Appendix L

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Delburn Wind Farm
Shadow flicker and blade glint assessment

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For better energy projects

Management

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v.2	22 January 2021	Revised release, reflecting turbine model changes in response to DELWP RFI
v.1	27 August 2020	Original release

Contents

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1 Introduction

Delburn Wind Farm Pty Ltd has commissioned K2 Management to undertake a shadow flicker assessment of the Delburn Wind Farm. This shadow flicker assessment corresponds to layout version 3.4, as shown in Figure 1.2.

1.1 Turbine dimension

The turbine dimensions that have been modelled in this assessment are summarised in the table below. At the time of writing the design parameters for a turbine with a 180 m rotor were not available. The blade chord for a particular turbine does not scale with rotor length as it depends on the design specification of the machine. In order to estimate an appropriate blade chord for a 180 m rotor K2M has reviewed similar sized machines. The following table details the findings.

Turbine model	Blade chord [m]
Vestas V150-5MW	4.2
GE 5.5-158	4.0
Vestas V162-5.6MW	4.3
Siemens Gamesa SG6.0-170	4.5

Table 1.1 Blade chord lengths

Therefore, K2M has assumed a maximum blade chord of 4.5 m which is considered reasonable.

	Number of turbines	Rotor diameter [m]	Hub height [m]	Maximum blade chord [m]
Modelled turbine	33	180.0	160.0	4.5

Table 1.2 Turbine dimensions used in shadow flicker modelling

1.2 Site location

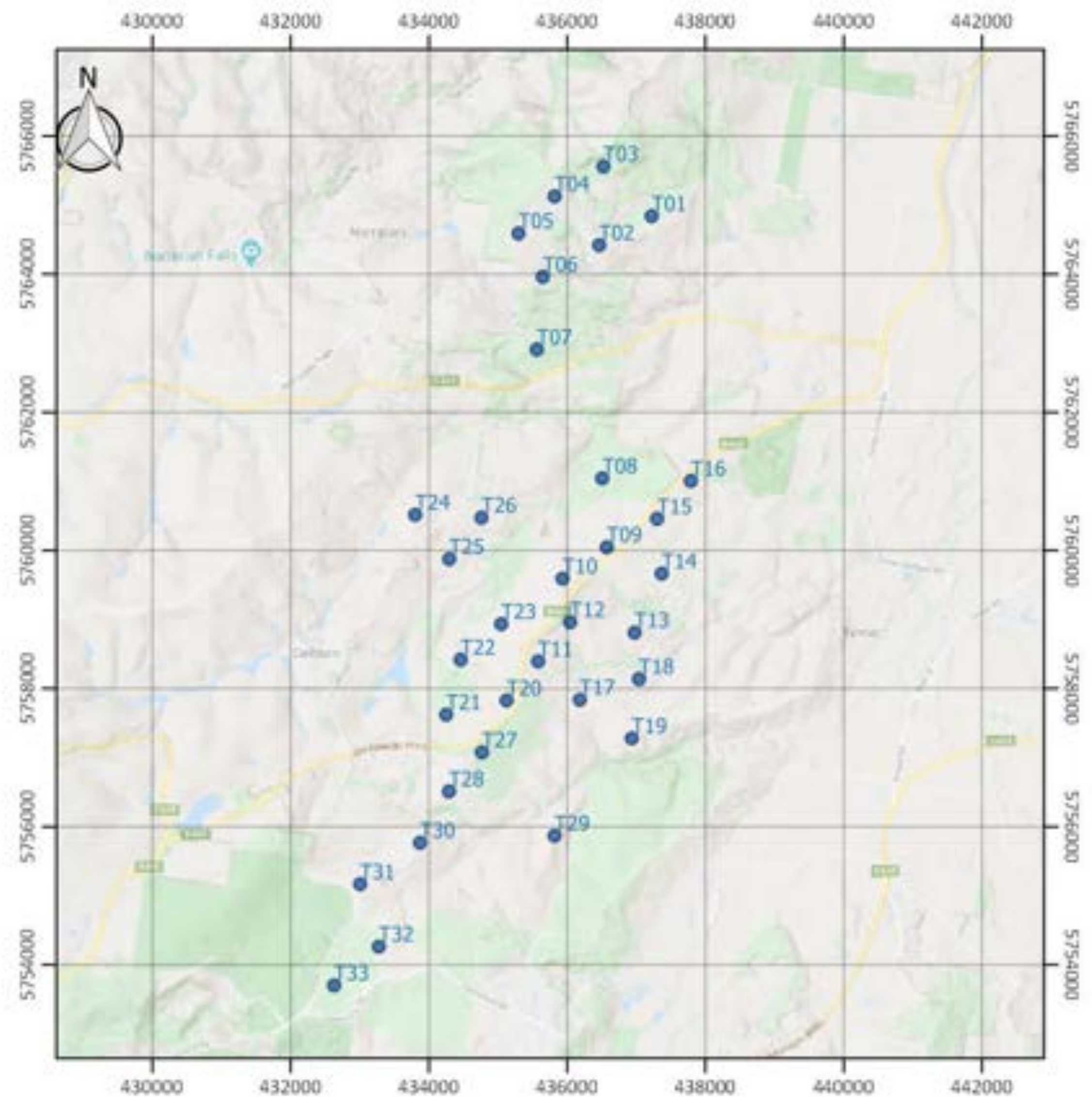
The location of the proposed wind farm is shown in Figure 1.1. The Delburn site is located approximately 126 km southeast of Melbourne.

Figure 1.1 Delburn Wind Farm location

1.3 Site description

The site area is presented in Figure 1.1. This shadow flicker assessment corresponds to layout version 3.4, as shown in Figure 1.2. Turbine coordinates are presented in Appendix Table A1.

The proposed wind farm is situated on an elevated plain, 10 km south-east of Morwell in Victoria. The site area extends approximately 6km east to west and 15 km north to south. The terrain is forested and varies in elevation between 100 m in the south west corner to 300 m towards the centre of site. The Bass Highway runs through the centre of the proposed site, 40 km from the coast of Bass Straight, to the south. The site is also in proximity to a number of open cut coal mines.



Legend

● Proposed Delburn Wind Farm turbine

Notes

- Coordinate system is UTM Grid Zone-55 WGS84 Datum.

Figure 1.2 Proposed turbine layout (version 3.4)

2 Shadow flicker

At the request of the Client, K2 Management has undertaken shadow flicker modelling for the latest layout at the Delburn Wind Farm. The following sections describe the methodology and assumptions applied.

2.1 Applicable guidelines

The Policy and Planning Guidelines for Wind Farm Development in Victoria state that 'shadow flicker experienced immediately surrounding the area of a dwelling (garden fenced area) must not exceed 30 hours per year'.

The methodology applied to assess the annual shadow flicker exposure at each dwelling follows the approach prescribed in the Australian National Guidelines[1] and discussed in Section 2.2.

2.2 Methodology

This section sets out the basis and application of the methodology applied to assess shadow flicker at the Delburn Wind Farm.

2.2.1 Assessment methodology

The National Guidelines determine that the optimum method of assessment is to:

- Evaluate the shadow flicker impact up to a distance of 265 x maximum blade chord (no assessment is required for dwellings beyond this distance).
- Identify all residences within the extent of shadows from proposed turbine positions.
- Use modelling software with relevant modelling parameters, to calculate the theoretical annual shadow flicker duration at each residence, accounting for topography and cumulative effects.
- If necessary, modify turbine layout and repeat calculations, or introduce mitigation measures to achieve compliance.
- Depending on jurisdictions, shadow flicker assessment may not be required for associated landowners.

The National Guidelines state the following with respect to the recommended modelling assumptions:

"Calculation of shadow flicker in an ideal model (with the assumptions specified here) will provide a conservative estimate of the actual shadow flicker. In most circumstances where a dwelling experiences a 'Modelled' level of shadow flicker less than 30 hours per year, no further investigation is required. However, if this level is exceeded in the modelled scenario, mitigation measures may be introduced and the 'actual' or 'measured' level of shadow flicker will need to be determined".

Further detail is provided in the guidelines for how to estimate the "actual" number of annual shadow flicker hours accounting for cloud cover.

2.2.2 Shadow flicker assessment boundary

The shadow flicker assessment boundary of 1192.5 m was determined based on an assumed turbine blade chord length of 4.5 m, considered reasonable for turbines with rotors up to 180 m.

[1] National Wind Farm Development Guidelines – Draft, July 2010

2.2.3 Dwellings within the assessment boundary

The Client provided a list of dwellings[2] in the vicinity of the wind farm. The coordinates of all dwellings assessed as part of this analysis are provided in Appendix Table A2. Only existing dwellings have been assessed; future developments have not been considered.

The Policy and Planning Guidelines for Wind Farm Development in Victoria, place a limit on the hours of shadow flicker experienced immediately surrounding the area of a dwelling referred to as the 'garden fenced area'. K2M has not conducted a site visit to the Delburn Wind Farm in order to survey nearby dwellings. Instead, publicly available aerial photography has been used to determine the 'garden fenced area' for each dwelling. In some cases, the property has no discernible 'garden fenced area'. Where this is the case K2M has assumed a garden area with a radius of 50 m in all directions as suggested in the Draft National Wind farm Development guidelines.

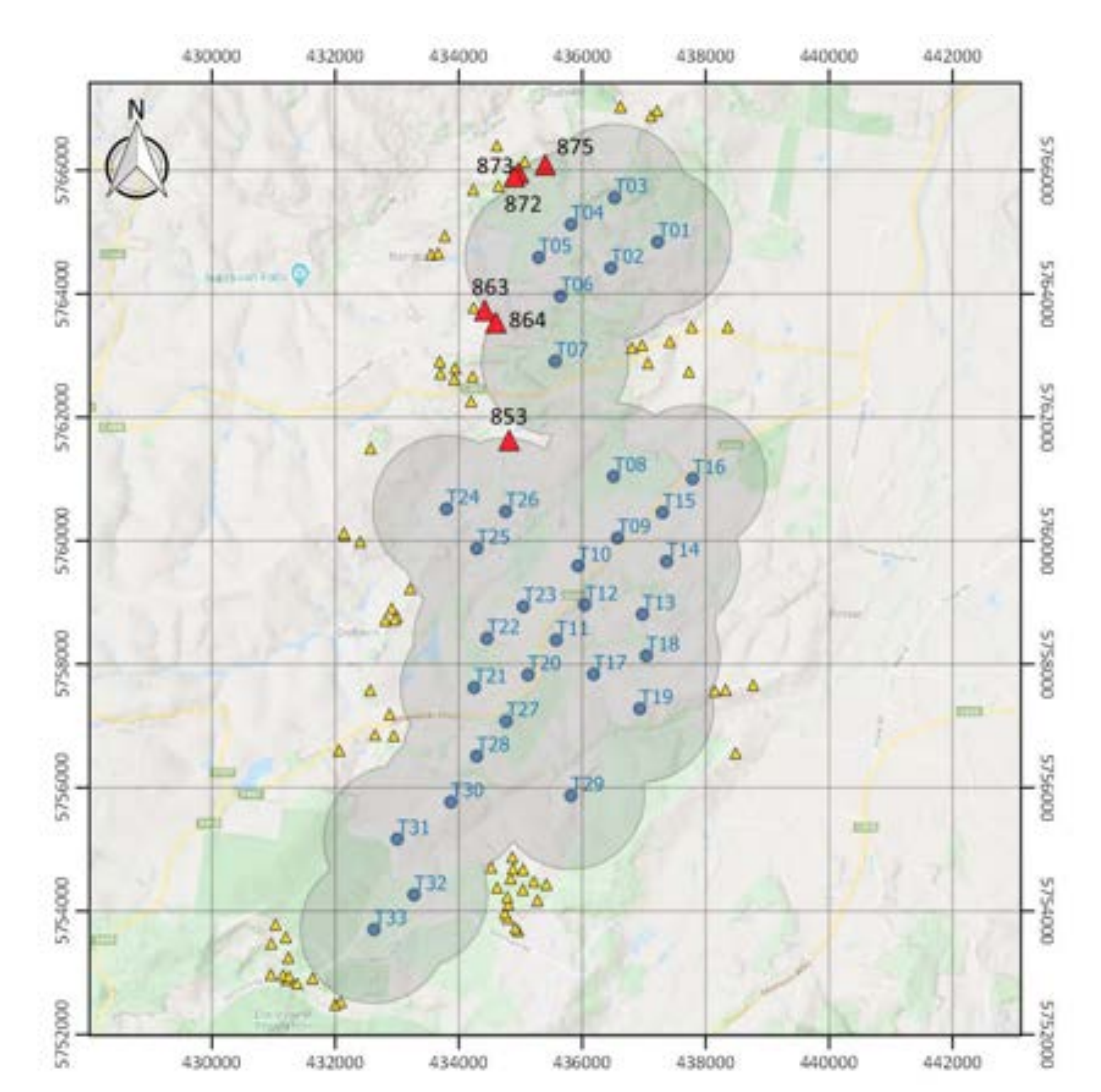
The extent of shadow flicker has been modelled at dwellings and their associated garden areas within the 1192.5 m assessment boundary. The six relevant dwellings are detailed in Table 2.1 below which also sets out how the garden area was determined. Publicly available aerial Images for the dwellings are provided in Appendix A2.

The assessment boundary and dwelling locations are shown in Figure 2.1 below.

Dwelling	Distance from dwelling to nearest turbine [m]	Nearest Turbine	Garden area definition
875	1053	T04	50 m radius
873	1193	T04	50 m radius
872	1204	T04	50 m radius
863	1172	T06	Publicly available imagery
864	1050	T07	Publicly available imagery
853	1157	T26	50 m radius

Table 2.1 Dwellings within 1192.5 m assessment boundary

[2] "DWF Dwellings Feb2020.kmz", Dwelling coordinates .kmz file, 20 Feb 2020.



Legend

●	Proposed turbine location	▭	265 x maximum chord length boundary (1192.5 m)
△	All dwellings supplied	▲	Dwelling within 1192.5 m

Notes

- Coordinate system is UTM Grid Zone-55 WGS84 Datum

Figure 2.1 Dwelling locations and assessment boundary

2.2.4 Modelling methodology

Under certain combinations of geographical position and time of day, the sun may pass behind the moving turbine rotor blades and cast a shadow that alternates on and off. The frequency of the flicker depends on the rate of rotation and the number of blades of the wind turbine. Shadow flicker is more evident inside a residence as compared to out in the open as light outside comes from all directions. The number of annual hours of shadow flicker at a given location can be calculated using geometric models that incorporate the following information:

- The sun path across the sky for the specific site latitude and longitude;

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- The topography of the site and its surroundings;
- The wind turbine rotor diameter, hub height and number and dimensions of blades;
- The location of the wind turbines and residences.

Windpro software version 3.3 has been used to undertake shadow flicker modelling at the Delburn Wind Farm. Table 2.2 shows the modelling assumptions applied.

Model parameter	Guideline setting	Setting applied
Shadow flicker assessment boundary	265 x maximum blade chord	1192.5m Maximum chord (4.5 m)
Minimum angle to the sun	3°	3°
Shape of sun	Disk	Disk
Time and duration of modelling	On full year representing a non-leap year, 12 -15 years after the data of DA submission	2035
Orientation of rotor	Sphere or disk facing the sun	Disk facing the sun
Offset between rotor and tower	Not required	Not modelled
Time step	10 minutes or less	Map: 10 minutes Receptor calculation: 1 minute
Effects of topography	Include	Included
Receptor height	1.5 m – 2m and window/balcony height where dwellings have more than one storey.	2 m
Receptor location	The area of a dwelling, garden fenced area.	Locations shown in Figure 2.1 and garden areas shown in Appendix A.
Grid for mapping and assessment of shadow flicker at receptor location	Not more than 25 m	25 m

Table 2.2 Modelling assumptions

(i) Worst case model

The following assumptions are made in the worst-case model:

- The minimum sun height for influence is 3° above the horizon line because when the sun is below this limit, the shadow dissipates before it reaches the ground (or the receptor);
- Blade flicker is calculated only when more than 20% of the sun is covered by the blade.
- The sun is assumed to be shining all day, from sunrise to sunset, that is, there are never any clouds in the sky;
- The wind turbine rotor is modelled as a disc and assumed to be in the "worst case" orientation, that is, perpendicular to the sun-rotor vector at all times;

- The wind turbines are always operating.

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

- The amount of dispersants in the atmosphere has the ability to influence any shadows that may be cast. The amount of dispersants in the air varies with time and has the potential to vary the air density, which affects the refraction of light. This in turn affects the intensity of direct sunlight, which causes the shadows;
- There are substantial periods of time during daylight hours when clouds will prevent any shadow flicker effect;
- The wind turbines will not constantly yaw to the "worst case" position where the wind turbine is facing into or away from the sun-rotor vector;
- Periods where the wind turbine is not in operation due to low winds, high winds or operational and maintenance reasons are not taken into consideration;
- Vegetation may partially block visibility of turbines from residences, and is not taken into consideration;
- Houses will have screening afforded by the walls and roof; the windows are only in specific directions.

(ii) Expected case

In this case, the worst-case model assumption related to cloud cover is adjusted to better represent reality, resulting in a conservative, expected-case model.

Having determined the annual hours of shadow flicker at each residence, and when they occur, the following procedure, prescribed by the National Guidelines, is used to account for cloud cover.

- Obtain Bureau of Meteorology data on cloud cover from the closest site (reporting at least 9 am and 3 pm cloud cover) with at least three years of data;
- Determine monthly averages separately for the 9 am and 3 pm proportion of cloudy days;
- Reduce shadow flicker occurring in a given month by the proportion of cloudy days (evening shadow flicker should be reduced using the proportion from 3 pm and morning shadow flicker using the proportion from 9 am);
- Sum the reduced monthly totals to determine the revised annual exposure.

The expected-case model is different from the worst-case model as the results are scaled according to the likelihood of cloud cover, as a function of time of day, and month of year, based on cloud cover data from the Bureau of Meteorology.

2.2.5 Results

The shadow flicker results are presented in Table 2.3 and Figure 2.2.

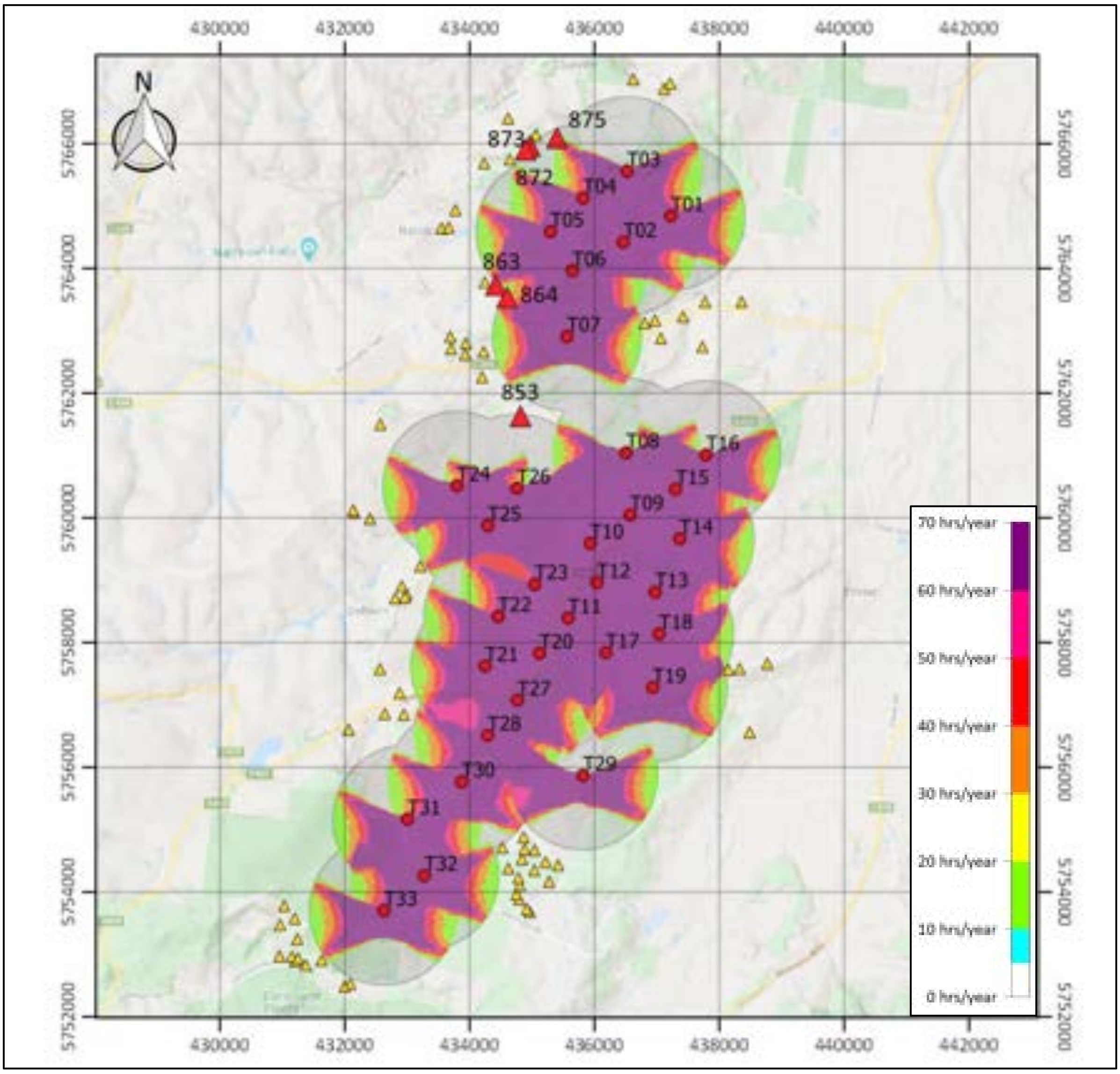
Should the turbine locations, turbine hub height, rotor diameter or blade chord assumption change, or additional dwellings be identified in proximity to the turbine locations, the shadow flicker analysis would need to be updated.

The shadow flicker model results are presented in Table 2.3. The maximum worst case shadow-flicker hours within the garden fenced area of each 'at risk' dwelling are shown. It has been found that, due to the relative positions of the dwellings and turbines and the site topography, that there are no dwellings that exceed the 30-

hour annual limit specified by the Policy and Planning Guidelines for Wind Farm Development. As the worst case hours are all within the specified limits there is no requirement to calculate the expected hours.

Residence	Stakeholder/Non-Stakeholder	Shadow flicker, 180 m rotor, 160 m hub height [hours/year]
		Worst case
875	Non-Stakeholder	0:00
873	Non-Stakeholder	0:00
872	Non-Stakeholder	0:00
863	Non-Stakeholder	24:52
864	Non-Stakeholder	25:42
853	Non-Stakeholder	0:00

Table 2.3 Shadow flicker results



Legend

- Proposed turbine location
- All dwellings supplied
- 265 x maximum chord length boundary (1192.5 m)
- Dwelling within 1192.5 m

Notes

- Coordinate system is UTM Grid Zone-55 WGS84 Datum

Figure 2.2 Shadow flicker results for Delburn Wind Farm for a rotor diameter of 180 m

3 Blade glint

Blade glint can result from the sun reflecting from 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, all relative to a dwelling. Blade glint can be mitigated by coating the surface of the wind turbine blades with a non-reflective paint as noted in Development of Wind Energy Facilities in Victoria Policy and Planning Guidelines 5.1.2(b):

> *Blade glint can result from the sun reflecting from turbine blades. Blades should be finished with a surface treatment of low reflectivity to ensure that glint is minimised.*

This approach is supported by the Australian National Guidelines which state that:

> *All major wind turbine blade manufacturers currently finish their blades with a low reflectivity treatment. This prevents a potentially annoying reflective glint from the surface of the blades and the possibility of a strobing reflection when the turbine blades are spinning. Therefore the risk of blade glint from a new development is considered to be very low.*
>
> *Proponents should ensure that blades from their supplier are of low reflectivity.*

The client, Delburn Wind Farm Pty Ltd, has provided a statement to K2M:

> *Delburn Wind Farm Pty Ltd commits that tendering and procurement documentation will specify that blades must be finished in a non-reflective coating to avoid any blade glint impacts.*

K2M therefore considers that the risk of blade glint at Delburn Wind Farm is very low.

4 Conclusions and recommendations

4.1 Conclusions

Shadow-flicker modelling at the Delburn Wind Farm, undertaken in accordance with the National and Victoria State planning guidelines, confirms compliance with the specified limit of 30 hours per year for all existing dwellings within the assumed shadow flicker assessment boundary of 1192.5 m. All the dwellings, including the garden fenced areas are sufficient distance from the turbines to ensure compliance with the limit.

The risk of blade glint is considered very low if the blades installed are of low reflectivity. It is understood that the procurement documentation will specify that blades must be finished in a non-reflective coating to avoid any blade glint impacts.

Appendix A

A1 Wind turbine layout coordinates

Turbine	Easting [m]	Northing [m]	Elevation [m]
T03	436525	5765561	273
T04	435819	5765128	300
T05	435296	5764592	299
T01	437223	5764842	206
T02	436464	5764422	237
T06	435648	5763965	227
T07	435562	5762911	212
T08	436508	5761045	178
T16	437789	5761008	177
T24	433800	5760517	243
T15	437301	5760459	176
T26	434761	5760476	203
T09	436574	5760048	215
T25	434294	5759876	200
T10	435933	5759594	231
T14	437368	5759666	190
T12	436043	5758962	241
T23	435046	5758935	220
T13	436975	5758811	202
T11	435580	5758395	250
T22	434458	5758419	210
T18	437039	5758139	179
T17	436184	5757839	203
T20	435123	5757829	259
T21	434250	5757623	222
T19	436935	5757281	189
T27	434768	5757077	257
T28	434290	5756512	258
T29	435818	5755871	175
T30	433871	5755768	242
T31	433005	5755169	216
T32	433276	5754264	188
T33	432628	5753703	184

Appendix Table A.1 Wind turbine layout coordinates

A2 Dwelling coordinates

These coordinates have been provided by the Client and have not been verified by K2 Management.

Dwelling number	Easting [m]	Northing [m]
875	435402	5766095
873	434969	5765965
872	434899	5765905
863	434422	5763736
864	434603	5763540
853	434817	5761632

Appendix Table A.2 Dwelling coordinates within 1192.5 m of turbine locations

The following figures show the 'garden fenced areas' that have been modelled as part of this assessment.

Appendix Figure A.1 Dwelling 875

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Appendix Figure A.2 Dwelling 873

Appendix Figure A.3 Dwelling 872

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Appendix Figure A.4 Dwelling 863

Appendix Figure A.5 Dwelling 864

Appendix Figure A.6 Dwelling 853