GOLDWIND AUSTRALIA

Coppabella Wind Farm

SHADOW FLICKER REPORT

JULY 2017

Coppabella Wind Farm

SHADOW FLICKER REPORT

Goldwind Australia

REV	DATE	DETAILS
01	27/03/2017	Preliminary report for issue
02	04/07/2017	Statistical results update

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ABBREVIATIONS

BoM	Bureau of Meteorology
d	day
h	hour
km	kilometre
m	minute
mAGL	Metres above ground level
mASL	metres above sea level
MWh	Megawatt hour
NWFD	National Wind Farm Development Guidelines [1]
WSP	WSP Australia Pty Ltd
WTG	Wind Turbine Generator
CWF	Coppabella Wind Farm

EXECUTIVE SUMMARY

Goldwind Australia has requested WSP Australia Pty Ltd (WSP) to undertake a shadow flicker assessment for the proposed Coppabella Wind Farm (CWF). CWF is located in New South Wales, approximately 30 km west from the town Yass. This shadow flicker will assess the 79 Wind Turbine Generator (WTG) layout as provided by Goldwind. This report is an update to an existing shadow flicker report undertaken by Epuron [2].

This report is a shadow flicker assessment for the 79 WTG layout consisting of one WTG model at a hub height of 100 m. The report assesses shadow flickering effects at 129 receptor locations, specified by Goldwind Australia. The shadow flicker assessment has been conducted using on-site measured data from April 2009 to April 2011 from the Coppabella 2 mast, as it records closest to the nominated hub height and is representative of the site. WSP has sheared and long-term adjusted this wind dataset for the CWF site. This dataset has been used to determine the WTG orientation and operational hours.

The shadow flicker assessment calculates the statistical average annual shadow flicker impact on each receptor. The assessment was performed using monitored data from the Bureau of Meteorology to represent average sunlight hours per day. Several sites were considered for average sunlight hour per day statistics, however the Canberra Airport (ARPT, Station Number 070014) station was selected because it is the closest in proximity and has the longest duration of recorded data (32 years, 1978-2010 using mean daily hours).

For the CWF, the applicable Australian guidelines for Wind Farm development include:

- National Wind Farm Development Guidelines (NWFD), Jul 2010 [1];
- NSW Planning Guidelines Wind Farms, Dec 2011 [3].

The NSW Planning Guidelines state that when undertaking an assessment for shadow flickering, the zone of influence that should be considered in the model is 2 km. The guidelines also specify that if a receptor is located within this zone of shadow flicker influence, receptor exposure to shadow exposure should not exceed 30 h/year. 129 receptors were assessed with only one predicted to experience shadow flickering. Receptor C02 has been estimated to experience 13:17 hours of shadow flickering per year as shown in Table ES.1 below.

Table ES.1 CWF Shadow flicker results on affected receptors (UTM WGS84 Zone 55)

RECEPTOR	GPS COORDINATES		MAXIMUM SHADOW HOURS (PER DAY)	STATISICAL AVERAGE ANNUAL SHADOW FLICKER
	Easting	Northing	h/day	h/year
(C02) Felicite Sue Swan[1]	636018	6153225	0:21	13:17

The shadow hours per day provide an estimate of the maximum shadow experienced by a receptor on a single day of the year. With maximum shadow exposure per day, the shadow hours per day may well occur on a day that is conducive to the worst case for shadow flicker (i.e. assuming the WTG is operating, the WTG is facing sun and there is no cloud cover is present on the given day that this occurs).

Based on the results presented in this report, the statistical average annual duration of shadow flicker caused by CWF is within the allowable shadow exposure to receptor C02 as dictated by the Draft National Wind Farm Guidelines [1] and Draft NSW Planning Guidelines [3]. It is noted that C02 is a participating landholder in the CWF project.

[1] C02 is a participating landholder in this project

1 PROJECT BACKGROUND

Goldwind Australia has requested WSP Australia Pty Ltd (WSP) undertake a shadow flicker assessment for the proposed Coppabella Wind Farm (CWF). CWF is located in New South Wales, approximately 30 km west from the town, Yass. This report is an update to an existing shadow flicker report undertaken by Epuron [2]. This shadow flicker report assesses the 79 Wind Turbine Generator (WTG) layout as provided by Goldwind. Table 1.1 presents the relevant WTG information for the WTG's at CWF.

Table 1.1: WTG information for CWF

MANUFACTURER	WTG MODEL	HUB HEIGHT	ROTOR DIAMETER	TURBINE CAPACITY	NUMBER OF WTG	INSTALLED CAPACITY
Goldwind	GW140-3.4MW	100 mAGL	140 m	3.40 MW	79	268.6 MW

Shadow flicker occurs when the sun passes behind the blades of a WTG, casting an intermittent shadow. This affect is known to cause irritation when this shadow is received at a dwelling. The severity and frequency of shadow flicker will decay with the distance from the WTG. If the dwelling is within 2 km of a WTG, there is potential for this intermittent shadow to be frequent enough to cause irritation to the resident.

An assessment using the NSW Planning Guidelines Wind Farms requires an evaluation of shadow flicker to a distance of 2 km from all WTGs [3].

1.1 Description of shadow flicker

Shadow flicker is the fluctuating light levels caused by intermittent (moving or changing) shadows. If a location is in the shadow of a moving object, then there will be a momentary reduction in the light intensity as the shadow passes by. This is most noticeable in an enclosed room that is lit by the sun, when the shadow falls across the window that is providing light. Wind turbines can cause shadow flicker from the moving shadow of the wind turbine blades. Shadow flicker can also be caused by any moving objects that cast a shadow, such as vehicles or planes.

The rate of flicker for a three bladed, horizontal axis wind turbine is three times the rotational speed of the wind turbine rotor. For example a three bladed win turbine with a rotor speed of 20 revolutions per minute (rpm) results in a flicker frequency of 1 Hertz (once per second). If the alternating light levels caused by the shadow flicker are of significant intensity and affect the whole light source of the room (i.e. the whole window is shadowed), it can disturb light-sensitive tasks, such as reading, creating a high level of irritation for the resident.

In order 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 is not met, shadow flicker is unlikely to occur, or will have a diminished impact, at that location.

- The sun must be in the correct position in the sky to cast a shadow of the turbine onto the location. This will only occur for certain times of the day, furthermore, days of the year.
- Wind direction will have an impact on shadow flicker. The area of the shadow cast by the wind turbine will depend on which direction the wind turbine is orientated (yaw), which in turn, is dependent on the wind direction.
- There must be unobstructed line of sight between the wind turbine and the location.
- The sun must not be significantly obscured by cloud or diffused by the atmosphere (significant diffusion typically occurs for angles of less than 3° above the horizon).
- The wind turbine must be operating (i.e. the blades operating).
- The dimension of the part of the blade causing the shadow must be large enough to cast significant shadow. The largest dimension of blades is the chord, located near the root (up to 5 m on large turbines),

and the smallest is the depth of the blade near the tip (0.3 m or less). The latter is not significant to cast any noticeable shadow. If the blade is edge-on to the sun, then the shadow will be very small.

- The shadow must fall over most of a room's natural light source, i.e. window or skylight. If the windows are large (compared to the size of the shadow), or do not face the wind turbine, then the room's light levels will not vary significantly.

The sun's position varies with the time of day and the time of year. This means that the location affected by shadow flicker from WTGs will also vary with the time of day and time of year.

The shadow flicker usually occurs to the east and west of the WTGs or to the south if there is a large height difference between the turbines and the observer location.

Flicker effects will be the strongest close to the WTGs, as the shadows cast by the rotating blades will be more dominant. As the distance from the WTG extends, the shadows cast by the blades will become less distinct, reducing the impact of the flicker.

1.2 Scope of work

The scope undertaken in this assessment is the standard scope of work involved in shadow flicker assessments completed by WSP | PB, and is as follows:

WSP will perform a shadow flicker assessment based on:

- A 79 WTG layout with one WTG model, supplied by Goldwind;
- WTG information, supplied by Goldwind;
- Daily sunshine data from the closest or most applicable BoM site;
- A list of coordinates of residences that Goldwind wishes to be included in the assessment.

WSP will detail the results of this assessment in a single report, which will include:

- A discussion of methodology and best practices;
- A discussion of calculation points;
- Documentation of the results for each residence of the statistical average annual shadow flicker hours per year.

1.3 Input data

Table 1.2 details the information supplied by Goldwind that was used in the production of the shadow flicker model.

Table 1.2 Summary of received data

NAME	DESCRIPTION	REFERENCE
Coppabella Mast Data.zip	Folder containing raw, .ndf wind monitoring data for Coppabella 1, Coppabella 2 and Coppabella 4 masts.	[4]
GWs General Arrangement Drawing.pdf	Engineering drawing of GW140-3.4MW, detailing rotor diameter and hub height.	[5]
RE Yass Valley Wind Farm - Shadow Flicker Receptors.msg	Email from Goldwind Australia, detailing the blade chord length.	[6]
GW140-3.4MW Wind Turbine Power and Thrust curves (1.225	Power and thrust curve values of GW140-3.4MW	[7]
YV-PI-SPC-0024_DA 79WTG 20160624.xlsx	Goldwind layout of primary 79WTG at Coppabella.	[8]
Yass List of Residences.xlsx	List of surrounding residents to be included in the shadow flicker assessment.	[9]

1.4 Applicable Guidelines

Applicable planning and development guidelines for the CWF include:

- National Wind Farm Development Guidelines (NWFD), Jul 2010 [1]
- NSW Planning Guidelines Wind Farms, Dec 2011 [3]

The NWFD Guidelines suggest that the effects of shadow flicker are dependent on the WTG blade dimensions and recommend an assessment distance of 265 times the maximum blade chord when investigating shadow flickering. The WTG blades for the CWF have a maximum chord length of 4.51 m, therefore according to the NWFD Guidelines, the assessment distance considered would be 1.2 km. However, the Draft NSW Planning Guidelines contain a more conservative zone of influence distance, a standard 2 km (irrespective of blade dimensions). Therefore, for this study, WSP has investigated shadow flicker within a maximum distance of influence of 2 km.

A brief summary on each of the guideline requirements are shown in Table 1.3 below.

Table 1.3 Wind Farm Development Guidelines

GUIDELINE	MAX DISTANCE OF INFLUENCE	MAX SHADOW FLICKER EXPOSURE
Draft National Wind Farm Development Guidelines – July 2010 [1]	265 times chord length 1.2 km	30 hrs per year
Draft NSW Planning Guidelines Wind Farms – Dec 2011 [3]	2 km	

1.5 Limitations of this report

This report has been prepared in accordance with the scope of work/services as agreed between WSP and Goldwind Australia. In preparing this report, WSP has relied upon data, surveys, analyses, plans and other information provided by Goldwind and other individuals and organisations. Except as otherwise stated in the report, WSP has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this report (conclusions) are based on whole or part on the information provided, those conclusions are contingent upon the accuracy and completeness of this information. WSP will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP, except that information collected directly from field surveys undertaken by WSP or information originally prepared by WSP.

This report has been prepared for the exclusive benefit of Goldwind and no other party. WSP assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with in this report, or for any loss or damage suffered by any other person or organisation arising from matter dealt with in this report, or for any loss or damage suffered by any other person or organisation arising from any negligent act or omission of WSP or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in this report. Other parties should not rely upon the report or accuracy or completeness of any conclusions and should make their own inquiries and obtain independent advice in relation to such matters.

To the best of WSP’s knowledge, the facts and matters described in this report reasonably represent the conditions at the time of report submission. However, the passage of time, the manifestation of latent condition or the impact of future events (including change in the applicable law) may have results in a variation to the conditions.

WSP will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

2 METHODOLOGY

WSP used WindPro v.3.1 to assess shadow flicker on supplied receptors at the CWF. The model used for the calculation of flicker effects contains a mathematical model of the suns position in the sky for a given location and time of year. Also contained in the model is information relating to the three-dimensional positions and sizes of the turbines and the locations where the flicker is to be calculated. This information is combined to calculate the times for which the WTG rotors will cast shadows over the locations of interest. Shadow flicker is assumed to occur when the centre of the sun passes behind any part of a WTG rotor.

Table 2.1 below details the statistical annual average shadow flicker assumptions.

Table 2.1 Statistical annual average shadow flicker assumptions

Sunlight Cover	Data obtained from Canberra ARPT BoM site [10] (mean data from 1978 to 2010)
WTG operational hours	Operational hours based on WTG power curve and Coppabella 2 mast data (April 2009 – April 2011); as a conservative measure, WSP has not modified the power curve for hysteresis. [4] [7]
WTG orientation	WTG orientation based on Coppabella 2 mast data (April 2009 – April 2011) [4]
WTG visibility	All WTG's are visible, except WTG's screened by topography
Maximum distance for influence	2 km
Minimum sun height over the horizon for influence	3°
Dimensions of receptor window	Represented by a vertical rectangle facing each turbine; termed as a "Greenhouse" configuration, 10 m wide and 2 m high, centred 1.5 m off the ground (any shadow on any part of this rectangle is included in the count).

In addition to the above assumptions, these calculations are based on the following WTG parameters:

- → WTG hub height of 100 m [5]
- → WTG rotor diameter of 140 m [5]
- → WTG blade chord length of 4.51 m [6]

WSP has considered a conservatively large receptor window of 10 m in width and 2 m in height to adequately include borderline situations where a receptor is marginally exempt from experiencing the effects of shadow flicker.

As previously mentioned, the NWFD Guidelines [1] recommend an assessment distance of 265 times the maximum blade chord when investigating shadow flickering. For the CWF, under the NWFD assessment distance is 1.2 km. However, the NSW Planning Guidelines [3] contain a more conservative zone of influence distance, a standard 2 km irrespective of blade dimensions. Therefore for this study, WSP will investigate shadow flicker within a maximum distance of influence of 2 km.

WSP has applied a reduction factor to account for cloud cover at the CWF site to provide a statistical average annual estimate of shadow flicker. This is based on recorded information on sunlight and cloud cover by the Bureau of Meteorology (BoM). The closest reference site is located at Canberra Airport (Station Number 070014), approximately 79 km southeast of CWF. This information is applied to the shadow flicker assessment on a monthly average basis, measured using a Campbell-Stokes device. The average daily sunshine hours are shown below in Table 2.2.

Table 2.2 Average sunshine hours per day on a monthly mean basis [10]

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Canberra Airport 070014 (averaged between 1978-2010)	9.5	9.0	8.1	7.3	6.0	5.2	5.8	7.0	7.7	8.6	8.9	9.4

The cloud cover reduction factor is applied to the shadow flicker results for the annual aggregate value only. Since the results are based on statistical averages, a dwelling may experience no cloud cover on the day of the year that has the maximum shadow flicker. Shown below in Figure 2.1 is the location of the Canberra airport station in relation to the proposed CWF site.

Figure 2.1: Location of Canberra Airport station and CWF monitoring masts

Wind speed and direction data from Coppabella 2 has been used as an input in this study [4] to determine the WTG orientation. The operational hours have been determined by applying the power curve to the wind speed data at a sheared, 100 m hub height. The WTG power curve can be found in Appendix B of this report. The operational hours of the WTG per direction have been calculated by grouping the operational hours in 30 degree directional sectors. The operational hours per direction sector are presented in below in Table 2.3.

Table 2.3 Operational hours per direction sector based on Coppabella 2 mast data [4]

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	SUM
401	353	494	1,679	730	142	270	698	1,281	825	653	710	8,236

3 RESULTS

Shown in Table 3.1, there is one receptor that experiences shadow flicker as a result of the CWF. Receptor C02 has been estimated to experience 13:17 hours of shadow flickering per year on a statistical average basis. The shadow flicker and receptor map is shown in Appendix A. A summary of the affected receptors and the resulting shadow flickering frequency is shown in Appendix C.

The receptor to WTG distances were determined from the information provided in the Goldwind layout spreadsheet [8] [9]. Some receptors being located up to 17 km away from the nearest WTG.

Applicable state guidelines state that when undertaking an assessment for shadow flickering, the zone of influence that should be considered is 2 km. The guidelines also specify that if a receptor is located within this zone of shadow flicker influence, receptor exposure should not exceed 30 hrs/year. As detailed in Table 3.1 and Appendix C, receptor C02 is located approximately 1.6 km from the nearest WTG, placing it within the zone of shadow flicker influence. Receptor C02, does not exceed the suggested allowable exposure of shadow flicker per year. Receptor C02 is a participating landholder however, this may still warrant consultation with the resident.

Table 3.1 CWF Shadow Flicker results on each receptor location (UTM WGS84 Zone 55H)

RECEPTOR	LOCATION COORDINATES		MAXIMUM SHADOW HOURS PER DAY	STATISTICAL ANNUAL AVERAGE SHADOW FLICKER
	Easting	Northing	h/day	h/year
C56	637828	6151303	0:00	0:00
C03	637337	6151336	0:00	0:00
C02	636018	6153225	0:21	13:17
C55	636410	6151622	0:00	0:00
C05	644196	6148246	0:00	0:00
C06	645147	6147452	0:00	0:00
C04	641145	6150582	0:00	0:00
C08	645794	6147060	0:00	0:00
C37	635365	6159642	0:00	0:00
C60	645429	6146810	0:00	0:00
C35	639487	6159589	0:00	0:00
C41	646810	6146831	0:00	0:00
C01	634541	6152997	0:00	0:00
C75	643338	6147617	0:00	0:00
C71	645409	6156831	0:00	0:00
C29	645491	6156830	0:00	0:00
C74	639282	6160379	0:00	0:00
C67	649305	6148446	0:00	0:00
C58	642782	6147348	0:00	0:00

RECEPTOR	LOCATION COORDINATES		MAXIMUM SHADOW HOURS PER DAY	STATISTICAL ANNUAL AVERAGE SHADOW FLICKER
C53	635285	6160771	0:00	0:00
C42	649156	6147588	0:00	0:00
C38	632047	6157837	0:00	0:00
C46a	649053	6147292	0:00	0:00
C13	634466	6150956	0:00	0:00
C22	641631	6147822	0:00	0:00
C76	638649	6148573	0:00	0:00
C49	649008	6146853	0:00	0:00
C62	649388	6147137	0:00	0:00
C07	631743	6154014	0:00	0:00
C59	643544	6145985	0:00	0:00
C61	648065	6145891	0:00	0:00
C30	643944	6159581	0:00	0:00
C77	649501	6147085	0:00	0:00
C76a	639064	6148250	0:00	0:00
C48	649388	6146698	0:00	0:00
C73	631162	6154520	0:00	0:00
C39	631508	6158554	0:00	0:00
C63	649566	6146692	0:00	0:00
C25	650904	6151073	0:00	0:00
C26	650347	6153680	0:00	0:00
C64	649624	6146615	0:00	0:00
G30	639014	6147880	0:00	0:00
H30	640134	6147862	0:00	0:00
C65	649665	6146568	0:00	0:00
C47	649751	6146653	0:00	0:00
C28a	648497	6156869	0:00	0:00
C66	649800	6146592	0:00	0:00
G32	638449	6147802	0:00	0:00
C28	648493	6156982	0:00	0:00
C80	649828	6146451	0:00	0:00
C78	649932	6146568	0:00	0:00
C34	643485	6160766	0:00	0:00

RECEPTOR	LOCATION COORDINATES		MAXIMUM SHADOW HOURS PER DAY	STATISTICAL ANNUAL AVERAGE SHADOW FLICKER
C79	649984	6146451	0:00	0:00
C33	644012	6160671	0:00	0:00
M25	650050	6146375	0:00	0:00
M26	649993	6146305	0:00	0:00
C12	634099	6149266	0:00	0:00
M9	650242	6146580	0:00	0:00
M28	650095	6146256	0:00	0:00
M29	650133	6146219	0:00	0:00
M30	650155	6146154	0:00	0:00
G31	651691	6149343	0:00	0:00
M31	650227	6146088	0:00	0:00
C68	651107	6154401	0:00	0:00
C27	651322	6154525	0:00	0:00
M13	650548	6145966	0:00	0:00
M18	652314	6149832	0:00	0:00
C52	649583	6157887	0:00	0:00
M41	651736	6155517	0:00	0:00
M21	651853	6155573	0:00	0:00
M32	652110	6146643	0:00	0:00
C89	652382	6155721	0:00	0:00
C69	652031	6157307	0:00	0:00
M42	653648	6155444	0:00	0:00
G15	655374	6149637	0:00	0:00
G16	655015	6147518	0:00	0:00
M22	654104	6156789	0:00	0:00
M48	655766	6149601	0:00	0:00
G29	654669	6144842	0:00	0:00
M40	654760	6157037	0:00	0:00
G26	654589	6142433	0:00	0:00
G46	654615	6142307	0:00	0:00
G3	654913	6142551	0:00	0:00
M39	657387	6155956	0:00	0:00
G10	657463	6144499	0:00	0:00

RECEPTOR	LOCATION COORDINATES		MAXIMUM SHADOW HOURS PER DAY	STATISTICAL ANNUAL AVERAGE SHADOW FLICKER
M37	658207	6155433	0:00	0:00
M38	658294	6155811	0:00	0:00
M35	658444	6155225	0:00	0:00
M4	658547	6154932	0:00	0:00
M24	658623	6154599	0:00	0:00
M3	658590	6154877	0:00	0:00
M20	658742	6154508	0:00	0:00
M34	658644	6155236	0:00	0:00
M36	658629	6155598	0:00	0:00
M1	658884	6154626	0:00	0:00
G14	659606	6150701	0:00	0:00
M2	658966	6154883	0:00	0:00
G38	659981	6150849	0:00	0:00
G13	660057	6151076	0:00	0:00
G12	660201	6149380	0:00	0:00
M8	660244	6151580	0:00	0:00
M384	660340	6152714	0:00	0:00
G4	658615	6142091	0:00	0:00
G60	659368	6143377	0:00	0:00
G8	659548	6143435	0:00	0:00
M46	660982	6152973	0:00	0:00
G7	659735	6143497	0:00	0:00
G11	661209	6147630	0:00	0:00
G24	660293	6144222	0:00	0:00
G59	659823	6143216	0:00	0:00
M6	661361	6152923	0:00	0:00
G9	660108	6143294	0:00	0:00
M5	661995	6152896	0:00	0:00
G23	661185	6144412	0:00	0:00
G20	661622	6145659	0:00	0:00
G36	662351	6150963	0:00	0:00
G18	662441	6149999	0:00	0:00
M7	662306	6152428	0:00	0:00

RECEPTOR	LOCATION COORDINATES		MAXIMUM SHADOW HOURS PER DAY	STATISTICAL ANNUAL AVERAGE SHADOW FLICKER
G5	660294	6142075	0:00	0:00
G40	662317	6147347	0:00	0:00
M33	662429	6152891	0:00	0:00
G39	662856	6150456	0:00	0:00
G19	662998	6149341	0:00	0:00
G44	662581	6145904	0:00	0:00
G41	662875	6146548	0:00	0:00
G58	662724	6145918	0:00	0:00
G57	662900	6146055	0:00	0:00
Kennedy	662587	6144838	0:00	0:00
G55	663369	6146057	0:00	0:00

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[8] Goldwind, "YV-PI-SPC-0024_DA 79WTG 20160624.xlsx," Goldwind, Sydney, 2016.

[9] Goldwind, "Yass List of Residences.xlsx," Goldwind, Sydney, 2017.

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Appendix A

SHADOW FLICKER MAPS

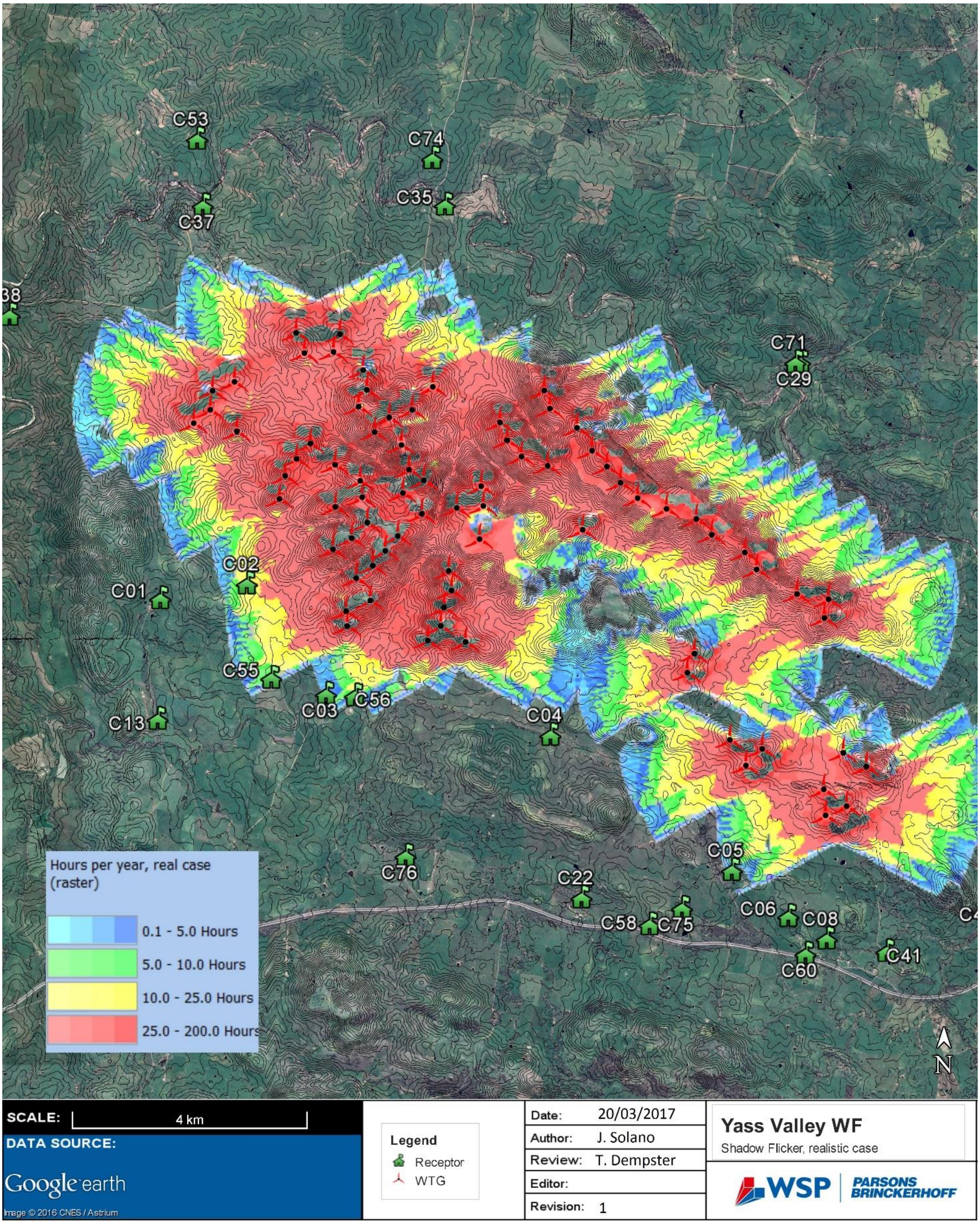

Figure A.1 CWF shadow flicker map

Appendix B

WTG LAYOUT AND POWER CURVE

Table B.1 CWF Goldwind 79WTG layout [8]

WTG ID	EASTING	NORTHING	ELEVATION	WTG CONFIGURATION	HUB HEIGHT
	UTM WGS84 Zone 55		mASL		mAGL
1	641135	6156615	657.5	GW140-3.4MW	100
2	642183	6155309	793.6	GW140-3.4MW	100
3	641934	6155584	760.9	GW140-3.4MW	100
4	641683	6155973	677.8	GW140-3.4MW	100
5	641228	6156306	657.5	GW140-3.4MW	100
6	644704	6153528	698.3	GW140-3.4MW	100
7	643949	6154128	727.2	GW140-3.4MW	100
8	643690	6154400	695.6	GW140-3.4MW	100
9	642410	6155033	809	GW140-3.4MW	100
10	642697	6154767	762.8	GW140-3.4MW	100
11	644507	6153820	700.7	GW140-3.4MW	100
12	645386	6153102	623.4	GW140-3.4MW	100
13	645920	6153005	607.9	GW140-3.4MW	100
14	645844	6152689	613.8	GW140-3.4MW	100
15	643186	6154579	761.6	GW140-3.4MW	100
16	640374	6156085	594	GW140-3.4MW	100
17	640731	6155502	632.6	GW140-3.4MW	100
18	640494	6155780	635.1	GW140-3.4MW	100
19	641174	6155340	649.7	GW140-3.4MW	100
25	639997	6154114	777.3	GW140-3.4MW	100
29	641753	6154245	654	GW140-3.4MW	100
30	640070	6154676	674.5	GW140-3.4MW	100
31	640038	6155010	632.4	GW140-3.4MW	100
32	639618	6154648	670.3	GW140-3.4MW	100
33	639464	6153582	688	GW140-3.4MW	100
34	638607	6154188	708.1	GW140-3.4MW	100
35	638391	6153940	705.9	GW140-3.4MW	100
36	639022	6154556	663.8	GW140-3.4MW	100
37	638704	6154914	642	GW140-3.4MW	100
38	639088	6155044	704	GW140-3.4MW	100
39	638176	6153691	658.9	GW140-3.4MW	100

WTG ID	EASTING	NORTHING	ELEVATION	WTG CONFIGURATION	HUB HEIGHT
	UTM WGS84 Zone 55		mASL		mAGL
40	637724	6153002	597.2	GW140-3.4MW	100
41	637724	6152676	552.2	GW140-3.4MW	100
42	637890	6153483	635.6	GW140-3.4MW	100
77	645814	6149346	575.5	GW140-3.4MW	100
78	644751	6150491	594.3	GW140-3.4MW	100
79	644471	6150212	566.3	GW140-3.4MW	100
80	644204	6150650	586.7	GW140-3.4MW	100
81	643496	6151799	559.5	GW140-3.4MW	100
82	643622	6152119	557.7	GW140-3.4MW	100
43	638123	6153103	606.6	GW140-3.4MW	100
44	637501	6153978	666.1	GW140-3.4MW	100
45	637821	6154164	698	GW140-3.4MW	100
46	638091	6154423	678.3	GW140-3.4MW	100
47	639088	6152412	544	GW140-3.4MW	100
48	639374	6152965	604.4	GW140-3.4MW	100
49	639508	6153251	659.7	GW140-3.4MW	100
50	639733	6152377	579.8	GW140-3.4MW	100
51	639315	6152655	577.2	GW140-3.4MW	100
52	637982	6155133	631.5	GW140-3.4MW	100
53	637955	6154807	685	GW140-3.4MW	100
54	637553	6154697	648.7	GW140-3.4MW	100
55	637558	6155411	576.3	GW140-3.4MW	100
56	638814	6155310	650.2	GW140-3.4MW	100
57	638692	6155728	700.6	GW140-3.4MW	100
58	638239	6155953	665.3	GW140-3.4MW	100
59	638546	6156147	666.4	GW140-3.4MW	100
60	637143	6155777	526.2	GW140-3.4MW	100
61	636904	6155521	582.4	GW140-3.4MW	100
62	636707	6155235	597.6	GW140-3.4MW	100
63	636604	6154848	586.5	GW140-3.4MW	100
64	637973	6156390	595.8	GW140-3.4MW	100
65	638118	6156671	556.7	GW140-3.4MW	100

WTG ID	EASTING	NORTHING	ELEVATION	WTG CONFIGURATION	HUB HEIGHT
	UTM WGS84 Zone 55		mASL		mAGL
66	638884	6156320	595.9	GW140-3.4MW	100
67	639241	6156706	504.4	GW140-3.4MW	100
68	638060	6157008	506.7	GW140-3.4MW	100
69	635163	6156152	466.4	GW140-3.4MW	100
70	635491	6156697	453.7	GW140-3.4MW	100
71	635449	6156374	469.9	GW140-3.4MW	100
72	635867	6156842	452	GW140-3.4MW	100
73	646131	6150401	644.6	GW140-3.4MW	100
74	646521	6150162	653.2	GW140-3.4MW	100
75	645789	6149787	583.4	GW140-3.4MW	100
76	646174	6149496	592.1	GW140-3.4MW	100
126	636929	6157657	464.6	GW140-3.4MW	100
127	637065	6157311	482.9	GW140-3.4MW	100
128	637560	6157324	451.6	GW140-3.4MW	100
129	637674	6157619	468	GW140-3.4MW	100
130	635896	6156000	564.1	GW140-3.4MW	100

Table B.2 GW140-3.4MW Wind turbine power and thrust values, with 1.225kg/m^3 air density [7]

WIND SPEED (M/S)	POWER (KW)	THRUST COEFFICIENT (CT)
0	0	-
1	0	-
2	0	-
2.5	15	1.214
3.0	74	1.052
3.5	153	0.935
4.0	249	0.845
4.5	366	0.800
5.0	503	0.801
5.5	674	0.801
6.0	879	0.801
6.5	1,120	0.801
7.0	1,395	0.801
7.5	1,707	0.801
8.0	2,059	0.801
8.5	2,432	0.801
9.0	2,794	0.765
9.5	3,094	0.723
10.0	3,277	0.547
10.5	3,375	0.452
11.0	3,397	0.382
11.5	3,400	0.328
12.0	3,400	0.285
12.5	3,400	0.250
13.0	3,400	0.221
13.5	3,400	0.197
14.0	3,400	0.176
14.5	3,400	0.158
15.0	3,400	0.143
15.5	3,400	0.130
16.0	3,400	0.118
16.5	3,400	0.108

WIND SPEED (M/S)	POWER (KW)	THRUST COEFFICIENT (CT)
17.0	3,400	0.099
17.5	3,400	0.091
18.0	3,400	0.084
18.5	3,400	0.078
19.0	3,400	0.073
19.5	3,400	0.068
20.0	3,400	0.064

Appendix C

SHADOW FLICKER CALENDAR

Table C.1 summarises the periods during which shadow flicker is estimated to occur at the affected receptor. As discussed in section 3 of this report, only one receptor is expected to experience shadow flicker within the maximum distance of influence (2km).

The worst case shadow flicker illustrated in Table C.1 is statistically an extremely unlikely occurrence. The worst case calculation makes the following assumptions;

- Direct sunlight during all daylight hours (i.e. no clouds are ever experienced over the wind farm site).
- The wind turbines are always operating (i.e. it is always windy, and the turbines are never inoperable due to maintenance or faults).
- The wind turbines are always turned in the horizontal plane to face the sun (i.e. the turbine rotor casts the maximum possible shadow).

Table C.1 Receptor C02 shadow flicker calendar

DATE	SUNRISE, TIME	SUNSET, TIME	SHADOW FLICKER TIME, START (WORST CASE)	SHADOW FLICKER TIME, END (WORST CASE)	FLICKER SOURCE	DISTANCE FROM FLICKER SOURCE	DURATION (WORST CASE)	DURATION (STATISTICAL ANNUAL AVERAGE), ROUNDED TO CLOSEST MINUTE
Day-Month	hh:mm	hh:mm	hh:mm	hh:mm	WTG	km	min	min
22-Jan	6:16	20:20	6:55	6:58	41	1.79	3.00	1.25
23-Jan	6:17	20:20	6:53	7:02	41	1.79	9.00	3.76
24-Jan	6:18	20:19	6:52	7:03	41	1.79	11.00	4.60
25-Jan	6:19	20:19	6:51	7:05	41	1.79	14.00	5.86
26-Jan	6:20	20:18	6:50	7:06	41	1.79	16.00	6.69
27-Jan	6:21	20:18	6:50	7:07	41	1.79	17.00	7.11
28-Jan	6:22	20:17	6:49	7:08	41	1.79	19.00	7.95
29-Jan	6:23	20:16	6:49	7:08	41	1.79	19.00	7.95
30-Jan	6:24	20:16	6:49	7:09	41	1.79	20.00	8.37
31-Jan	6:25	20:15	6:50	7:09	41	1.79	19.00	7.95
1-Feb	6:26	20:14	6:50	7:09	41	1.79	19.00	7.99
2-Feb	6:27	20:14	6:50	7:09	41	1.79	19.00	7.99
3-Feb	6:28	20:13	6:51	7:09	41	1.79	18.00	7.57
4-Feb	6:29	20:12	6:52	7:09	41	1.79	17.00	7.15
5-Feb	6:30	20:11	6:53	7:08	41	1.79	15.00	6.31
6-Feb	6:31	20:10	6:54	7:07	41	1.79	13.00	5.47
7-Feb	6:32	20:09	6:55	7:05	41	1.79	10.00	4.21
8-Feb	6:34	20:09	6:59	7:02	41	1.79	3.00	1.26
17-Feb	6:42	19:59	7:26	7:33	40	1.72	7.00	3.14
18-Feb	6:43	19:58	7:24	7:35	40	1.72	11.00	4.94

DATE	SUNRISE, TIME	SUNSET, TIME	SHADOW FLICKER TIME, START (WORST CASE)	SHADOW FLICKER TIME, END (WORST CASE)	FLICKER SOURCE	DISTANCE FROM FLICKER SOURCE	DURATION (WORST CASE)	DURATION (STATISTICAL ANNUAL AVERAGE), ROUNDED TO CLOSEST MINUTE
19-Feb	6:44	19:57	7:22	7:37	40	1.72	15.00	6.73
20-Feb	6:45	19:56	7:21	7:38	40	1.72	17.00	7.63
21-Feb	6:46	19:55	7:20	7:39	40	1.72	19.00	8.53
22-Feb	6:47	19:54	7:20	7:39	40	1.72	19.00	8.53
23-Feb	6:48	19:53	7:20	7:39	40	1.72	19.00	8.53
24-Feb	6:49	19:51	7:19	7:38	40	1.72	19.00	8.53
25-Feb	6:50	19:50	7:19	7:38	40	1.72	19.00	8.53
26-Feb	6:51	19:49	7:20	7:38	40	1.72	18.00	8.08
27-Feb	6:52	19:48	7:21	7:37	40	1.72	16.00	7.18
28-Feb	6:53	19:46	7:22	7:36	40	1.72	14.00	6.28
1-Mar	6:54	19:45	7:24	7:34	40	1.72	10.00	4.38
21-Mar	7:10	19:18	7:58	8:02	42	1.89	4.00	1.86
22-Mar	7:11	19:17	7:54	8:04	42	1.89	10.00	4.64
23-Mar	7:12	19:15	7:52	8:06	42	1.89	14.00	6.50
24-Mar	7:13	19:14	7:51	8:07	42	1.89	16.00	7.42
25-Mar	7:14	19:13	7:50	8:07	42	1.89	17.00	7.89
26-Mar	7:14	19:11	7:50	8:08	42	1.89	18.00	8.35
27-Mar	7:15	19:10	7:49	8:07	42	1.89	18.00	8.35
28-Mar	7:16	19:08	7:49	8:06	42	1.89	17.00	7.89
29-Mar	7:17	19:07	7:50	8:06	42	1.89	16.00	7.42
30-Mar	7:17	19:06	7:51	8:05	42	1.89	14.00	6.50
31-Mar	7:18	19:04	7:51	8:02	42	1.89	11.00	5.10
1-Apr	7:19	19:03	7:54	7:59	42	1.89	5.00	2.29
27-Apr	6:39	17:30	7:38	7:47	44	1.66	9.00	4.19
28-Apr	6:40	17:29	7:36	7:49	44	1.66	13.00	6.05
29-Apr	6:41	17:28	7:34	7:49	44	1.66	15.00	6.98
30-Apr	6:42	17:27	7:33	7:51	44	1.66	18.00	8.38
1-May	6:42	17:26	7:33	7:51	44	1.66	18.00	7.49
2-May	6:43	17:25	7:32	7:52	44	1.66	20.00	8.32
3-May	6:44	17:24	7:32	7:53	44	1.66	21.00	8.74

DATE	SUNRISE, TIME	SUNSET, TIME	SHADOW FLICKER TIME, START (WORST CASE)	SHADOW FLICKER TIME, END (WORST CASE)	FLICKER SOURCE	DISTANCE FROM FLICKER SOURCE	DURATION (WORST CASE)	DURATION (STATISTICAL ANNUAL AVERAGE), ROUNDED TO CLOSEST MINUTE
4-May	6:45	17:23	7:32	7:53	44	1.66	21.00	8.74
5-May	6:46	17:22	7:31	7:52	44	1.66	21.00	8.74
6-May	6:46	17:21	7:32	7:52	44	1.66	20.00	8.32
7-May	6:47	17:20	7:32	7:52	44	1.66	20.00	8.32
8-May	6:48	17:19	7:33	7:52	44	1.66	19.00	7.91
9-May	6:49	17:18	7:34	7:51	44	1.66	17.00	7.07
10-May	6:49	17:17	7:34	7:50	44	1.66	16.00	6.66
11-May	6:50	17:16	7:35	7:49	44	1.66	14.00	5.83
12-May	6:51	17:15	7:36	7:48	44	1.66	12.00	4.99
13-May	6:52	17:15	7:38	7:46	44	1.66	8.00	3.33
30-Jul	7:02	17:23	7:51	7:55	44	1.66	4.00	1.65
31-Jul	7:02	17:24	7:48	7:57	44	1.66	9.00	3.71
1-Aug	7:01	17:25	7:46	7:59	44	1.66	13.00	6.01
2-Aug	7:00	17:25	7:45	8:00	44	1.66	15.00	6.94
3-Aug	6:59	17:26	7:44	8:00	44	1.66	16.00	7.4
4-Aug	6:58	17:27	7:43	8:01	44	1.66	18.00	8.32
5-Aug	6:57	17:27	7:43	8:02	44	1.66	19.00	8.79
6-Aug	6:56	17:28	7:42	8:02	44	1.66	20.00	9.25
7-Aug	6:55	17:29	7:42	8:02	44	1.66	20.00	9.25
8-Aug	6:54	17:30	7:42	8:02	44	1.66	20.00	9.25
9-Aug	6:53	17:30	7:41	8:02	44	1.66	21.00	9.71
10-Aug	6:52	17:31	7:40	8:01	44	1.66	21.00	9.71
11-Aug	6:51	17:32	7:41	8:00	44	1.66	19.00	8.79
12-Aug	6:50	17:33	7:41	8:00	44	1.66	19.00	8.79
13-Aug	6:49	17:33	7:42	7:59	44	1.66	17.00	7.86
14-Aug	6:48	17:34	7:43	7:57	44	1.66	14.00	6.47
15-Aug	6:47	17:35	7:44	7:56	44	1.66	12.00	5.55
16-Aug	6:46	17:36	7:46	7:54	44	1.66	8.00	3.7
11-Sep	6:12	17:54	6:47	6:52	42	1.89	5.00	2.29
12-Sep	6:11	17:55	6:43	6:54	42	1.89	11.00	5.04

DATE	SUNRISE, TIME	SUNSET, TIME	SHADOW FLICKER TIME, START (WORST CASE)	SHADOW FLICKER TIME, END (WORST CASE)	FLICKER SOURCE	DISTANCE FROM FLICKER SOURCE	DURATION (WORST CASE)	DURATION (STATISTICAL ANNUAL AVERAGE), ROUNDED TO CLOSEST MINUTE
13-Sep	6:09	17:56	6:42	6:55	42	1.89	13.00	5.95
14-Sep	6:08	17:56	6:41	6:56	42	1.89	15.00	6.87
15-Sep	6:07	17:57	6:39	6:56	42	1.89	17.00	7.79
16-Sep	6:05	17:58	6:39	6:56	42	1.89	17.00	7.79
17-Sep	6:04	17:58	6:38	6:55	42	1.89	17.00	7.79
18-Sep	6:02	17:59	6:38	6:55	42	1.89	17.00	7.79
19-Sep	6:01	18:00	6:38	6:54	42	1.89	16.00	7.33
20-Sep	5:59	18:01	6:39	6:53	42	1.89	14.00	6.41
21-Sep	5:58	18:01	6:39	6:50	42	1.89	11.00	5.04
22-Sep	5:56	18:02	6:42	6:48	42	1.89	6.00	2.75
12-Oct	6:29	19:17	6:59	7:05	40	1.72	6.00	2.66
13-Oct	6:27	19:18	6:56	7:08	40	1.72	12.00	5.31
14-Oct	6:26	19:19	6:54	7:09	40	1.72	15.00	6.64
15-Oct	6:25	19:20	6:53	7:10	40	1.72	17.00	7.52
16-Oct	6:23	19:21	6:52	7:10	40	1.72	18.00	7.97
17-Oct	6:22	19:22	6:52	7:11	40	1.72	19.00	8.41
18-Oct	6:21	19:22	6:50	7:10	40	1.72	20.00	8.85
19-Oct	6:20	19:23	6:50	7:10	40	1.72	20.00	8.85
20-Oct	6:18	19:24	6:50	7:09	40	1.72	19.00	8.41
21-Oct	6:17	19:25	6:51	7:09	40	1.72	18.00	7.97
22-Oct	6:16	19:26	6:52	7:08	40	1.72	16.00	7.08
23-Oct	6:15	19:27	6:53	7:07	40	1.72	14.00	6.2
24-Oct	6:14	19:28	6:54	7:05	40	1.72	11.00	4.87
25-Oct	6:13	19:28	6:56	7:01	40	1.72	5.00	2.21
3-Nov	6:03	19:37	6:27	6:32	41	1.79	5.00	2
4-Nov	6:02	19:38	6:25	6:36	41	1.79	11.00	4.39
5-Nov	6:01	19:39	6:24	6:37	41	1.79	13.00	5.19
6-Nov	6:00	19:40	6:23	6:38	41	1.79	15.00	5.99
7-Nov	5:59	19:41	6:22	6:39	41	1.79	17.00	6.79
8-Nov	5:59	19:42	6:21	6:39	41	1.79	18.00	7.19

DATE	SUNRISE, TIME	SUNSET, TIME	SHADOW FLICKER TIME, START (WORST CASE)	SHADOW FLICKER TIME, END (WORST CASE)	FLICKER SOURCE	DISTANCE FROM FLICKER SOURCE	DURATION (WORST CASE)	DURATION (STATISTICAL ANNUAL AVERAGE), ROUNDED TO CLOSEST MINUTE
9-Nov	5:58	19:43	6:21	6:40	41	1.79	19.00	7.59
10-Nov	5:57	19:44	6:21	6:40	41	1.79	19.00	7.59
11-Nov	5:56	19:45	6:21	6:40	41	1.79	19.00	7.59
12-Nov	5:55	19:46	6:20	6:40	41	1.79	20.00	7.99
13-Nov	5:55	19:47	6:21	6:40	41	1.79	19.00	7.59
14-Nov	5:54	19:48	6:22	6:40	41	1.79	18.00	7.19
15-Nov	5:53	19:49	6:22	6:39	41	1.79	17.00	6.79
16-Nov	5:53	19:50	6:23	6:39	41	1.79	16.00	6.39
17-Nov	5:52	19:51	6:24	6:38	41	1.79	14.00	5.59
18-Nov	5:51	19:52	6:26	6:37	41	1.79	11.00	4.39
19-Nov	5:51	19:52	6:27	6:36	41	1.79	9.00	3.59
20-Nov	5:50	19:53	6:30	6:33	41	1.79	3.00	1.2