GL Garrad Hassan

SHADOW FLICKER ASSESSMENT FOR THE PROPOSED FLAT ROCKS WIND FARM

Client	Moonies Hill Energy
Contact	Sarah Rankin
Document No	45392/PR/01
Issue No	A
Status	Draft
Classification	Client's Discretion
Date	11 May 2011

Author: D Price

Checked by: J Jobin

Approved by: G Slack

Garrad Hassan Pacific Pty Ltd ACN 094 520 760
Suite 25, Level 8, 401 Docklands Drive, Docklands, Melbourne, Victoria 3008,Australia
Phone +61 3 9600-1993 Facsimile +61 3 9602-1714

IMPORTANT NOTICE AND DISCLAIMER

This report ("Report") is prepared and issued by Garrad Hassan Pacific Pty Ltd ("GH" or "Garrad Hassan") for the sole use of the client named on its title page (the "Client") on whose instructions it has been prepared, and who has entered into a written agreement directly with Garrad Hassan. Garrad Hassan's liability to the Client is set out in that agreement. Garrad Hassan shall have no liability to third parties (being persons other than the Client) in connection with this Report or for any use whatsoever by third parties of this Report unless the subject of a written agreement between Garrad Hassan and such third party. The Report may only be reproduced and circulated in accordance with the Document Classification and associated conditions stipulated or referred to in this Report and/or in Garrad Hassan's written agreement with the Client. No part of this Report may be disclosed in any public offering memorandum, prospectus or stock exchange listing, circular or announcement without the express written consent of Garrad Hassan. A Document Classification permitting the Client to redistribute this Report shall not thereby imply that Garrad Hassan has any liability to any recipient other than the Client.

This report has been produced from information relating to dates and periods referred to in this report. The report does not imply that any information is not subject to change.

Acceptance of this document by the client is on the basis that Garrad Hassan Pacific Pty Ltd are not in any way to be held responsible for the application or use made of the findings of the results from the analysis and that such responsibility remains with the client.

KEY TO DOCUMENT CLASSIFICATION

Strictly Confidential	:	Recipients only
Private and Confidential	:	For disclosure to individuals directly concerned within the recipient's organisation
Commercial in Confidence	:	Not to be disclosed outside the recipient's organisation
GH only	:	Not to be disclosed to non GH staff
Client's Discretion	:	Distribution at the discretion of the client subject to contractual agreement
Published	:	Available to the general public

Revision History

Issue	Issue Date:	Summary
A	11 May 2011	Draft Issue.

Circulation:	Copy No:
Client	Electronic
GH Pacific	Electronic

Copy No: Electronic

CONTENTS

1 EXECUTIVE SUMMARY

Garrad Hassan Pacific Pty Ltd (GH) has been commissioned by Moonies Hill Energy (MHE) to independently assess the shadow flicker in the vicinity of the proposed Flat Rocks Wind Farm. The results of the work are reported here. This document has been prepared pursuant to an email proposal sent by Sarah Rankin of MHE to Sherrin Yeo of GH on 11 March 2011.

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

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

This report assesses the shadow flicker of a 74 turbine layout developed in a previously issued report [2]. MHE has supplied locations of 34 houses (including a proposed location) in the vicinity of the wind farm extending to approximately 2 km from the wind farm boundary [3], and 2 m resolution height contours for the site and surrounding area. These inputs have been used to determine the theoretical duration of shadow flicker at each dwelling.

In WA there are no specific Guidelines on how to assess shadow flicker generated by wind turbines. However, a number of assessments throughout Australia have applied the Victorian Planning Guidelines [4] which recommend a shadow flicker limit of 30 hours per year in the area immediately surrounding a dwelling.

In addition, the EPHC Draft National Wind Farm Development Guidelines [5] recommend a limit on the theoretical shadow flicker duration of 30 hours per year, and a limit on the actual shadow flicker duration of 10 hours per year. The Draft National Guidelines also recommend a modelling methodology.

This assessment was based on the methodology recommended in the Draft National Wind Farm Development Guidelines. Calculations were carried out assuming houses had a single story with a window height of 2 m, with the exception of house NSH03 which is double story. The relevant shadow flicker duration at a dwelling was taken as the maximum duration occurring within 50 m of the dwelling.

The results indicated that there are 5 existing dwellings that are predicted to experience some shadow flicker, and no dwellings predicted to experience theoretical shadow flicker duration in excess of 30 hours per year. When considering the actual shadow flicker duration, which takes into account the reduction of shadow flicker due to turbine orientation and cloud cover, no dwellings were found to experience more than 10 hours per year.

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

2 DESCRIPTION OF THE PROPOSED WIND FARM SITE

2.1 General site description

The site is located to the east of the Albany Highway, approximately 260 km southeast of Perth and 30 km southwest of the township of Katanning in southwest Western Australia. The Palgarup State Forest lies approximately 66 km to the southwest of the site and the mountains of the Stirling Range are located approximately 60 km to the southeast.

The proposed wind farm lies on undulating terrain of elevation varying from approximately 320 to 390 m asl. The site and surrounding area consists mainly of farmland containing scattered trees, however there are some large patches of dense forestry. The general terrain at the site appears to be characterised by moderate slopes and rolling hills. GH has not visited the site.

A more detailed contour map of the region surrounding the proposed wind farm, which also includes proposed turbine and house locations and site boundaries, can be seen in Figure 3.

2.2 Proposed Wind Farm layout

The 74 turbine wind farm layout analysed here was developed in a previous report [2], and a list of the co-ordinates of the proposed turbine locations are given in Table 1.

The turbine analysed here has a hub height of 84 m, a rotor diameter of 112 m and a maximum blade chord of 4 m. These turbine parameters were used for the shadow flicker modelling.

2.3 House locations

A list of the co-ordinates of dwellings in the vicinity of the wind farm has been provided by MHE [3], and is shown in Table 2.

Only houses within 1120 m of the proposed turbines have been considered in the current analysis. This distance has been selected to meet the requirements of the EPHC [5], which states that shadow flicker zones of influence should be calculated to a minimum distance of 265 x maximum blade chord (ie 1060 m in this case), however as a conservative criteria (refer to Section 3), 10 times the rotor diameter has been used to determine the calculation distance (1120 m). Figure 3 shows a map of the site with the proposed turbine layout and house locations.

MHE has provided elevation contours with a vertical resolution of 2 m for the site and surrounds.

3 PLANNING GUIDELINES

In WA there are no specific Guidelines for the assessment of shadow flicker generated by wind turbines. However, a number of assessments throughout Australia have applied the Victorian Planning Guidelines which 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".*

In addition, the EPHC Draft National Wind Farm Development Guidelines released in July 2010 [5] include recommendations for shadow flicker limits relevant to wind farms in Australia.

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 should be assessed by calculating the maximum shadow flicker occurring within 50 m of the centre of a dwelling.

The Draft National Guidelines 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 [6] or approximately 1 km for a modern wind turbine. 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 maximum blade chords[1] as an appropriate limit, which corresponds to approximately 800 to 1325 m for modern wind turbines (which typically have maximum blade chord lengths of 3 to 5 m). The UK wind industry and UK government consider that 10 rotor diameters is appropriate, which corresponds to approximately 800 to 1200 m for modern wind turbines (which typically have rotor diameters of 80 to 120 m).

In this analysis case, 10 rotor diameters has been used for the calculation distance as this gives the most conservative distance when considering the above criteria, resulting in a shadow flicker calculation limit of 1120 m from each turbine.

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

4 SHADOW FLICKER ASSESSMENT

4.1 Shadow Flicker Overview

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

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

- Direction of the property relative to the turbine.
- Distance from the turbine (the further the observer is from the turbine, the less pronounced the effect will be);
- Wind direction (the shape of the shadow will be determined by the position of the sun relative to the blades which will be oriented to face the wind);
- Turbine height and rotor diameter;
- Time of year and day (the position of the sun in the sky);
- Weather conditions (cloud cover reduces the occurrence of shadow flicker)

4.2 Theoretical Modelled Shadow Flicker Duration

The theoretical number of hours of shadow flicker experienced annually at a given location can be calculated using a geometrical model which incorporates the sun path, topographic variation over the wind farm site and wind turbine details such as rotor diameter and hub height.

The wind turbines have been modelled assuming they are spherical objects, which is equivalent to assuming the turbines are always oriented perpendicular to the sun-turbine vector. This assumption will mean the model calculates the maximum duration for which there is potential for shadow flicker to occur.

In line with the methodology proposed in the Draft National Guidelines, GH has assessed the shadow flicker at the surveyed house locations and has determined the highest shadow flicker duration within 50 m of the centre of each 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 (in the case of NSH03). The shadow receptors are simulated as fixed points, representing the worst case scenario, as real windows would be facing a particular direction. The shadow flicker calculations for dwelling locations have been carried out with a temporal resolution of 1 minute; if shadow flicker occurs in any 1 minute period, the model records this as 1 minute of shadow flicker. The shadow flicker map was generated using a temporal resolution of 10 min to reduce computational requirements to acceptable levels.

An assumption has been made 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 [6], while the Draft National Guidelines suggest a distance equivalent to 265 maximum blade chords as an appropriate limit, corresponding to approximately 800 to 1200 m for modern wind turbines. Considering the turbine dimensions provided by MHE, the most conservative value corresponds to 10 rotor diameters, or 1120 m.

The model makes the following assumptions and simplifications:

- There are clear skies every day of the year;
- The turbines are always rotating;
- The blades of the turbines are always perpendicular to the direction of the line of sight from the specified location to the sun.

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

The settings used to execute the model can be seen in Table 3.

To illustrate typical results, an indicative shadow flicker map for a turbine located in a relatively flat area is shown in Figure 2. The geometry of the shadow flicker map can be characterised as a butterfly shape, with the four protruding lobes corresponding to slowing of solar north-south travel around the summer and winter solstices for morning and evening. The lobes to the north of the indicative turbine location result from the summer solstice and conversely the lobes to the south result from the winter solstice. The lobes to the west result from morning sun while the lobes to the east result from evening sun. When the sun is low in the sky, the length of shadows cast by the turbine increases, increasing the areas around the turbine affected by shadow flicker.

4.3 Factors Affecting Shadow Flicker Duration

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

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

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

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

   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 disk 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 shadow flicker duration.

4.4 Predicted Actual Shadow Flicker Duration

As discussed above, there are a number of effects which may reduce the incidence of shadow flicker, such as cloud cover and variation in turbine orientation, that are not taken into account in the calculation of the theoretical shadow flicker duration. Exclusion of these effects means that the theoretical calculation is conservative. An attempt has been made to quantify the likely reduction in shadow flicker duration due to these effects, and therefore produce a prediction of the actual shadow flicker duration likely to be experienced at a dwelling.

Cloud cover is typically measured in oktas or eighths of the sky covered with cloud. GH has obtained data from 3 Bureau of Meteorology (BoM) stations located in proximity to the site. These stations are:

- 010582 Kojonup (Located approximately 18 km from the site) [7];
- 010579 Katanning Comparison (Located approximately 28 km from the site) [8];
- 010647 Wagin (Located approximately 63 km from the site) [9];

Due to the significant availability of cloud coverage data (over a 26 year period) for Kojonup BoM station, and its close proximity to the site, the reduction in shadow flicker duration caused by cloud cover was calculated using this BoM station. The cloud cover recorded at Katanning and Wagin were used to confirm these results.

The results show that the average annual cloud cover values obtained from readings at 9 am and 3 pm are approximately 4.5 and 4.4 oktas, respectively. This means that on an average day, 4.45/8 or approximately 55.6 % of the sky in the vicinity of the wind farm is covered with clouds at these times. Although it is not possible to definitively calculate the effect of cloud cover on shadow flicker duration, a reduction in the shadow flicker duration proportional to the amount of cloud cover is a reasonable assumption. An assessment of the likely reduction in shadow flicker duration due to cloud cover was conducted on a monthly basis, which indicated that monthly reductions of 51 to 62 % are expected.

Similarly, turbine orientation can have an impact on the shadow flicker duration. The shadow flicker impact 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 data recorded at the 80 m site mast, and used in a previous energy assessment [10], has been used to estimate the reduction in shadow flicker duration due to rotor orientation. The measured annual wind rose is shown overlaid on an indicative shadow flicker map in Figure 2. An assessment of the likely reduction in shadow flicker duration due to variation in turbine orientation was conducted on a monthly basis, which indicated that reductions of approximately 31 to 34 % can be expected at this site.

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. It is therefore likely that the adjusted shadow flicker durations presented here can still be regarded as a conservative assessment.

5 RESULTS OF THE ANALYSIS

The theoretical maximum predicted shadow flicker durations at receptors within the vicinity of the proposed Flat Rocks Wind Farm, as well as the maximum predicted theoretical shadow flicker durations within 50 m of these receptors, are presented in Table 4. The results are also presented in the form of a shadow flicker map at 2 m above ground in Figure 3.

These results indicate that 5 dwellings are predicted to experience some shadow flicker. Of these 5 dwellings, none are expected to experience theoretical shadow flicker durations of more than 30 hours per year.

An assessment of the level of conservatism associated with the worst-case results has been conducted by calculating the possible reduction in shadow flicker duration due to turbine orientation (based on the wind rose measured at the site) and cloud cover. These adjusted results are presented as predicted actual shadow flicker durations in Table 4. Consideration of turbine orientation and cloud cover reduces the predicted shadow flicker duration by 66 to 75 % at the dwellings considered.

After the application of these factors, the predicted actual shadow flicker durations at all houses remain below the limit of 10 hours recommended in the Draft National Guidelines.

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, GH considers that this additional reduction due to turbine orientation is representative, 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.

5.1 Mitigation Options

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

6 CONCLUSION

An analysis has been conducted to determine the duration of shadow flicker experienced at dwellings in the vicinity of the proposed Flat Rocks Wind Farm, based on the methodology proposed in the Draft National Guidelines. The results of the assessment are presented in the form of a shadow flicker map in Figure 3. The shadow flicker results for each receptor identified by MHE to GH are also listed in Table 4.

The assessment of theoretical shadow flicker hours shows that all dwellings identified by MHE are predicted to experience theoretical shadow flicker duration below the recommended limit of 30 hours per year recommended in both the Victorian Guidelines and Draft National Guidelines.

Approximation of the degree of conservatism associated with the worst-case results has been conducted by calculating the possible reduction in shadow flicker duration due to turbine orientation and cloud cover.

The results of this analysis, also presented in Table 4, show that all dwellings identified by MHE are predicted to experience actual shadow flicker duration below the limit of 10 hours recommended by the Draft National Guidelines. However it should be noted that the methodology used to assess the actual shadow flicker duration is different from that prescribed in the Draft National Guidelines, and that GH considers that only one of the limits in the Draft National Guidelines needs to be satisfied at a given dwelling.

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

7 REFERENCES

1. "Influences of the opaqueness of the atmosphere, the extension of the sun and the rotor blade profile on the shadow impact of wind turbines", Freund H-D, Kiel F.H., DEWI Magazine No. 20, Feb 2002, pp43-51

2. "MHE Flat Rocks Wind Farm layout optimisation.doc", GH document 45392/PT/01 Issue B, 28th April 2011.

3. Email from Sarah Rankin (MHE) to David Price (GH), 28th March 2011.

4. "Policy and planning guidelines for development of wind energy facilities in Victoria", Sustainable Energy Authority Victoria, 2009

5. "National Wind Farm Development Guidelines – Public Consultation Draft", Environmental Protection and Heritage Council (EPHC), July 2010

6. "Planning for Renewable Energy – A Companion Guide to PPS22", Office of the Deputy Prime Minister, UK, 2004

7. "Climate statistics for Australian locations – Kojonup", Bureau of Meteorology, February 2011, viewed 3rd May 2011, http://www.bom.gov.au/climate/averages/tables/cw_010582.shtml

8. "Climate statistics for Australian locations – Katanning Comparison", Bureau of Meteorology, February 2011, viewed 3rd May 2011, http://www.bom.gov.au/climate/averages/tables/cw_010579.shtml

9. "Climate statistics for Australian locations – Wagin", Bureau of Meteorology, February 2011, viewed 3rd May 2011, http://www.bom.gov.au/climate/averages/tables/cw_010647_All.shtml

10. "45195PT02A MHE Flat Rocks Wind Farm layout, wind, energy.pdf", GH technical note, 16th August 2010

LIST OF TABLES

LIST OF FIGURES

Turbine ID	Easting [m]	Northing [m]	Turbine ID	Easting [m]	Northing [m]
1	533353	6251758	38	526877	6242486
2	533872	6251546	39	527681	6242229
3	532675	6251443	40	526488	6242210
4	533626	6251119	41	527310	6241900
5	532328	6250880	42	528113	6241847
6	533248	6250736	43	531840	6241787
7	533756	6250500	44	532391	6241738
8	531575	6250252	45	527860	6241246
9	532922	6250191	46	532100	6241227
10	532333	6250139	47	531471	6241171
11	533464	6250113	48	530014	6241007
12	533791	6249619	49	530604	6240976
13	533260	6249574	50	532458	6240750
14	536267	6247980	51	530327	6240492
15	536201	6247429	52	532848	6240303
16	534497	6246947	53	530035	6240010
17	530818	6247319	54	533060	6239760
18	536269	6246950	55	529575	6239800
19	534021	6246789	56	533224	6239233
20	535002	6246668	57	533285	6238735
21	531467	6246454	58	533253	6238266
22	530744	6246520	59	531682	6237572
23	535002	6245864	60	530107	6237475
24	535977	6246267	61	531221	6237400
25	531130	6246118	62	530660	6237354
26	534675	6246351	63	530360	6236850
27	535305	6246210	64	531585	6236810
28	531636	6245855	65	530044	6236516
29	534457	6245858	66	531584	6236243
30	531663	6245378	67	528030	6236155
31	531924	6244916	68	530335	6236001
32	534160	6246308	69	527800	6235752
33	534374	6244473	70	531374	6235569
34	531927	6244440	71	527479	6235400
35	533574	6244165	72	527103	6235127
36	534120	6244096	73	527537	6234777
37	531648	6246882	74	528087	6234661

Co-ordinate system is UTM zone 50H, WGS84 datum.

Table 1 Proposed turbine layout for the Flat Rocks Wind Farm site.

House ID	Easting (m)	Northing (m)	Stakeholder?	Distance from nearest turbine (km)	Nearest turbine
NSH01	529798	6252398	N	2.8	8
NSH02	534034	6254130	N	2.5	1
NSH03	534715	6252104	N	1.0	2
NSH04	533706	6248509	N	1.1	12
NSH05	538397	6245086	N	2.7	24
NSH06	536092	6244487	N	1.7	33
NSH07	536187	6243019	N	2.3	33
NSH08	533602	6237033	N	1.3	58
NSH09	533299	6237262	N	1.0	58
NSH10	527067	6249862	N	4.5	8
NSH11	527858	6248864	N	3.3	17
NSH12	529822	6247171	N	1.0	17
NSH13	530084	6245361	N	1.3	25
NSH14	531650	6243477	N	1.0	34
NSH15	532980	6242569	N	1.0	44
NSH16	527583	6245239	N	2.8	38
NSH17	525526	6244591	N	2.5	38
NSH18	525548	6238704	N	3.4	45
NSH19	528558	6237293	N	1.3	67
NSH20	531581	6233170	N	2.4	70
NSH21	526817	6247723	N	4.0	17
NSH22	529707	6247138	N	1.1	17
NSH23	527880	6245017	N	2.7	38
NSH24	529664	6247150	N	1.2	17
NSH25	539639	6249790	N	3.8	14
SH26	537647	6239337	Y	4.4	57
SH27	534084	6239794	Y	1.0	54
SH28	531662	6251703	Y	1.0	3
SH29	533630	6245183	Y	1.0	35
SH30	528913	6240557	Y	1.0	55
SH31	529077	6237156	Y	1.1	60
SH32	528718	6236883	Y	1.0	67
SH33	537743	6239372	Y	4.5	57
Proposed NSH34	531507	6239494	N	1.5	51

Co-ordinate system is UTM zone 50H, WGS84 datum.

Table 2 House locations in the vicinity of the proposed Flat Rocks Wind Farm turbines.

Model Setting	Value
Maximum shadow length	1120 m
Year of calculation	2026
Minimum elevation of the sun	3°
Time step	1 min (10 min for map)
Rotor modelled as	Sphere
Sun modelled as	Disc
Offset between rotor and tower	None
Receptor height (single storey)	2 m
Receptor height (double storey)	6 m
Grid size for determining maximum shadow flicker within 50 m of centre of dwelling	25 m

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

			Theoretical			Predicted Actual[3]
House ID	**Easting[1] [m]**	**Northing[1] [m]**	**At Dwelling[2] [hr/yr]**	**Max Within 50m of Dwelling[2] [hr/yr]**	**Contributing Turbines**	**Max Within 50m of Dwelling[2] [hr/yr]**
NSH12	529850	6247175	8.4	9.1	17	2.6
NSH22	529750	6247150	0.0	6.9	17	1.9
SH27	534050	6239775	12.1	12.8	54	3.7
SH28	531700	6251675	11.6	12.4	3	4.2
SH31	529100	6237175	12.5	13.2	60	3.3
Limits			**30**	**30**	**n/a**	**10**

Notes:
[1] MGA Zone 50 (WGS84 datum)
[2] Dwellings with zero hours shadow flicker have been omitted from this table
[3] Considering likely reductions in shadow flicker duration due to cloud cover and turbine orientation

Table 4 Theoretical and predicted actual shadow flicker durations at 2m.

GL Garrad Hassan

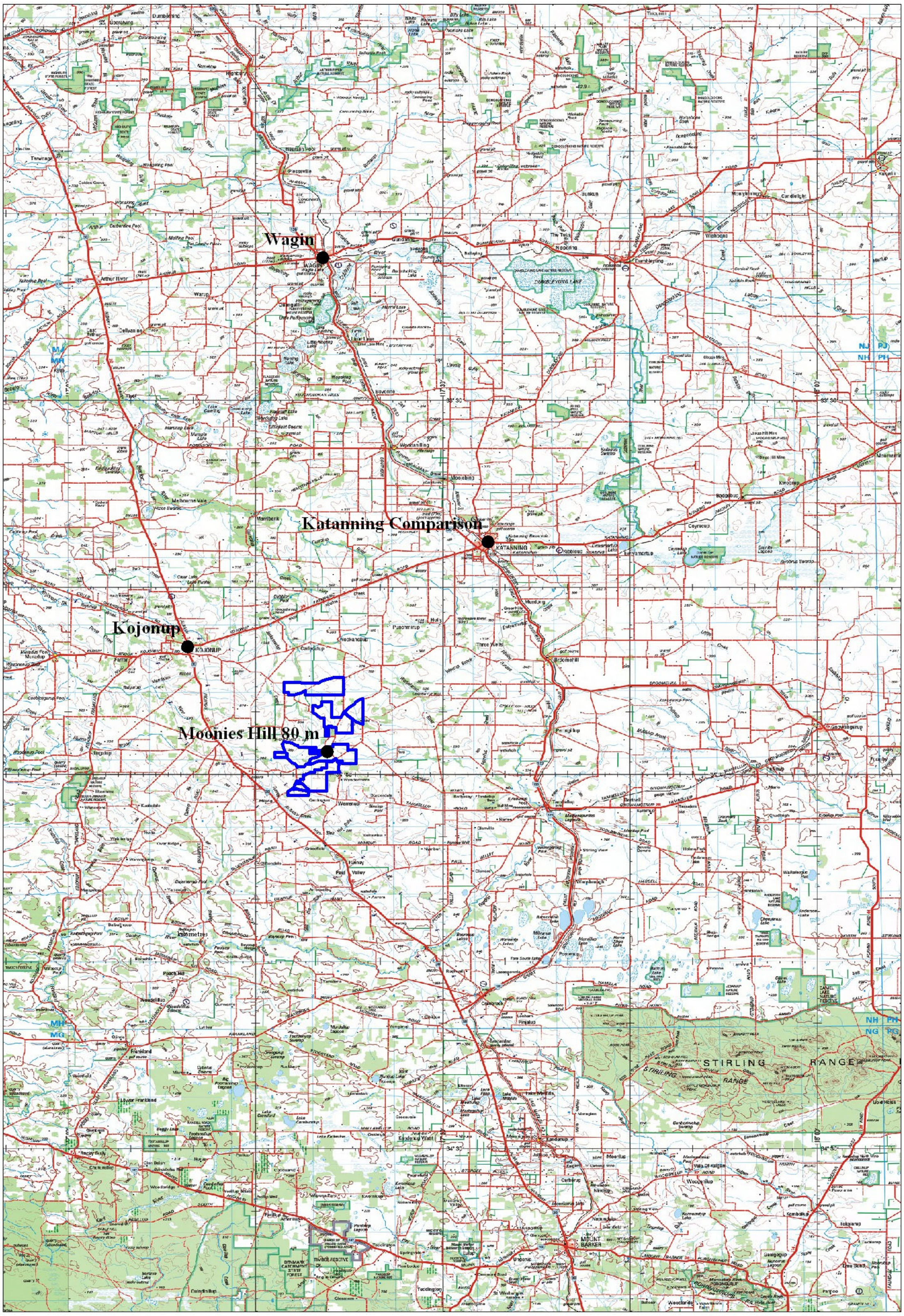


Figure 1 Location of the proposed Flat Rocks (Moonies Hill) Wind Farm site, as well as nearby BoM stations.

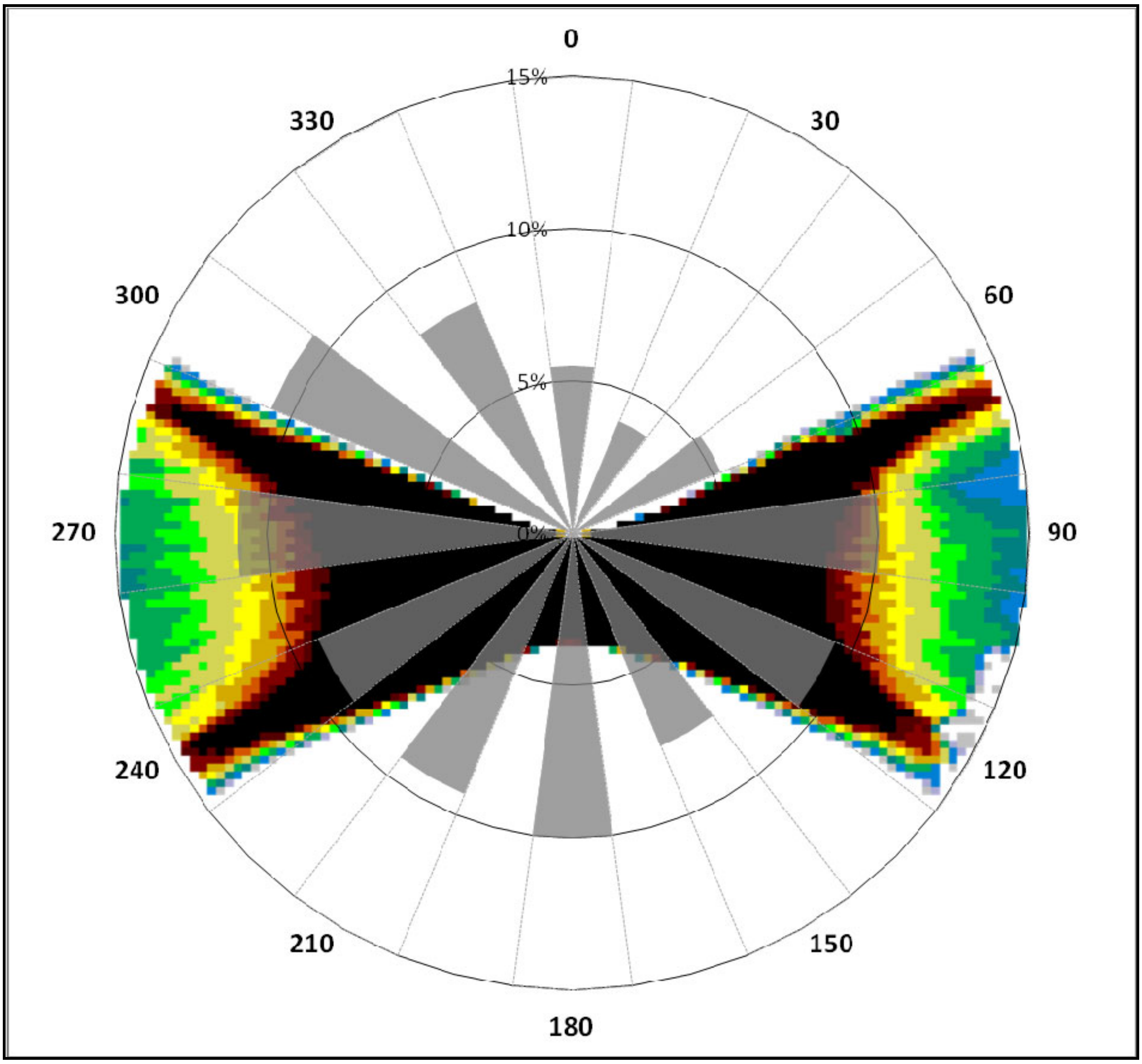
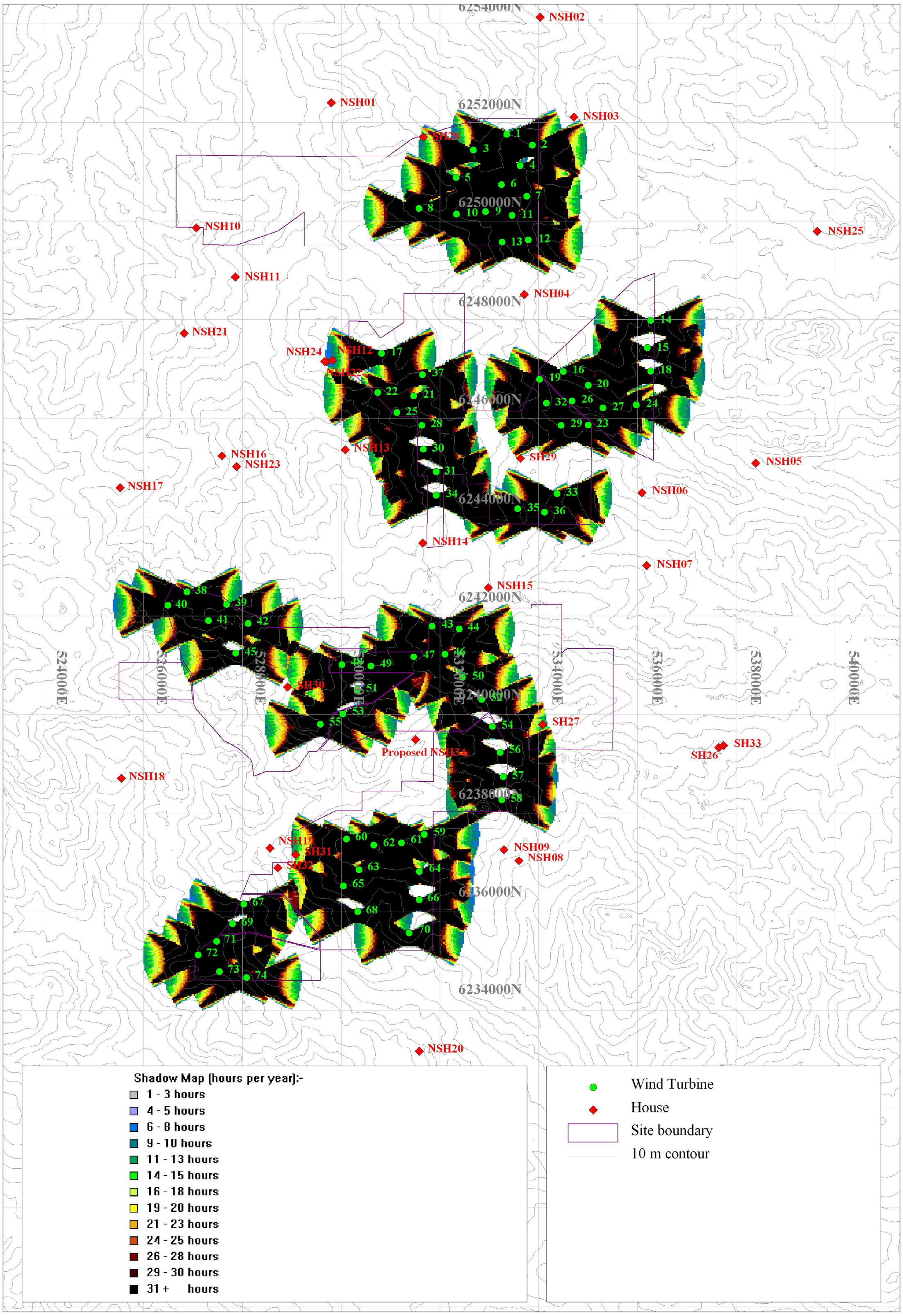


Figure 2 **Indicative shadow flicker map and wind direction frequency distribution (for 80 m site mast).**



Note: Coordinate system is UTM Zone 50, WGS84.

Figure 3 Map of proposed Flat Rocks Wind Farm showing turbines, house locations and theoretical shadow flicker duration at 2 m.