].
2. *Dwellings identified by the Proponent as dilapidated dwellings* [11].

**Table 3 Shadow flicker model settings for theoretical shadow flicker calculation**

| Model setting | |
|---|---|
| Shadow distance limit (10D) | 1900 m |
| Year of calculation | 2034 |
| Minimum elevation of the sun | 3° |
| Time step | 1 min (5 min for map) |
| Rotor modelled as | Sphere (disc for turbine orientation reduction calculation) |
| Sun modelled as | Disc |
| Offset between rotor and tower | None |
| Receptor height (single storey) | 2 m |
| Receptor height (double storey) | 6 m |
| Locations used for determining maximum shadow flicker within 50 m of each dwelling | 8 points evenly spaced (every 45°) on 25 m and 50 m radius circles centred on the provided house location |

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**Table 4 Theoretical and predicted actual annual shadow flicker duration**

| House ID[1] | Status | Easting[2] [m] | Northing[2] [m] | Contributing turbines | Theoretical annual | | | | Predicted actual annual[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | At dwelling [hr/yr] | | Max within 50 m [hr/yr] | | At dwelling [hr/yr] | | Max within 50 m [hr/yr] | |
| | | | | | 2 m | 6 m | 2 m | 6 m | 2 m | 6 m | 2 m | 6 m |
| D1[4] | Stakeholder | 602338 | 5778517 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D2[4] | Stakeholder | 602249 | 5778671 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D4[4] | Stakeholder | 603939 | 5778286 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D6 | Stakeholder | 604693 | 5776249 | T41 T45 T50 T51 T52 T53 T54 | **113.0** | **111.4** | **120.5** | **118.9** | **26.5** | **26.2** | **28.7** | **28.3** |
| D7[5] | Stakeholder | 604270 | 5778099 | T42 | 4.4 | 4.6 | 13.9 | 13.9 | 0.4 | 0.5 | 2.6 | 2.6 |
| D8 | Stakeholder | 604307 | 5774639 | T38 T39 T40 T52 | **60.4** | **59.4** | **77.4** | **75.7** | **14.2** | **13.9** | **17.4** | **17.0** |
| D11 | Non-stakeholder | 604612 | 5774248 | T39 T40 | 25.3 | 24.9 | 27.4 | 26.9 | 6.1 | 6.0 | 6.6 | 6.5 |
| D14[4] | Stakeholder | 599057 | 5778429 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D15 | Stakeholder | 606009 | 5777950 | T47 T48 | **44.8** | **43.9** | **48.6** | **47.5** | **11.2** | **10.9** | **12.2** | **11.9** |
| D17 | Non-stakeholder | 604805 | 5773236 | T44 | 11.1 | 10.9 | 12.0 | 11.8 | 2.8 | 2.7 | 3.1 | 3.0 |
| D18 | Non-stakeholder | 604962 | 5773291 | T44 | 0.0 | 0.0 | 9.5 | 9.2 | 0.0 | 0.0 | 2.4 | 2.3 |
| D21[4] | Non-stakeholder | 597313 | 5778556 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D22 | Non-stakeholder | 598908 | 5772235 | T20 T22 | 25.6 | 25.0 | 27.6 | 26.9 | 5.6 | 5.5 | 6.0 | 5.8 |
| D23[4] | Non-stakeholder | 597075 | 5778833 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D25 | Non-stakeholder | 608204 | 5776320 | T54 T55 | 20.4 | 20.2 | 28.5 | 28.2 | 4.1 | 4.1 | 6.4 | 6.3 |
| D26[4] | Non-stakeholder | 604978 | 5771412 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D28 | Stakeholder | 607967 | 5774731 | T55 T56 T58 | **85.2** | **86.2** | **107.1** | **107.7** | **18.2** | **18.4** | **23.8** | **24.0** |
| D29 | Non-stakeholder | 598950 | 5771721 | T20 | 16.9 | 16.6 | 18.7 | 18.5 | 3.4 | 3.3 | 3.7 | 3.6 |

| House ID[1] | Status | Easting[2] [m] | Northing[2] [m] | Contributing turbines | Theoretical annual | | | | Predicted actual annual[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | At dwelling [hr/yr] | | Max within 50 m [hr/yr] | | At dwelling [hr/yr] | | Max within 50 m [hr/yr] | |
| | | | | | 2 m | 6 m | 2 m | 6 m | 2 m | 6 m | 2 m | 6 m |
| D34[4] | Non-stakeholder | 597821 | 5772016 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D36[4] | Non-stakeholder | 605508 | 5771178 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D39[5] | Non-stakeholder | 608652 | 5775369 | T55 T56 | 13.4 | 13.1 | 24.2 | 23.5 | 3.3 | 3.2 | 5.9 | 5.8 |
| D40[4] | Non-stakeholder | 598861 | 5771212 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D44 | Stakeholder | 595730 | 5778083 | T1 T2 | **83.4** | **83.2** | **92.0** | **91.6** | **20.0** | **20.0** | **22.4** | **22.4** |
| D88 | Stakeholder | 594116 | 5778220 | T2 | **91.0** | **90.7** | **100.6** | **100.8** | **22.9** | **22.7** | **26.8** | **26.8** |
| D90[4] | Non-stakeholder | 594390 | 5773941 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D97 | Non-stakeholder | 593563 | 5776282 | T3 T5 | 21.2 | 20.2 | 28.6 | 27.8 | 4.1 | 3.9 | 5.8 | 5.6 |
| D107 | Non-stakeholder | 593478 | 5775056 | T4 | 9.5 | 9.3 | 10.2 | 10.0 | 2.2 | 2.2 | 2.4 | 2.3 |
| D123[4] | Non-stakeholder | 592583 | 5777111 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D124[4] | Non-stakeholder | 592534 | 5776194 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D354 | Non-stakeholder | 594014 | 5774302 | T4 | 17.6 | 16.8 | 26.4 | 25.7 | 3.0 | 2.8 | 4.9 | 4.8 |
| D355[5] | Stakeholder | 604198 | 5775087 | T34 T38 T39 T45 T52 | **98.0** | **96.3** | **105.2** | **103.3** | **22.7** | **22.4** | **24.2** | **23.8** |
| D356[4] | Non-stakeholder | 597839 | 5771804 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D374[4,5] | Non-stakeholder | 605063 | 5773027 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D375 | Stakeholder | 599299 | 5774080 | T19 T21 T23 | **104.3** | **104.0** | **123.5** | **123.4** | **26.1** | **26.1** | **31.9** | **31.9** |
| D383 | Non-stakeholder | 598921 | 5771659 | T20 | 17.1 | 16.6 | 19.0 | 18.9 | 3.3 | 3.2 | 3.6 | 3.5 |
| D460[5] | Stakeholder | 600889 | 5772922 | T19 T22 T26 T30 T31 T35 T36 T37 | **673.7** | **675.0** | **732.5** | **737.9** | **145.1** | **145.4** | **163.1** | **164.3** |

| House ID[1] | Status | Easting[2] [m] | Northing[2] [m] | Contributing turbines | Theoretical annual | | | | Predicted actual annual[3] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | At dwelling [hr/yr] | | Max within 50 m [hr/yr] | | At dwelling [hr/yr] | | Max within 50 m [hr/yr] | |
| | | | | | 2 m | 6 m | 2 m | 6 m | 2 m | 6 m | 2 m | 6 m |
| D482[5] | Stakeholder | 597337 | 5775111 | T6 T7 T8 T10 T11 T13 T15 T17 T18 | **578.9** | **571.0** | **763.1** | **754.4** | **115.8** | **114.0** | **149.9** | **148.1** |
| D484[5] | Stakeholder | 603225 | 5775960 | T29 T33 T45 | 5.6 | 5.6 | **151.9** | **168.5** | 0.7 | 0.7 | **13.8** | **16.1** |
| D485[5] | Stakeholder | 603199 | 5775999 | T29 | 0.0 | 0.0 | 5.6 | 5.6 | 0.0 | 0.0 | 0.7 | 0.7 |
| ***Recommended duration limits*** | | | | | ***30 hr/yr*** | | | | ***10 hr/yr*** | | | |

1. *Dwellings identified in Table 2 for which there is no theoretical shadow flicker occurrence up to a distance limit of 15 times the rotor diameter have been omitted from this table.*
2. *Coordinate system: MGA zone 54, GDA2020 datum* [17].
3. *Considering likely reductions in shadow flicker duration due to cloud cover and turbine orientation.*
4. *Dwelling is not predicted to experience any high intensity shadow flicker, but may experience some low intensity shadow flicker.*
5. *Dwellings identified by the Proponent as dilapidated dwellings* [11].

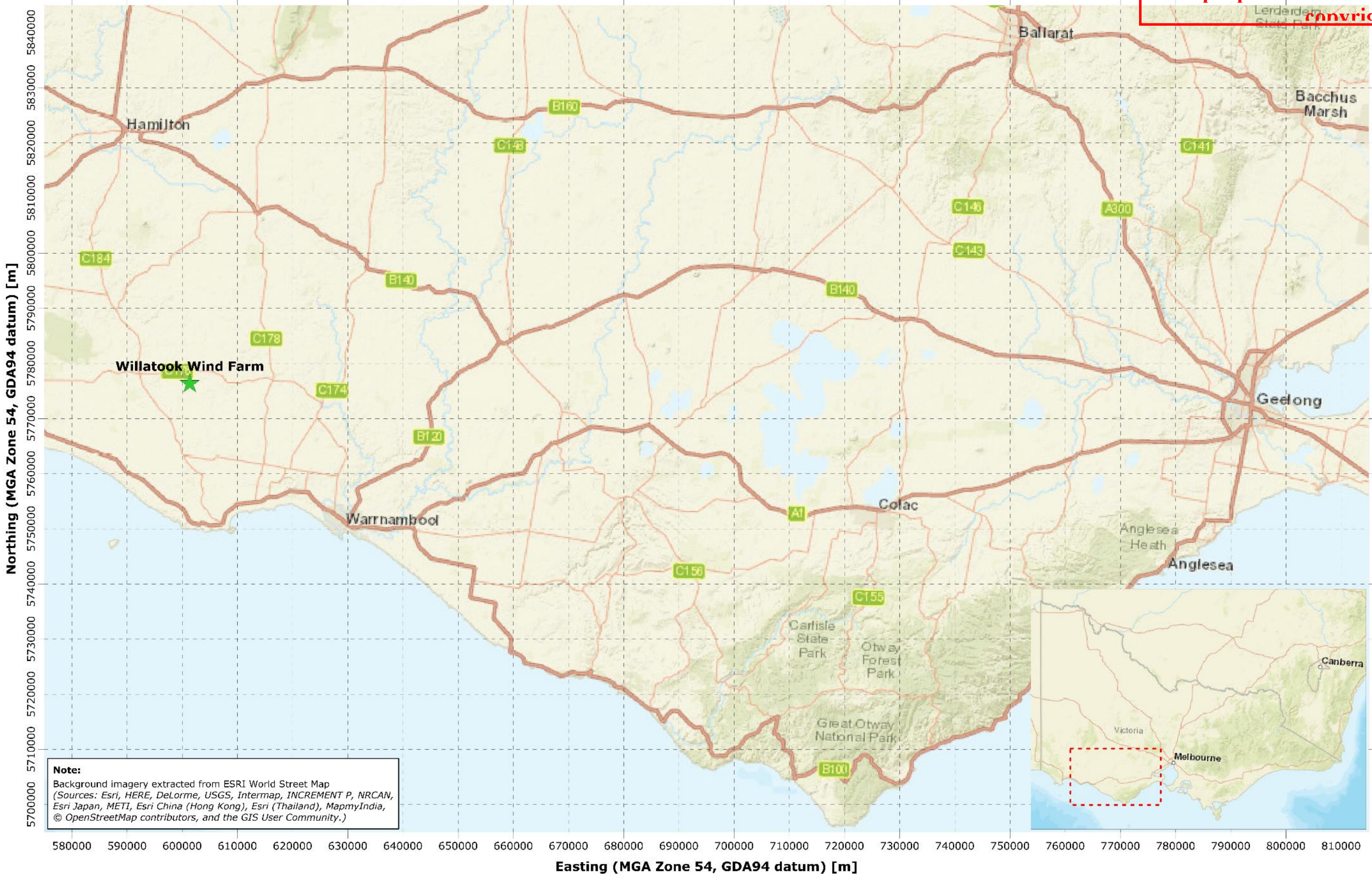


**Figure 2 Location of the Project**

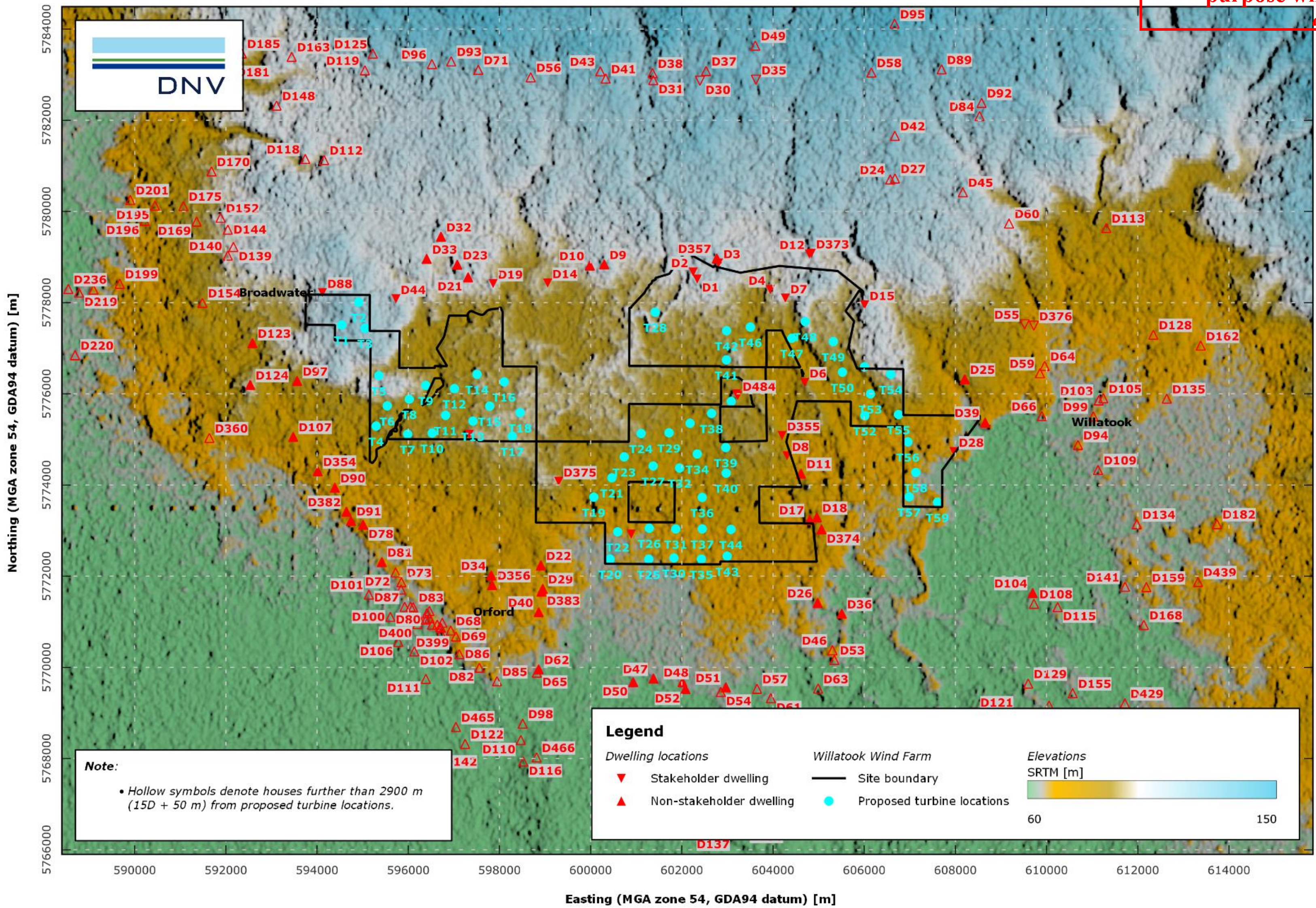


**Figure 3 Elevation map of the Project**

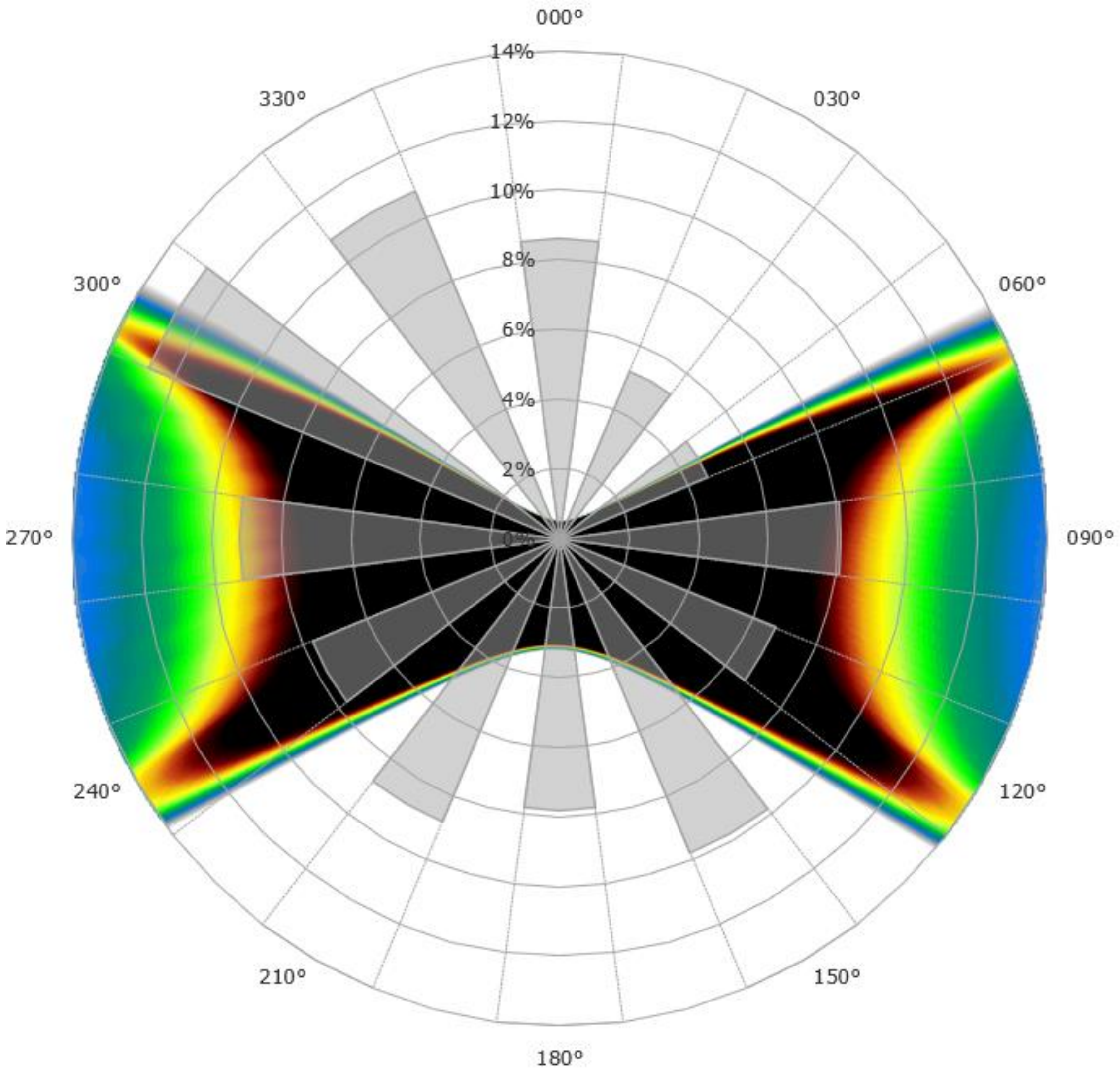


**Figure 4 Indicative shadow flicker map and wind direction frequency distribution**

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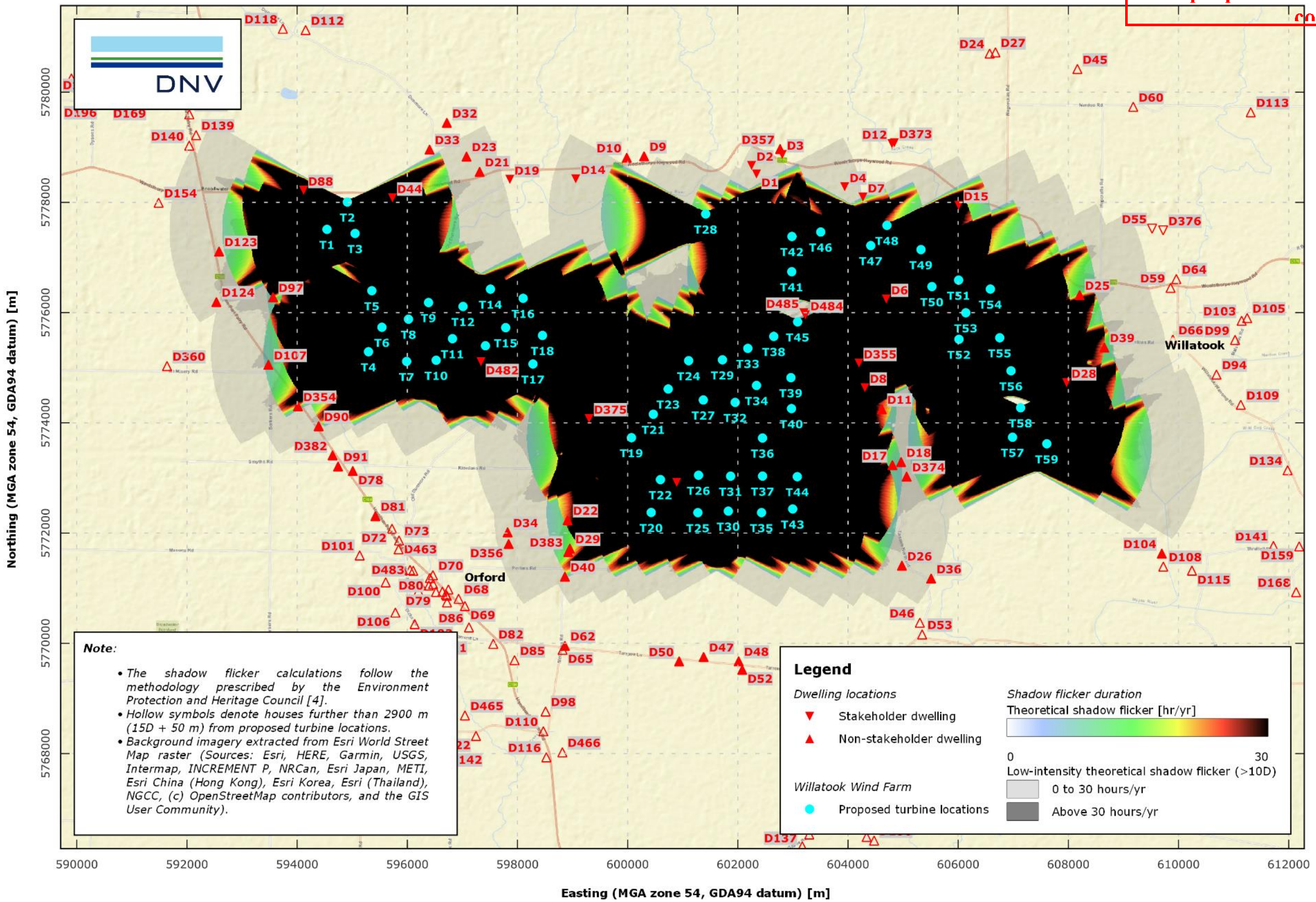


**Figure 5 Theoretical annual shadow flicker duration map**

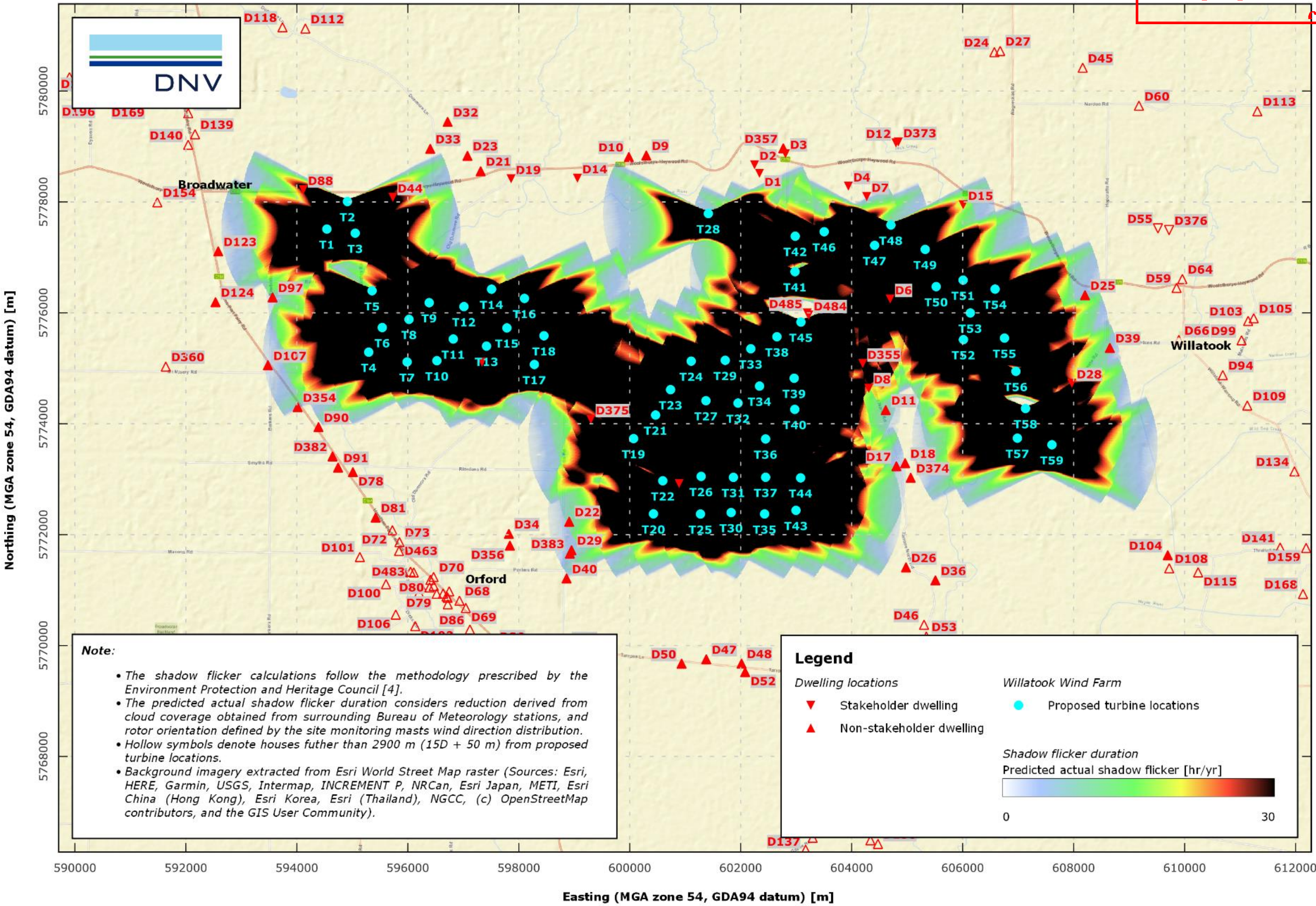


**Figure 6 Predicted actual annual shadow flicker duration map**

| | |
|---|---|
|  | Shadow flicker module cabinet with cabling |
|  | Light sensor mounted to the tower of a wind turbine |
|  | Light sensor mounted on top of the wind turbine nacelle |

**Figure 7  Shadow flicker protection system components**

## About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimising the performance of a wind farm, analysing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.