Appendix A – GL Garrad Hassan Shadow Flicker Assessment

GL Garrad Hassan

SHADOW FLICKER AND BLADE GLINT ASSESSMENT FOR THE PROPOSED PALING YARDS WIND FARM

Client	Green Bean Design
Contact	Andy Homewood
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Author:

M Clifton-Smith

Checked by:

J Jobin

Approved by:

M Bechly

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

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Revision History

Issue	Issue Date:	Summary
A	12 Sept 2011	Original Issue
B	20 Jan 2012	Revised turbine layout with multiple turbine scenarios. Theoretical Shadow flicker time of day plots added. Theoretical Shadow Flicker at window locations added.
C	8/08/2012	Revised turbine layout with two new turbine scenarios.
D	4/12/2013	Final.

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CONTENTS

1 EXECUTIVE SUMMARY

Garrad Hassan Pacific Pty Ltd (GL GH) has been commissioned by Green Bean Design (GBD) to independently assess the shadow flicker in the vicinity of the proposed Paling Yards Wind Farm (PYWF). The wind farm proponent is Union Fenosa Wind Australia (UFWA). The results of the work are reported here. This document has been prepared pursuant to the GL GH proposal P1149/PP/01 Issue A, and is subject to the terms and conditions contained therein.

The Director-General's Requirements (DGRs) for the preparation of an Environmental Assessment (EA) for the Paling Yards Wind Farm state that the EA must assesses the impact of shadow "flicker" and blade "glint" from the wind farm. In accordance with these DGRs, this report makes the findings and recommendations discussed below.

Shadow flicker involves the modulation of light levels resulting from the periodic passage of a rotating wind turbine blade between the sun and a viewer. 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 Paling Yards 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.

UFWA has supplied a layout for the wind farm consisting of 59 turbines, surveyed locations of houses in the vicinity of the wind farm, and elevation contours for the area [2]. These have been used here to determine the theoretical duration of shadow flicker at each dwelling.

In NSW there are no specific Guidelines on how to assess shadow flicker generated by wind turbines. However, a number of assessments have applied the Victorian Planning Guidelines [3] 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 [4] 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.

An estimate of shadow flicker duration has been undertaken by assessing theoretical shadow flicker and also by assessing predicted actual shadow flicker hours by taking into account two of the factors (turbine orientation and cloud cover) which are likely to reduce the actual shadow flicker duration to values well below the theoretical duration.

The modelling shows that based on the methodology recommended in the Draft National Wind Farm Development Guidelines, there are seven existing dwellings that are predicted to experience some shadow flicker. All dwellings were assumed to have two storeys, and the modelling was undertaken at 2 m and 6 m above ground.

When considering the maximum shadow flicker duration within 50 m of each dwelling, seven dwellings are 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, seven dwellings are found to experience more than the limit of 10 hours per year.

Therefore, compliance with both the Victorian Planning Guidelines and the Draft National Wind Farm Development Guidelines is not predicted to be achieved for seven of the provided dwelling locations. However, GL GH understands that UFWA will negotiate an agreement with the inhabitants of these dwellings. It should be noted that some additional potential sources of conservatism are still included in the assessment. For example, screening due to vegetation is not considered in this desktop assessment.

To assist UFWA negotiate an agreement with these dwellings, detailed time of day theoretical shadow flicker durations have been presented along with detail theoretical shadow flicker durations at key window locations for the key effected houses.

Blade glint involves the reflection of light from a turbine blade, and can be seen by an observer as a periodic flash of light coming from the wind turbine. Blade glint is not generally a problem for modern turbines provided non-reflective coatings are used for the surface of the blades.

2 DESCRIPTION OF THE PROPOSED WIND FARM SITE

2.1 Site description

The Paling Yards site is located approximately 46km south of Oberon in the Oberon Shire Council. The general location of the area of interest is shown in Figure 1. A more detailed contour map of the region surrounding the proposed wind farm, which also includes proposed turbine locations, can be seen in Figure 3.

The proposed Paling Yards site (the site) is located on the Great Dividing Range, New South Wales. The site is located on a land parcel with an area of 39 sq km.

The site consists of moderately complex terrain with rolling undulating, some areas of steep slopes, and with site elevation ranging between 933 m and 1046 m above ground level (agl).

The site is predominantly cleared farmland.

2.2 House locations

A list of the co-ordinates of dwellings in the vicinity of the wind farm has been provided by UFWA [5]. Due to the distance limit of the shadows cast by wind turbines as described in Section 3, only houses within 2 km of the proposed wind farm have been considered in the current analysis, and are shown in Table 1.

Detailed GPS coordinates and photos of window locations, external corners and window heights around the key effected residences have been provided by GBD [6]. Four window locations have been used for each residence as requested by UFWA [7] and are shown in Table 2.

All co-ordinates presented in this report are in MGA Zone 55 (GDA94 datum).

2.3 Proposed Wind Farm layout

GBD has supplied the layout of the wind farm, which is composed of 59 wind turbines. The proposed turbine options are shown below:

	Option 1:	
Hub height	**Diameter**	**Turbine Locations:**
80 m	100 m	P19, P20, P24, P32, P33, P34, P38, P44, P45, P46, P48, P50, P51
91 m	117 m	All other locations
	Option 2:	
Hub height	**Diameter**	**Turbine Locations:**
80 m	100 m	P19, P20, P24, P32, P33, P34, P38, P39, P44, P45, P46, P47, P48, P50, P51
107 m	136 m	All other locations

These parameters were used for the shadow flicker modelling.

A list of co-ordinates of proposed turbine locations has been provided by UFWA [8], with the grid coordinates given in MGA Zone 55 (GDA94 datum). These co-ordinates, together with the identifiers which have been supplied by UFWA are shown in Table 3.

Figure 3 shows a map of the site with the proposed turbine layout and surrounding house locations.

3 PLANNING GUIDELINES

The Paling Yards Wind Farm DGRs cite two guidelines require the potential impacts of shadow flicker to be assessed. The guidelines are the NSW Wind Energy Facilities Draft EIA Guidelines [9] and the Auswind Best Practice Guidelines [10].

However, in NSW there are no specific Guidelines for the assessment shadow flicker generated by wind turbines that provide detailed methodologies to assess impacts of shadow flicker. A number of assessments 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 2010 [4] 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 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 analysis contained in this report has met, if not exceeded, the recommendations of these guidelines.

The impact of shadow flicker is typically only significant up to a distance of around 10 rotor diameters from a turbine [11] 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 1050 m for modern wind turbines (which typically have maximum blade chord lengths of 3 to 4 m). The UK wind industry and UK government consider that 10 rotor diameters is appropriate, which corresponds to approximately 800 to 1100 m for modern wind turbines (which typically have rotor diameters of 80 to 110 m).

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

> *"The sun's light may be reflected form 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*

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

> *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."*

GL GH considers that the recommendations of EPHC draft national guidelines meet, if not exceed, the recommendations of both the NSW Wind Energy Facilities EIA Guidelines and the Auswind Best Practice Guidelines.

The NSW government recently released draft NSW Planning Guide lines for Wind Farms [12]. Although the guidelines were released follow the issue of the DGR's for the Paling Yards Wind Farm, GL GH considers that the approach used in this report meets the requirements of the new NSW Draft Guidelines.

4 SHADOW FLICKER AND BLADE GLINT 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, GL 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 6m, to represent second floor windows. The shadow receptors are simulated as fixed points, representing the worst case scenario, as real windows would be facing a particular direction.

Additional simulations have been performed at actual window locations, obtained by GBD using a hand held GPS device [6]. Where the Shadow flicker durations have been calculated for window locations, the tilt, orientation and height of the window has been taken into account.

All simulations 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.

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 [11], while the Draft National Guidelines suggest a distance equivalent to 265 maximum blade chords as an appropriate limit, corresponding to approximately 800 to 1050 m for modern wind turbines. For each turbine option, the maximum length of the shadow cast by the wind turbine is 10 times the maximum rotor diameters. i.e. For Option 1 and 2 it is 1120 m and for option 3, 1170 m is appropriate.

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 4.

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. GL GH has obtained data from 2 Bureau of Meteorology (BoM) stations located in proximity to the site. These stations are:

- 063063 Oberon (Located approximately 10 km from the site) [13];
- 070080 Taralga Post Office (Located approximately 12 km from the site) [14];

The reduction in shadow flicker duration caused by cloud cover was calculated using an average across both stations.

The results show that the average annual cloud cover values obtained from readings at 9 am and 3 pm are approximately 4.1 and 4.5 okta's, respectively. This means that on an average day, 4.3 / 8 or approximately 54% 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 57% 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 a site mast has been supplied to GL GH from the site Mast PY1 covering a short period from July 2003 to September 2003, and a second longer period from March 2005 to December 2007. [15]. The provided annual wind rose is shown overlaid on the 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 22% to 35% 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 actual shadow flicker durations presented here can still be regarded as a conservative assessment.

4.5 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. As discussed, blade glint is not generally a problem for modern wind turbines, provided the blades are coated with a non-reflective paint, and it is not considered further here.

5 RESULTS OF THE ANALYSIS

The theoretical maximum predicted shadow flicker durations at receptors within the vicinity of the proposed Paling Yards Wind Farm are presented in Table 5 and Table 6. The maximum predicted theoretical shadow flicker durations within 50 m of receptors are also presented in Table 5 and Table 6. The results are presented in the form of a shadow flicker maps at 2 m and 6 m above ground in Figure 4 through to Figure 7.

These results indicate that seven dwellings are predicted to experience some shadow flicker. All of these dwellings are expected to experience theoretical shadow flicker durations of more than 30 hours per year. However, these dwelling are owned by landholders whom UFWA will negotiate an agreement with. Additionally, some of these dwellings may not be permanent residences.

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 the predicted actual shadow flicker duration in Table 5 and Table 6. Consideration of turbine orientation and cloud cover reduces the predicted shadow flicker duration by 64% to 74%.

After the application of these factors, the predicted actual shadow flicker durations at all seven of the dwellings mentioned above remain above the limit of 10 hours recommended in the Draft National Guidelines. As before, these dwellings are inhabited by a landholder whom UFWA will negotiate an agreement with.

Often shadow flicker durations in excess of those permitted under the relevant guidelines are deemed acceptable by landowners who have an agreement with the wind farm developer. According to information supplied by UFWA, the dwellings where the draft guideline recommendations are not met are owned by an involved landholder. This suggests that the current layout is acceptable under the Victorian Guidelines and Draft National Guidelines. However it should be noted that the shadow flicker durations predicted at many of the dwellings would be considered as high, with theoretical shadow flicker durations of up to an hour per day for a significant portion of the year predicted at some dwellings.

Shadow Flicker durations at various window locations at the key properties are shown in Table 7 through to Table 8, and time of day shadow flicker durations are shown in Figure 8 though to Figure 15. The shadow flicker durations at each window location takes into account the tilt, orientation and height of that window.

It should be noted that the method prescribed by the Draft National Guidelines for assessing actual shadow flicker duration recommends that only cloud cover, and not turbine orientation, be considered when assessing the actual shadow flicker duration. However, GL GH considers that this additional reduction due to turbine orientation is justified, 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. It should also be noted that some additional potential sources of conservatism, such as screening due to vegetation and turbine shutdown, have not been accounted for in the assessment.

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 has the potential to occur, or relocation of turbines.

6 CONCLUSION

An analysis has been conducted to determine the duration of shadow flicker experienced at shadow receptors in the vicinity of the proposed Paling Yards 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 4 to Figure 7. The shadow flicker results for each receptor identified to GL GH are also listed in Table 5 and Table 6. The assessment of theoretical shadow flicker hours shows that all except seven of the dwellings identified by UFWA comply with the recommended limit of 30 shadow flicker hours per year.

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 5 and Table 6 show that the seven dwellings that are predicted to experience theoretical shadow flicker duration in excess of 30 hours per year are also likely to experience more than the recommended limit of 10 actual shadow flicker hours per year.

Often shadow flicker durations in excess of those permitted under the relevant guidelines are deemed acceptable by landowners who have an agreement with the wind farm developer. GL GH understands UFWA will negotiate an agreement with the landholders in question in this case. However it should be noted that the shadow flicker durations predicted at many of the dwellings would be considered as high. To assist UFWA to reach an agreement with these dwellings, detailed time-of-day theoretical shadow flicker durations have been presented along with detail theoretical shadow flicker durations at key window locations for the key effected houses are presented.

It should be noted that 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 adjusted values may still be regarded as a conservative assessment.

Blade glint is not likely to cause a problem for observers in the vicinity of the wind farm provided non-reflective coatings are used on the blades of the turbines.

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LIST OF TABLES

LIST OF FIGURES

House ID	Easting [m][1]	Northing [m][1]	Distance from nearest turbine [km]	Nearest turbine
3	758065	6222550	2.6	P51
4	757528	6222283	2.0	P51
5	757652	6222233	2.1	P51
6	758725	6221219	2.4	P52
6A	759168	6220843	2.4	P52
7	755733	6219927	0.5	P50
7A	754852	6219783	0.4	P46
8	752720	6217349	0.5	P30
8A	752775	6217645	0.6	P36
9	752455	6215508	0.6	P18
9A	752297	6215538	0.5	P20
9B	752581	6215711	0.5	P25
10	745869	6215678	2.1	P1
126	755608	6213611	2.9	P22
128	753128	6211506	2.9	P21
135	755459	6213072	3.0	P22
n	754842	6215362	1.7	P24

[1] The house coordinates are in MGA Zone 55 (GDA94 datum).

Table 1. House locations in the vicinity of the proposed Paling Yards Wind Farm turbines.

Window ID	Easting[1] [m]	Northing[1] [m]	Height [m]	Description / Facing
R7_ave	755755	6219920	-	Average coordinate of all house GPS points
R7_W10	755758	6219932	1.8	northeast
R7_W12	755766	6219925	1.8	northeast
R7_W5	755745	6219924	1.8	northwest
R7_W6	755747	6219927	1.8	northeast
R7A_ave	754867	6219775	-	Average coordinate of all house GPS points
R7A_W1	754864	6219766	1.8	southeast
R7A_W3	754855	6219771	1.8	southeast
R7A_W5	754867	6219782	1.8	northeast
R7A_W7	754873	6219777	2.5	northeast
R8_ave	752731	6217370	-	Average coordinate of all house GPS points
R8_W10	752734	6217371	1.8	northwest
R8_W3	752743	6217358	3.0	east
R8_W6	752722	6217351	3.5	west
R8_W9	752723	6217377	2.0	west
R9_ave	752476	6215503	-	Average coordinate of all house GPS points
R9_W11	752484	6215493	1.8	South southwest
R9_W14	752468	6215497	1.7	West southwest
R9_W15	752464	6215505	1.7	West southwest
R9_W3	752483	6215513	1.8	northwest

[1] MGA Zone 55 (GDA94 datum)

Table 2. Approximate window locations at key House locations in the vicinity of the proposed Paling Yards Wind Farm turbines

Turbine ID	Easting[1] (m)	Northing[1] (m)	Turbine ID	Easting[1] (m)	Northing[1] (m)
P1	747801	6214761	P32	751654	6217234
P2	748312	6214437	P33	751942	6217474
P3	748520	6214803	P34	752209	6217766
P4	748804	6214973	P35	751953	6218025
P5	749055	6215129	P36	753234	6217980
P6	749245	6213667	P37	753414	6218296
P7	749278	6214044	P38	753670	6217768
P8	749638	6214879	P39	753790	6218102
P9	750046	6215203	P40	753716	6219273
P10	750488	6215520	P41	753756	6218710
P11	750673	6216153	P42	753851	6219051
P12	750521	6215025	P43	753990	6219495
P13	750856	6215277	P44	754258	6219703
P14	751065	6215503	P45	754453	6219950
P15	750791	6214083	P46	754724	6220154
P16	751181	6214433	P47	754673	6220559
P17	751425	6214787	P48	755149	6220270
P18	751942	6215115	P49	755527	6220446
P19	751765	6215480	P50	756080	6220346
P20	751924	6215913	P51	756446	6220552
P21	752759	6214377	P52	757360	6219305
P22	752945	6214652	P53	757575	6219025
P23	753154	6215077	P54	757656	6218768
P24	753359	6216136	P55	757565	6218414
P25	752937	6216108	P56	757293	6218235
P27	752654	6216325	P57	757117	6217957
P28	752167	6216399	P58	756711	6217870
P29	752969	6216601	P59	757016	6217565
P30	752971	6216909	P60	757375	6217237
P31	751295	6216935			

[1] Coordinate system used is Zone 55 H, GDA94 datum

Table 3. Proposed turbine layout for the Paling Yards Wind Farm site.

Model Setting	Value
Maximum shadow length	10 x (Maximum) Rotor Diameter
Year of calculation	2024
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	20 m

Table 4. Shadow flicker model settings for theoretical shadow flicker calculation.

			Theoretical				Predicted Actual[3]			
			At Dwelling[2] [hr/yr]		Max Within 50m of Dwelling[2] [hr/yr]		At Dwelling[2] [hr/yr]		Max Within 50m of Dwelling[2] [hr/yr]	
House ID	Easting[1] [m]	Northing[1] [m]	At 2 m	At 6 m	At 2 m	At 6 m	At 2 m	At 6 m	At 2 m	At 6 m
7	755733	6219927	36	34	90	83	13	12	25	23
7A	754852	6219783	124	124	152	154	42	43	54	54
8	752720	6217349	51	50	71	70	18	17	25	25
8A	752775	6217645	172	173	175	177	52	53	54	55
9	752455	6215508	68	66	79	79	23	23	27	27
9A	752297	6215538	69	68	125	123	22	21	39	38
9B	752581	6215711	89	86	130	126	25	24	36	35
Limits			**30**	**30**	**30**	**30**	**10**	**10**	**10**	**10**

[1] MGA Zone 55 (GDA94 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 5. Theoretical and predicted actual shadow flicker durations for Turbine Option 1.
(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

House ID	Easting[1] [m]	Northing[1] [m]	Theoretical: At Dwelling[2] [hr/yr] At 2 m	Theoretical: At Dwelling[2] [hr/yr] At 6 m	Theoretical: Max Within 50m of Dwelling[2] [hr/yr] At 2 m	Theoretical: Max Within 50m of Dwelling[2] [hr/yr] At 6 m	Predicted Actual[3]: At Dwelling[2] [hr/yr] At 2 m	Predicted Actual[3]: At Dwelling[2] [hr/yr] At 6 m	Predicted Actual[3]: Max Within 50m of Dwelling[2] [hr/yr] At 2 m	Predicted Actual[3]: Max Within 50m of Dwelling[2] [hr/yr] At 6 m
7	755733	6219927	36	34	83	83	13	12	23	23
7A	754852	6219783	151	153	180	180	55	55	63	63
8	752720	6217349	51	50	70	70	18	17	25	25
8A	752775	6217645	186	187	197	197	56	57	58	58
9	752455	6215508	68	66	81	81	23	23	28	28
9A	752297	6215538	84	82	141	141	24	24	43	43
9B	752581	6215711	120	117	156	156	31	31	41	41
Limits			**30**	**30**	**30**	**30**	**10**	**10**	**10**	**10**

[1] MGA Zone 55 (GDA94 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 6. Theoretical and predicted actual shadow flicker durations for Turbine Option 2.
(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

Window ID	Easting[1] [m]	Northing[1] [m]	Theoretical [hr/yr]	Predicted Actual[3] [hr/yr]
R7_ave	755755	6219920	34	12
R7_W10	755758	6219932	0	0
R7_W12	755766	6219925	0	0
R7_W5	755745	6219924	35	12
R7_W6	755747	6219927	35	12
R7A_ave	754867	6219775	0	0
R7A_W1	754864	6219766	111	39
R7A_W3	754855	6219771	110	39
R7A_W5	754867	6219782	117	41
R7A_W7	754873	6219777	0	0
R8_ave	752731	6217370	0	0
R8_W10	752734	6217371	61	21
R8_W3	752743	6217358	61	21
R8_W6	752722	6217351	0	0
R8_W9	752723	6217377	52	18
R9_ave	752476	6215503	64	22
R9_W11	752484	6215493	66	23
R9_W14	752468	6215497	0	0
R9_W15	752464	6215505	64	22
R9_W3	752483	6215513	66	23

[1] MGA Zone 55 (GDA94 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 7. Theoretical and predicted actual shadow flicker durations for Turbine Option 1 at window locations identified by GBD.
(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

Window ID	Easting[1] [m]	Northing[1] [m]	Theoretical [hr/yr]	Predicted Actual[3] [hr/yr]
R7_ave	755755	6219920	34	12
R7_W10	755758	6219932	0	0
R7_W12	755766	6219925	0	0
R7_W5	755745	6219924	35	12
R7_W6	755747	6219927	35	12
R7A_ave	754867	6219775	0	0
R7A_W1	754864	6219766	148	53
R7A_W3	754855	6219771	150	53
R7A_W5	754867	6219782	153	54
R7A_W7	754873	6219777	0	0
R8_ave	752731	6217370	0	0
R8_W10	752734	6217371	61	21
R8_W3	752743	6217358	61	21
R8_W6	752722	6217351	0	0
R8_W9	752723	6217377	52	18
R9_ave	752476	6215503	64	22
R9_W11	752484	6215493	66	23
R9_W14	752468	6215497	0	0
R9_W15	752464	6215505	64	22
R9_W3	752483	6215513	66	23

[1] MGA Zone 55 (GDA94 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 8. Theoretical and predicted actual shadow flicker durations for Turbine Option 2 at window locations identified by GBD.

(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

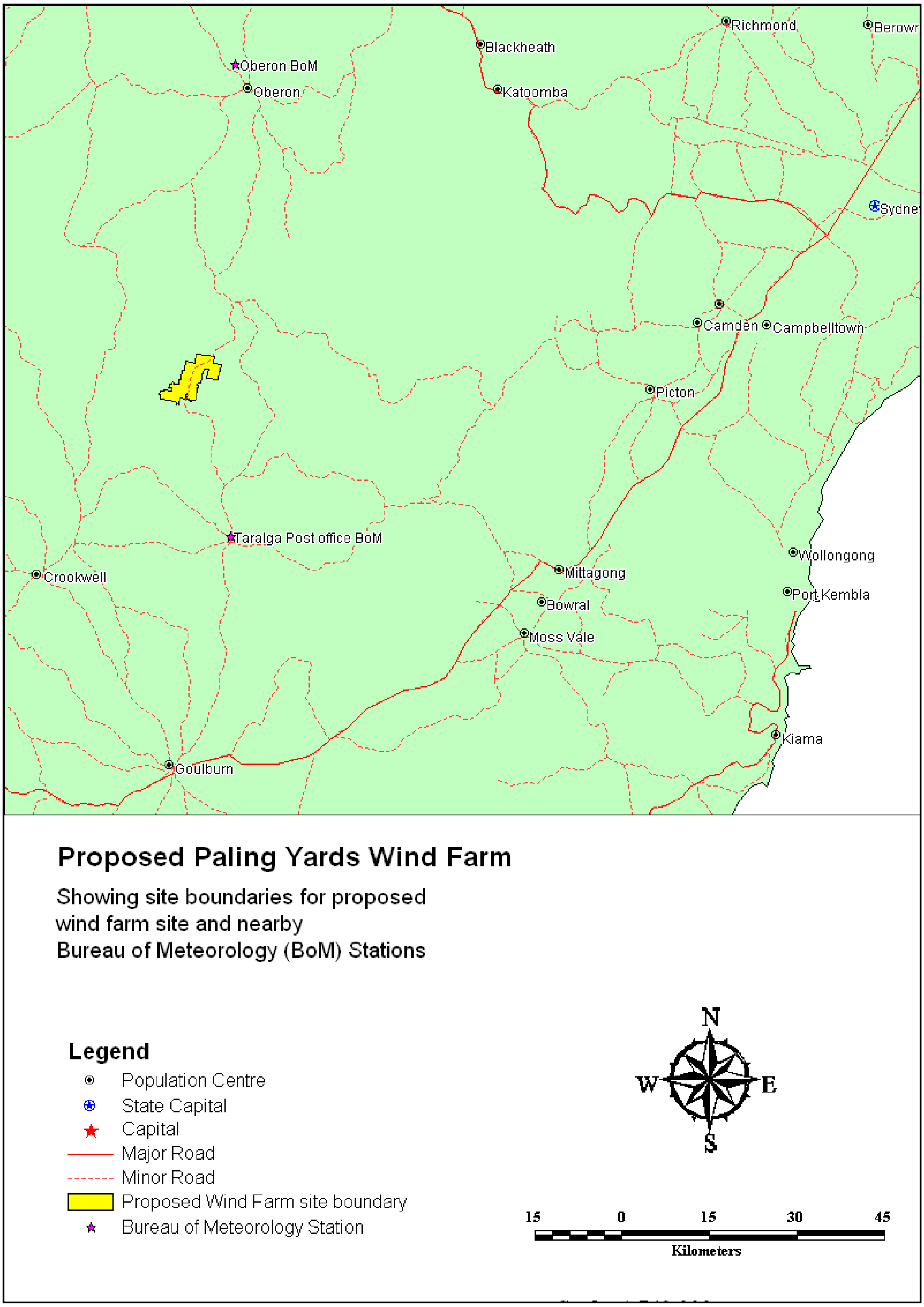

Figure 1. Location of the proposed Paling Yards Wind Farm site and nearby BoM stations

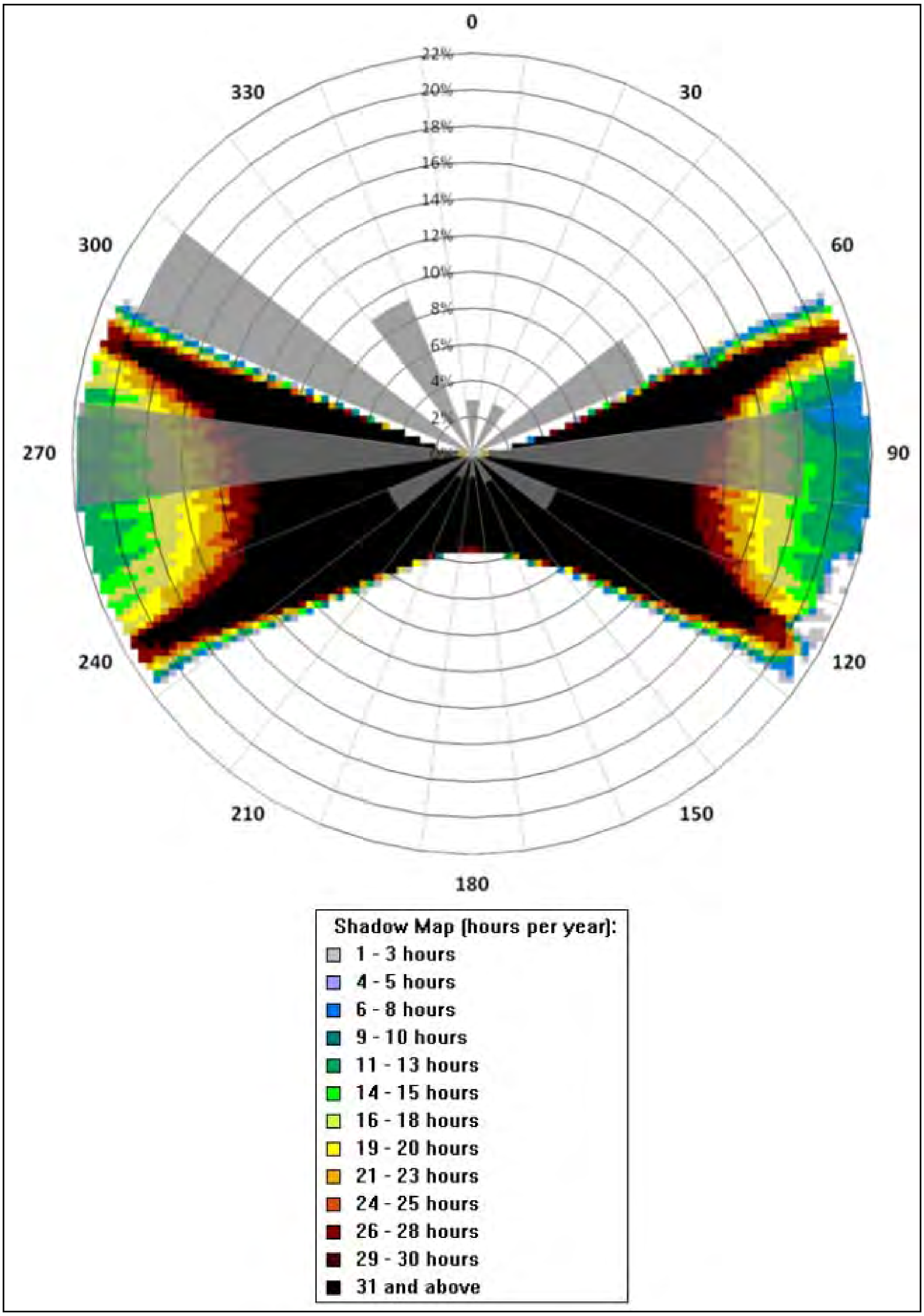

Figure 2. Indicative shadow flicker map showing modelled hours of shadow flicker per year and wind direction frequency distribution.

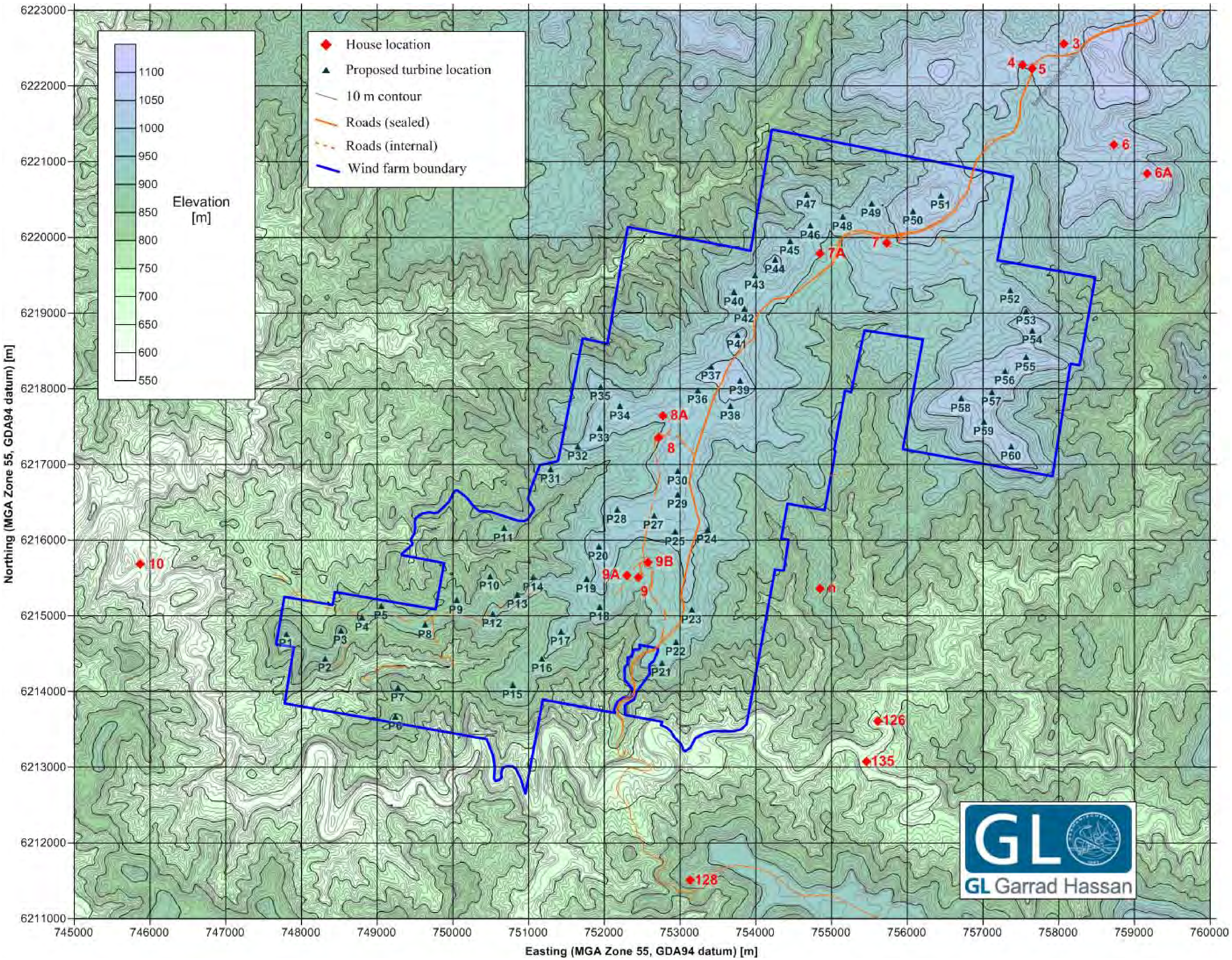

Figure 3. Map of the proposed Paling Yards Wind Farm layout, showing the terrain and house locations.

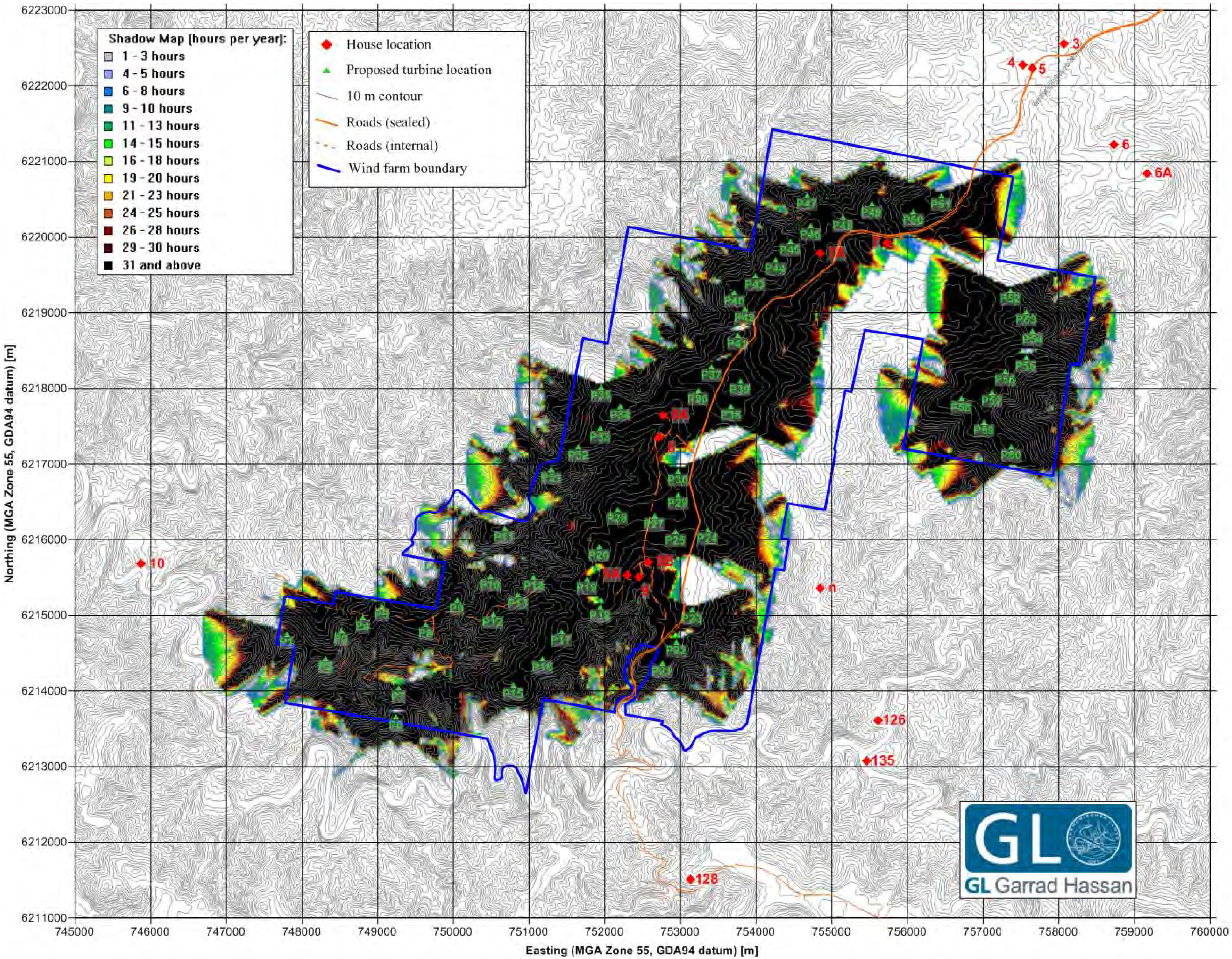

Figure 4. Map of proposed Paling Yards Wind Farm showing turbines, house locations and theoretical shadow flicker duration at 2 m for Turbine Option 1.
(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

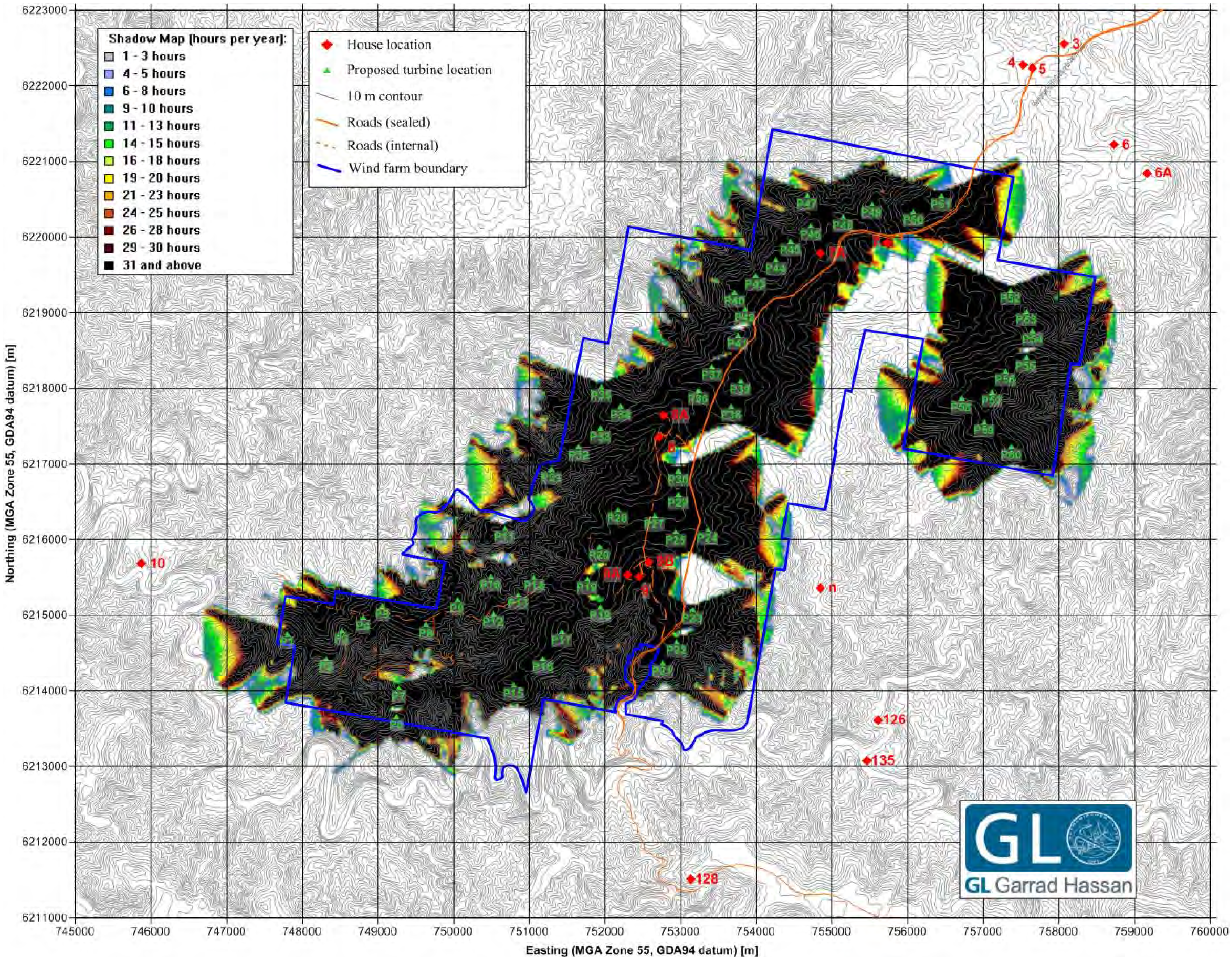

Figure 5. Map of proposed Paling Yards Wind Farm showing turbines, house locations and theoretical shadow flicker duration at 6 m for Turbine Option 1.
(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

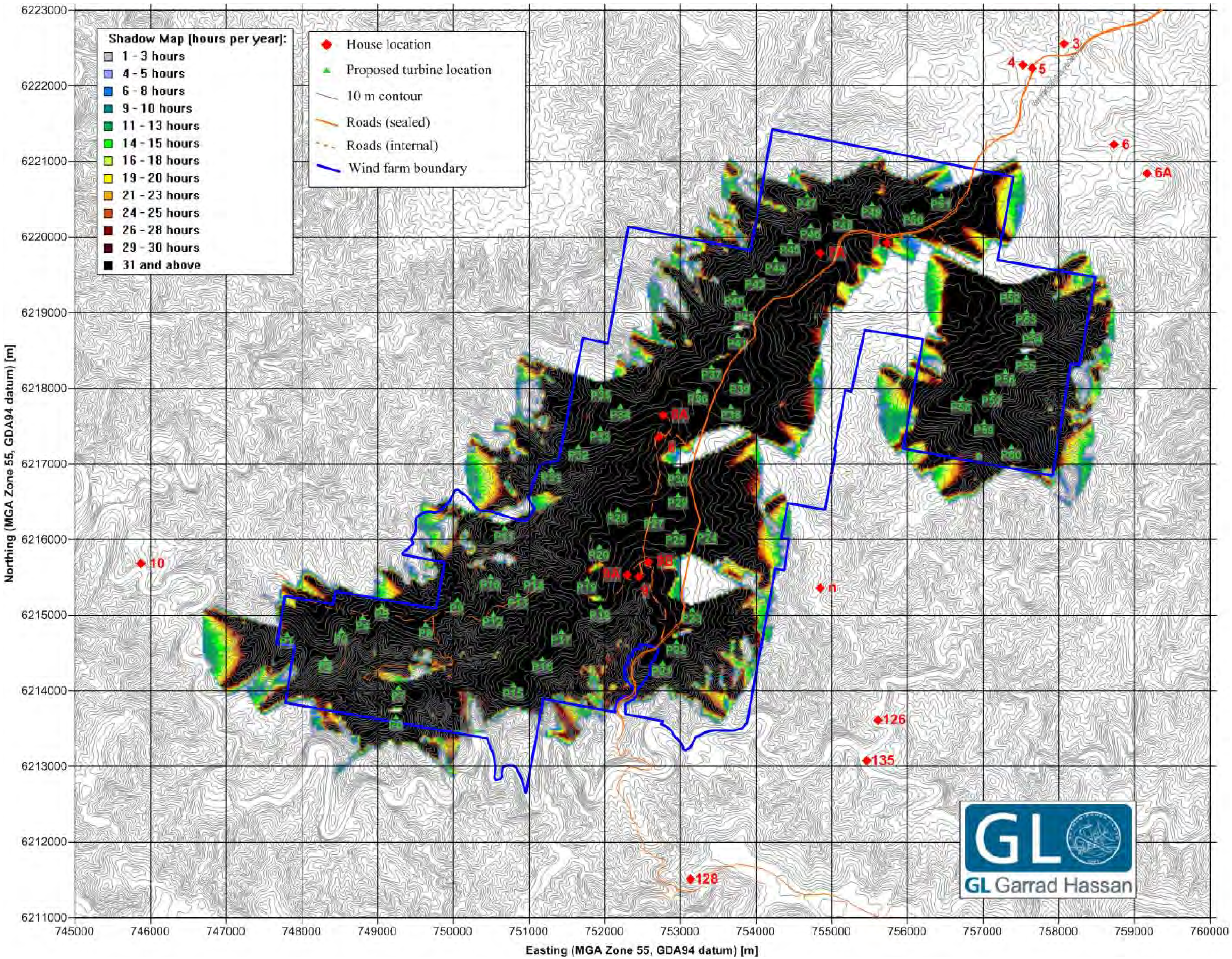

Figure 6. Map of proposed Paling Yards Wind Farm showing turbines, house locations and theoretical shadow flicker duration at 2 m for Turbine Option 2.
(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

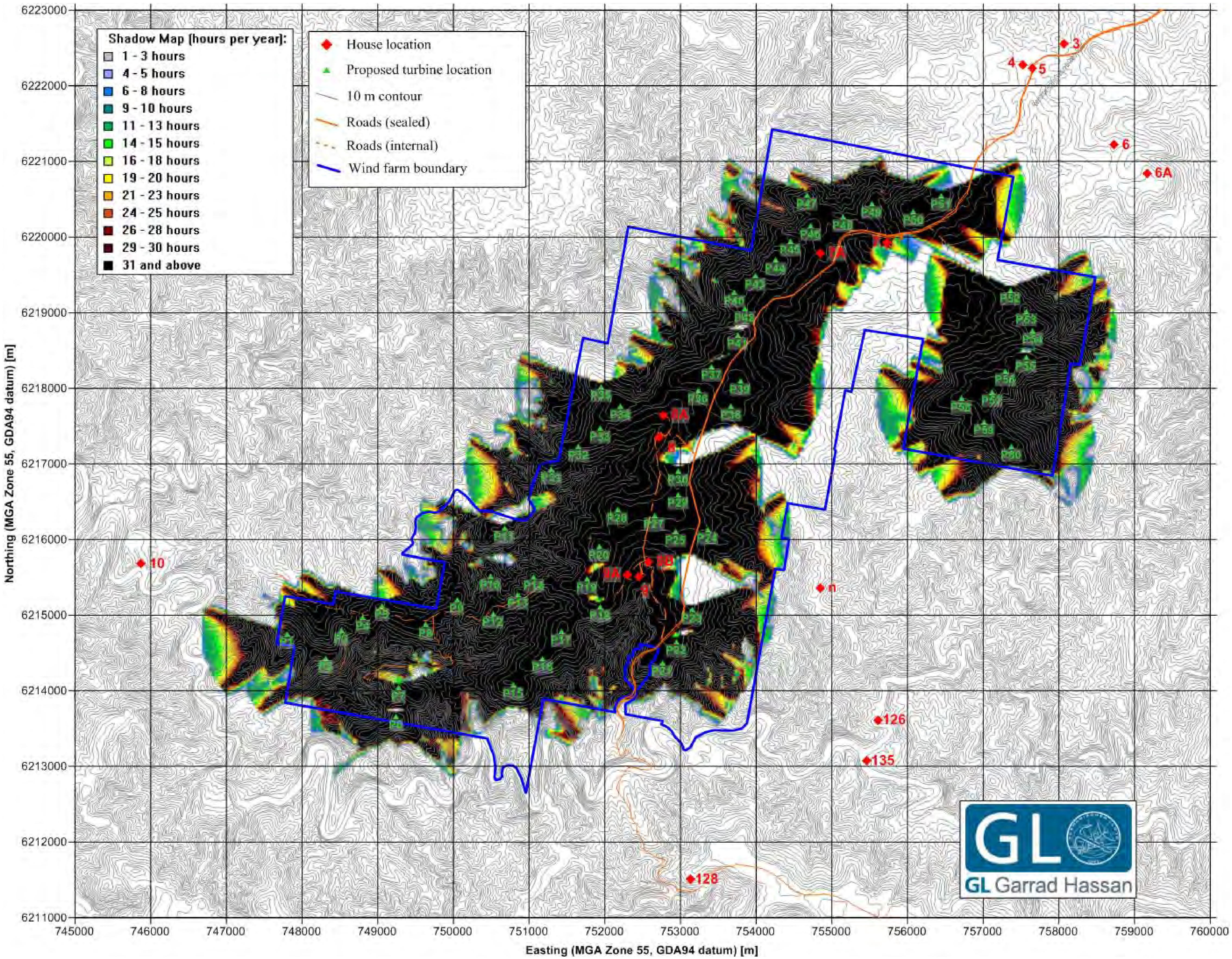

Figure 7. Map of proposed Paling Yards Wind Farm showing turbines, house locations and theoretical shadow flicker duration at 6 m for Turbine Option 2.
(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

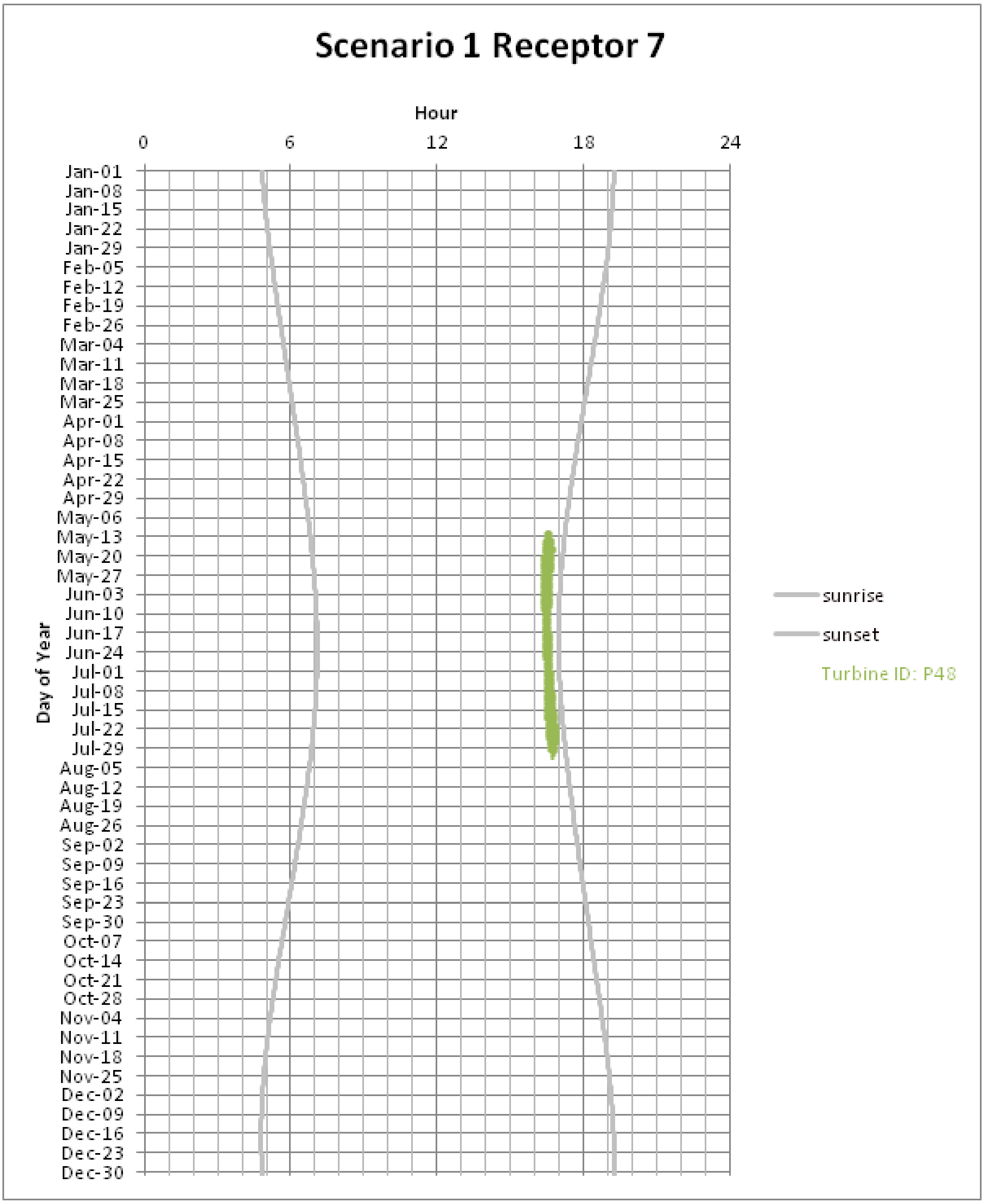

Figure 8 Theoretical time of day Shadow flicker durations at House 7 for turbine Option 1.

(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

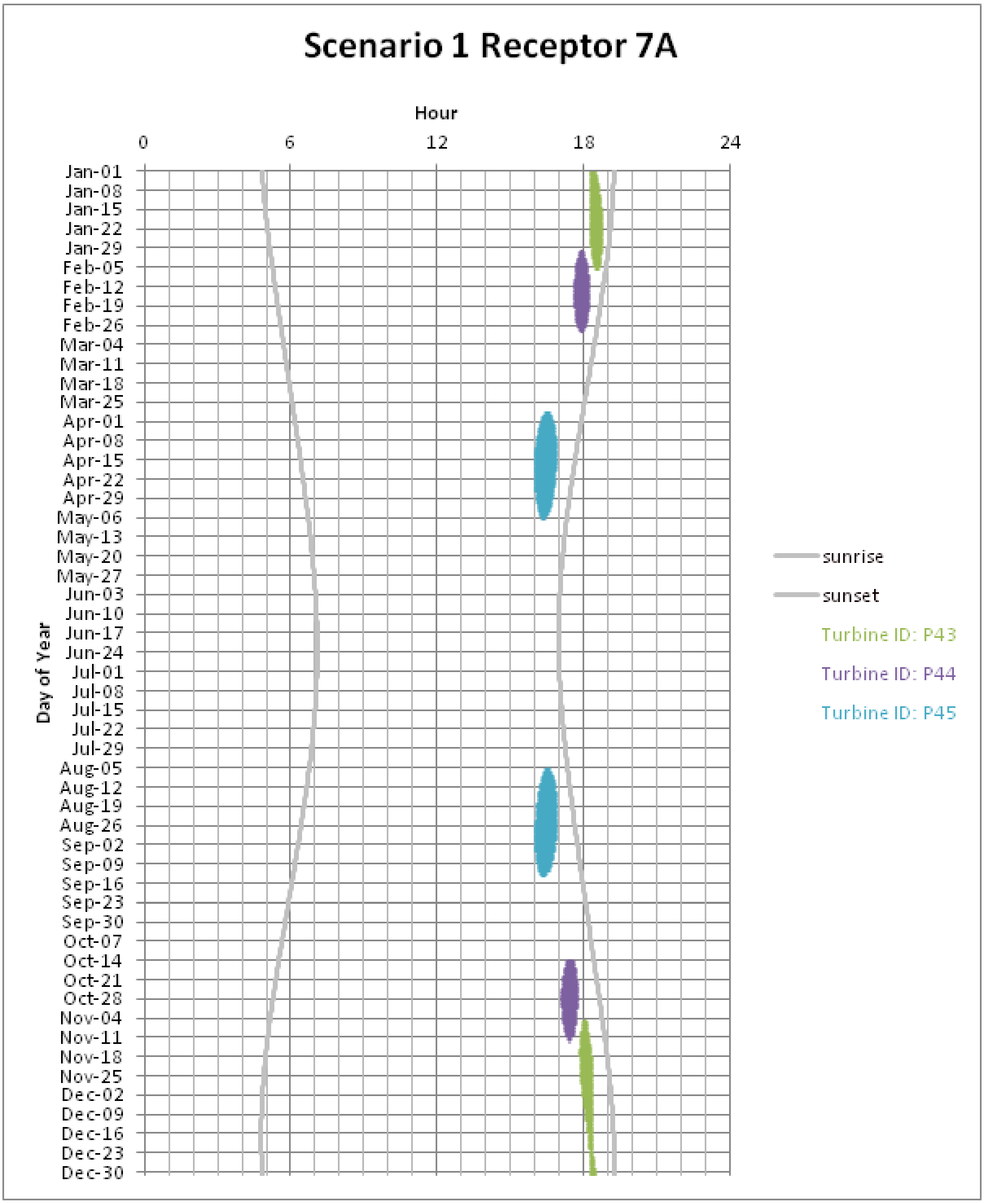

Figure 9 Theoretical time of day Shadow flicker durations at House 7A for turbine Option 1.

(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

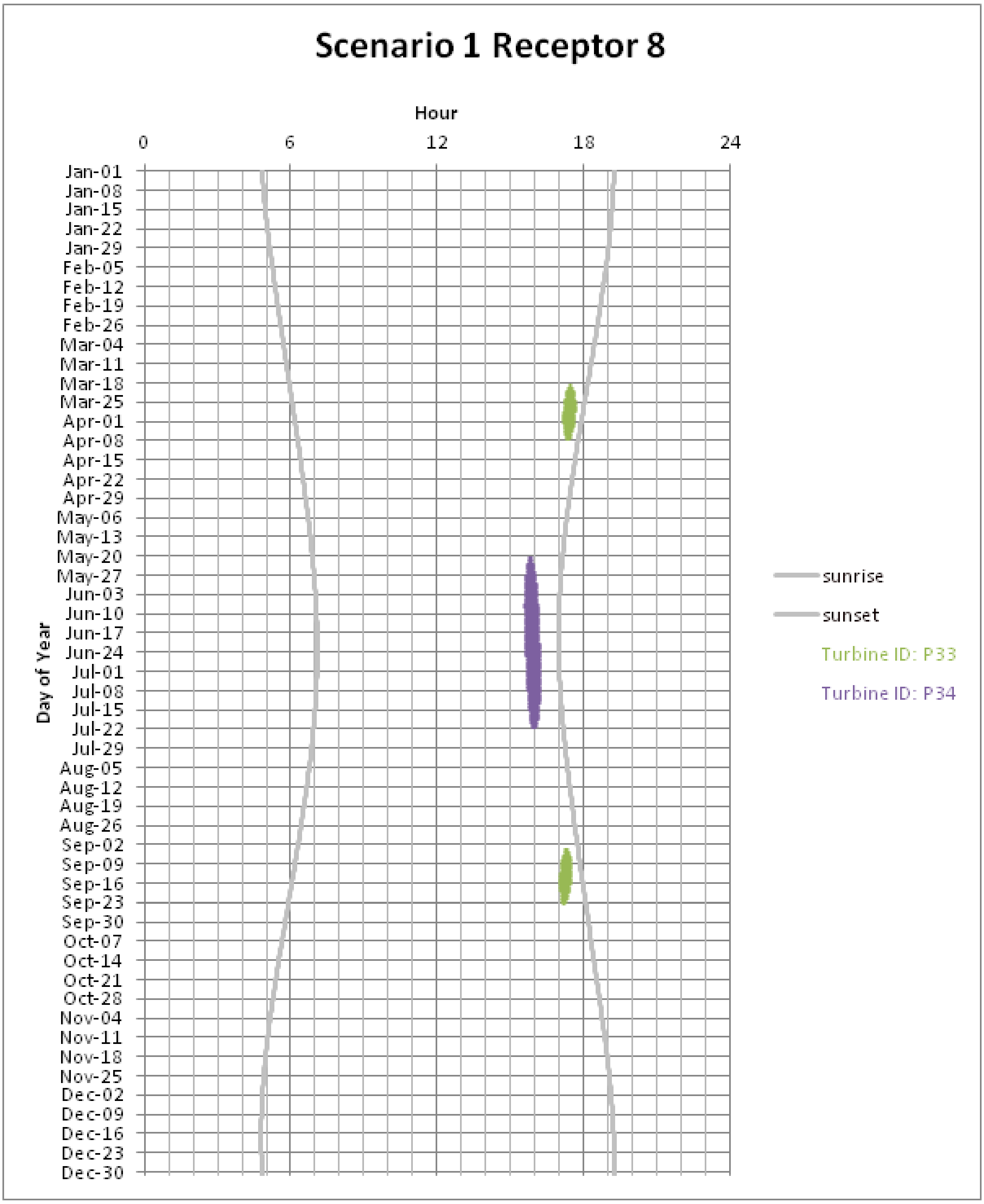

Figure 10 Theoretical time of day Shadow flicker durations at House 8 for turbine Option 1.

(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

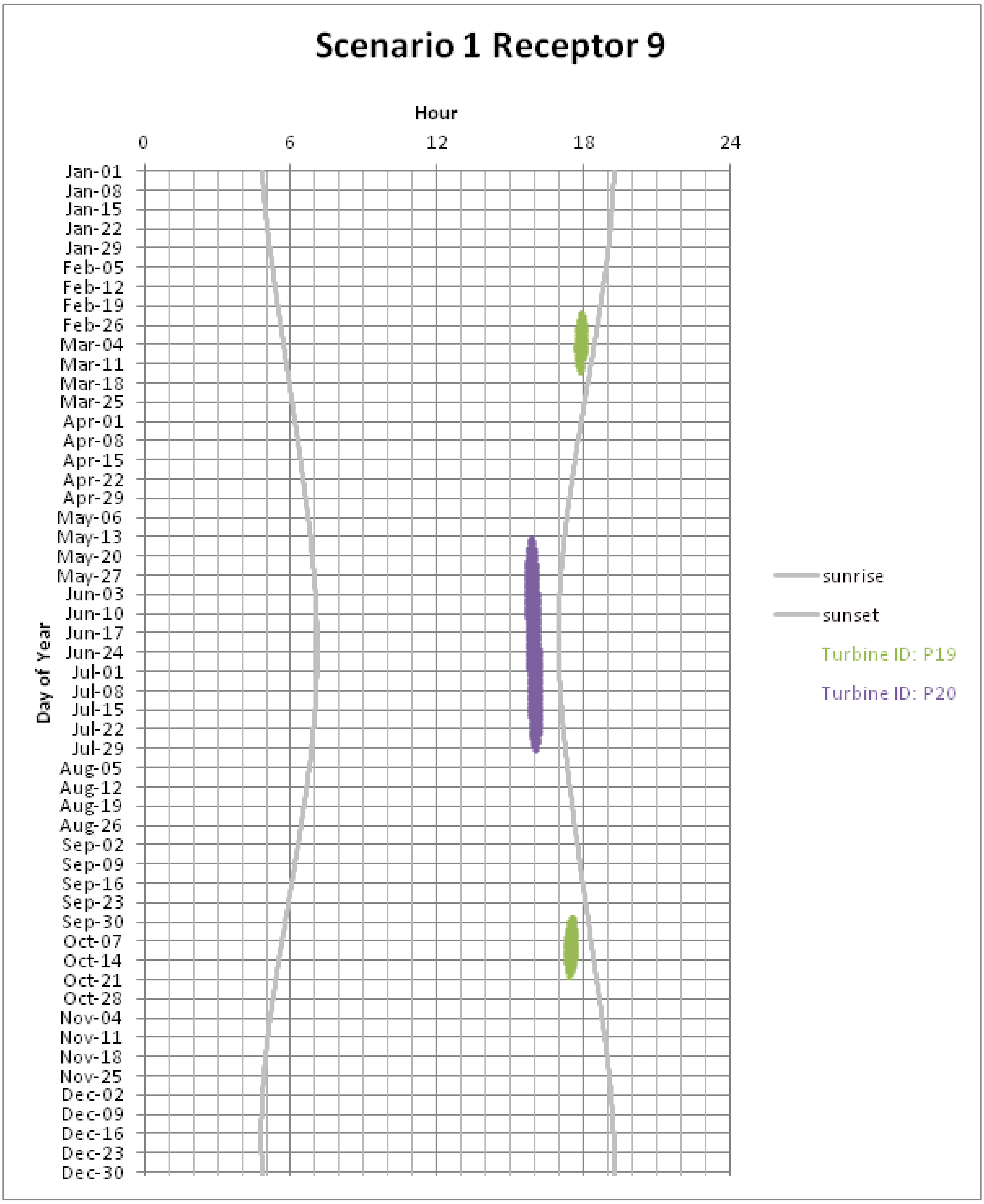

Figure 11 Theoretical time of day Shadow flicker durations at House 9 for turbine Option 1.

(13 turbines with an 100 m rotor diameter and an 80 m hub height, and 46 turbines with an 117 m rotor diameter and a hub height of 91 m)

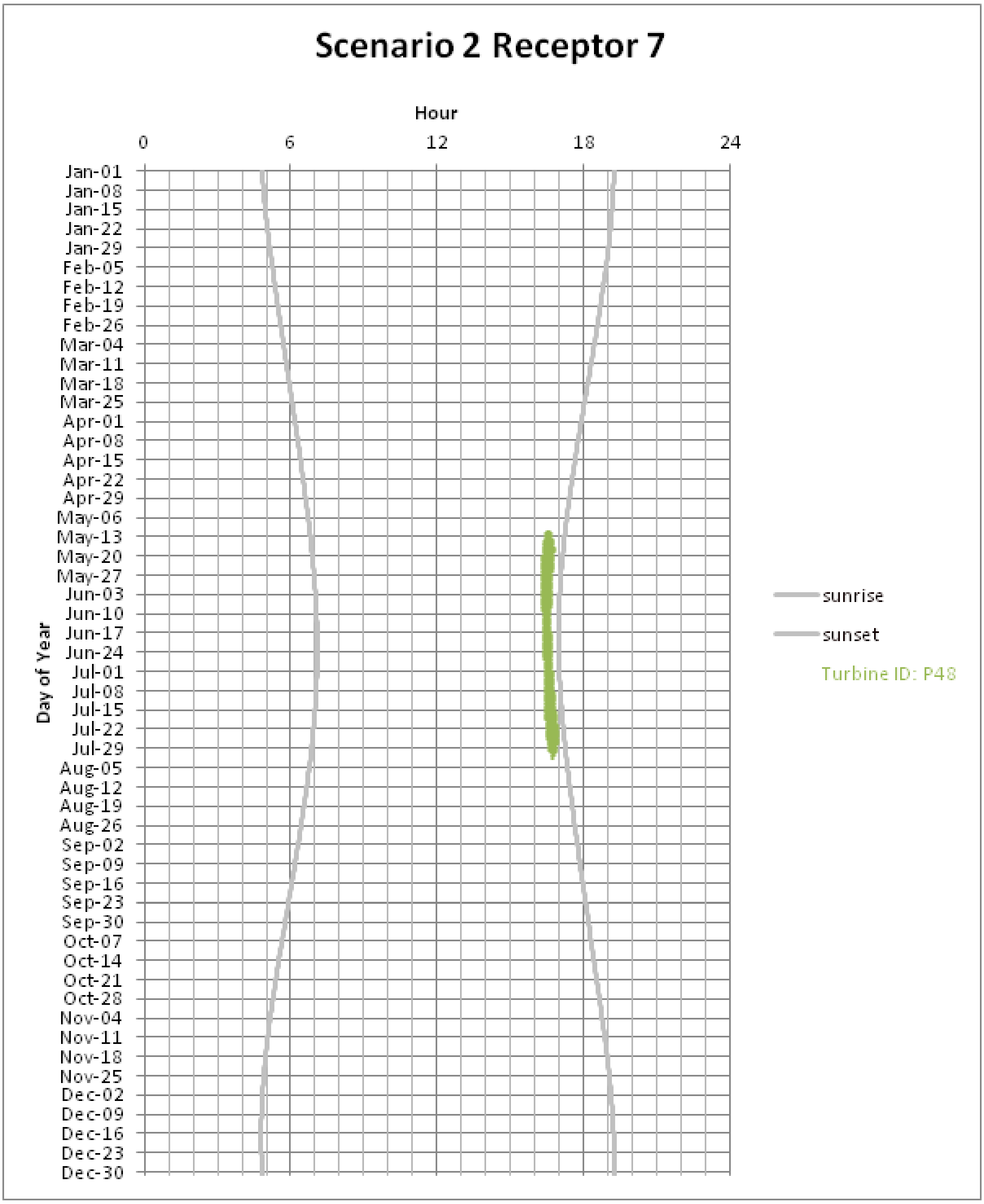

Figure 12 Theoretical time of day Shadow flicker durations at House 7 for turbine Option 2.

(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

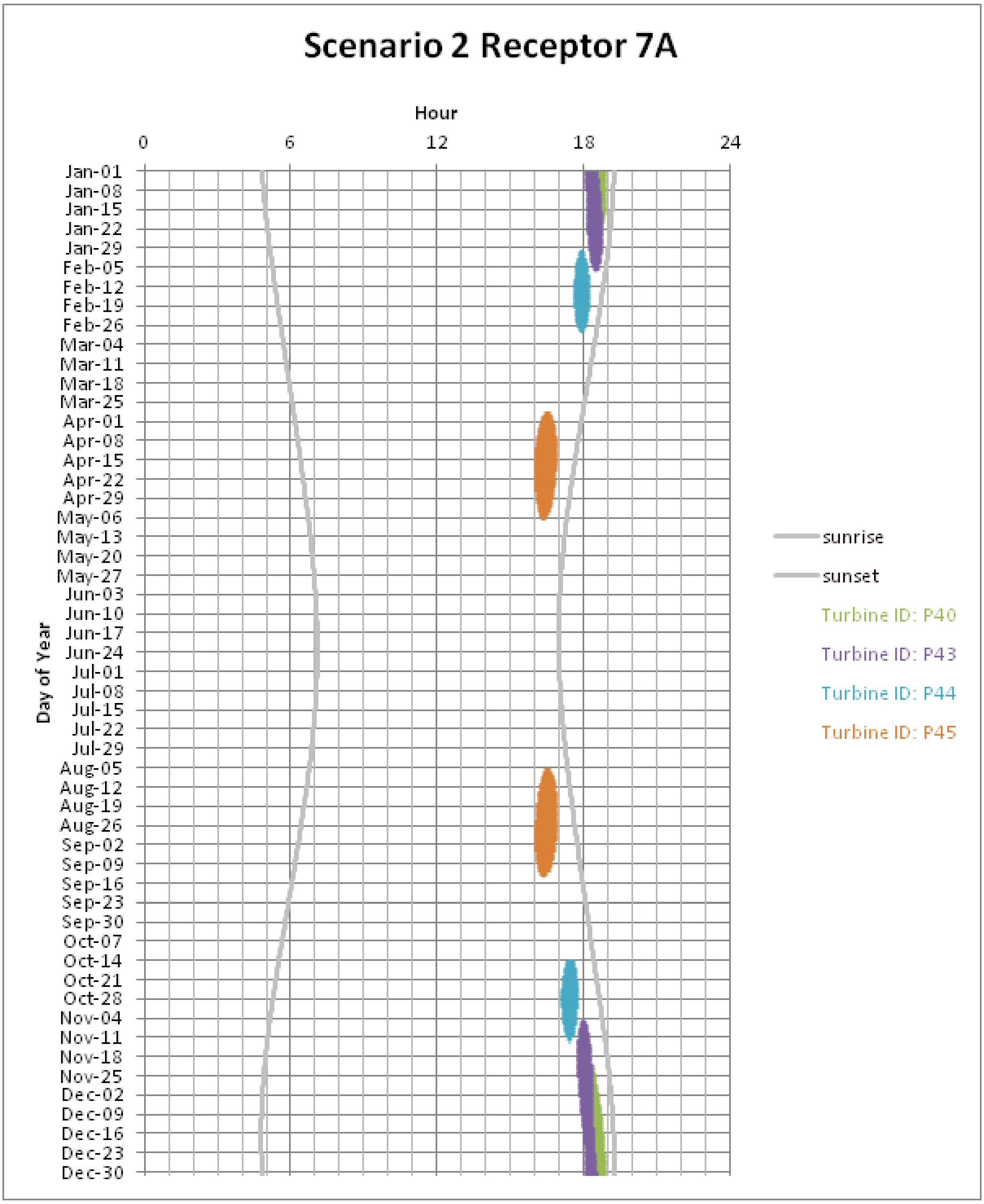

Figure 13 Theoretical time of day Shadow flicker durations at House 7A for turbine Option 2.

(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

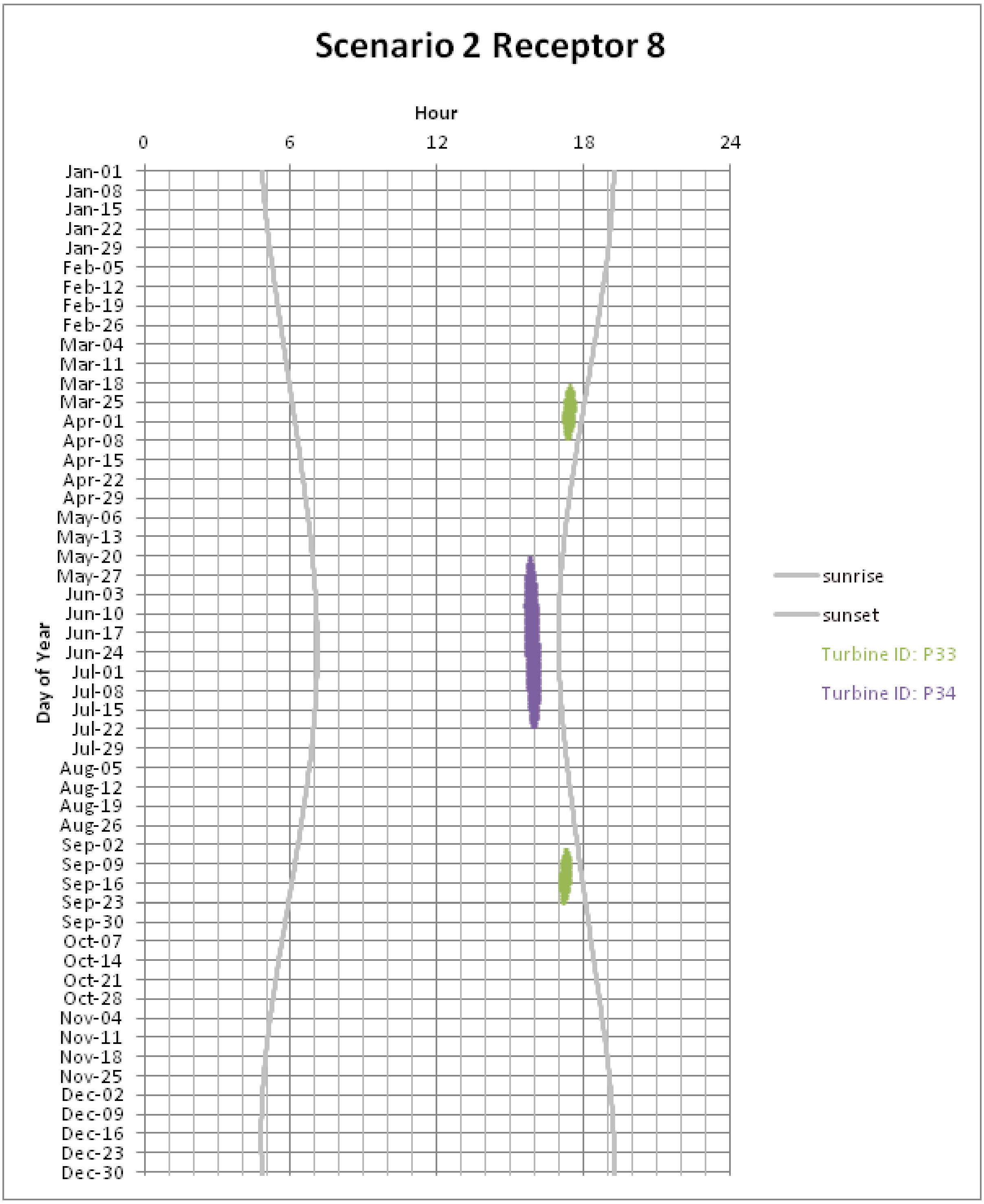

Figure 14 Theoretical time of day Shadow flicker durations at House 8 for turbine Option 2.

(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

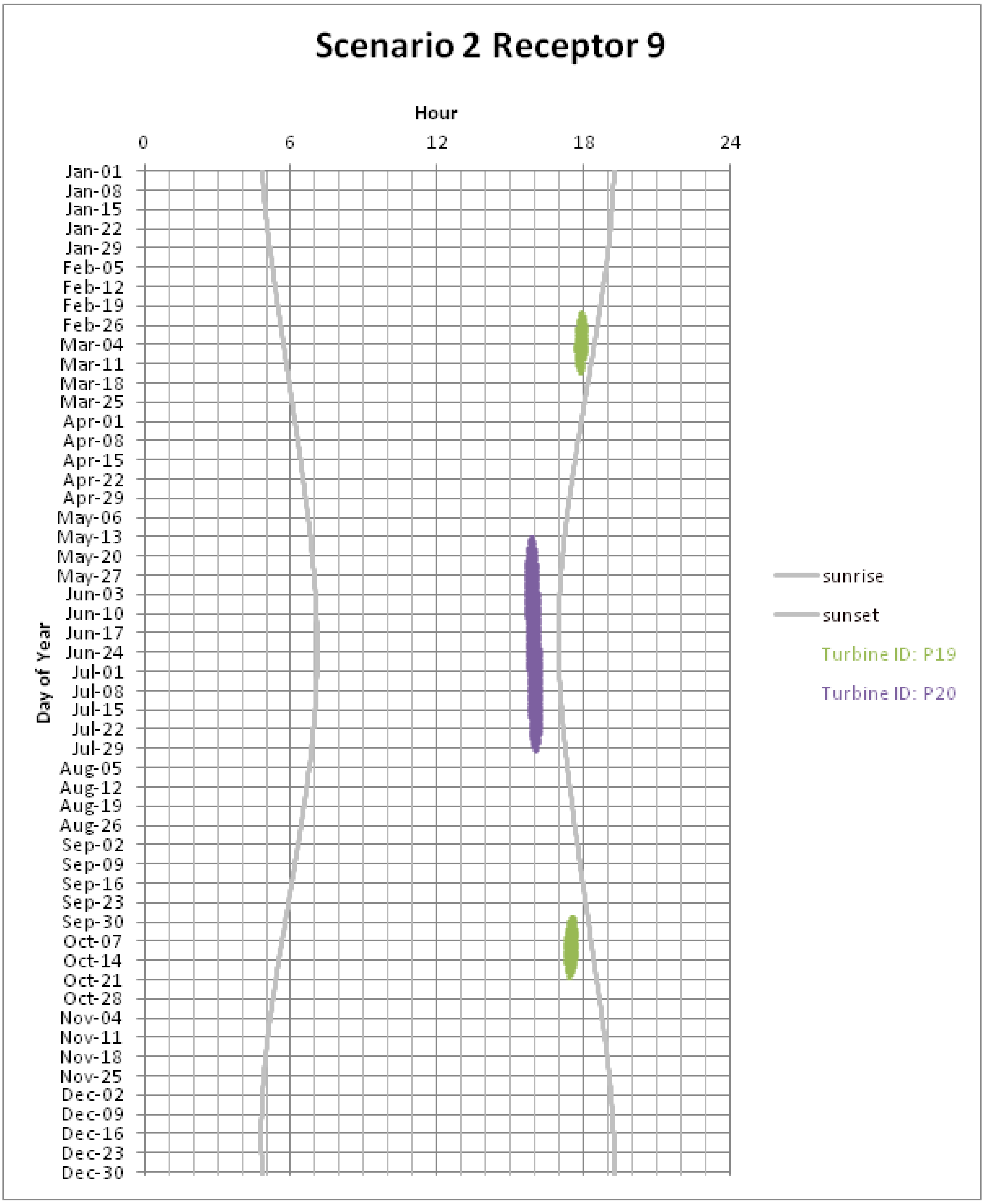

Figure 15 Theoretical time of day Shadow flicker durations at House 9 for turbine Option 2.

(15 turbines with an 100 m rotor diameter and an 80 m hub height, and 44 turbines with an 136 m rotor diameter and a hub height of 107 m)

Appendix B – Civil Aviation Safety Authority Advisory Circular AC139-18(0) July 2007 (Withdrawn)

Australian Government
Civil Aviation Safety Authority

Advisory Circular

AC 139-18(0) SEPTEMBER 2004

OBSTACLE MARKING AND LIGHTING OF WIND FARMS

CONTENTS

1. REFERENCES

- CASR Part 139, Subpart 139.E, and in particular
  - ◊ 139.365 Structures 110 metres or more above ground level.
  - ◊ 139.370 Hazardous objects etc.
- MOS-Part 139 Chapter 7 – Obstacle Restrictions and Limitations.
- MOS-Part 139 Section 8.10 – Obstacle Marking.
- MOS-Part 139 Section 9.4 – Obstacle Lighting.

2. PURPOSE

This Advisory Circular (AC) provides general information and advice on the obstacle marking and lighting of Wind Farms (including single wind turbines), where CASA has determined that the wind farm is, or will be, a hazardous object to aviation.

3. STATUS OF THIS AC

This is the first AC to be issued on this subject.

Advisory Circulars are intended to provide recommendations and guidance to illustrate a means but not necessarily the only means of complying with the Regulations, or to explain certain regulatory requirements by providing interpretative and explanatory material.

Where an AC is referred to in a 'Note' below the regulation, the AC remains as guidance material.

ACs should always be read in conjunction with the referenced regulations

4. GENERAL

4.1 This AC applies specifically to horizontal-axis wind turbines, which are the only type installed, or known to be proposed for installation, in Australia, at the date of issue of this document.

4.2 This AC applies to:

(a) a single wind turbine; or

(b) a group of wind turbines, referred to as a wind farm, which may be spread over a relatively large area.

4.3 The height of a wind turbine is defined to be the maximum height reached by the tip of the turbine blades.

4.4 Australian standards and recommended practices for the marking and lighting of obstacles and objects assessed as being hazardous to aviation, are consistent with international standards and recommended practices as published by the International Civil Aviation Organisation (ICAO) in Annex 14 Volume 1 (Aerodrome Design and Operations). The general requirements are:

(a) marking is used to make objects conspicuous to pilots, by day.

(b) lighting is used to make objects conspicuous to pilots, by night;

(c) lights are located as close as practicable to the top of the objects, and at other locations so as to indicate the general definition and extent of the objects.

4.5 Wind turbines pose a particular practical problem in that their highest point is not a fixed structure, and therefore lights can not be appropriately located. The highest fixed part of the turbine where lights can conveniently be located is the top of the generator housing, sometimes known as the nacelle, and this is typically of the order of 2/3 the maximum height of the turbine.

4.6 ICAO has not yet published standards and recommended practices specifically suited to wind turbines. The advice in this document has been derived by allowing some variations to standards and recommended practices to accommodate the specific practical difficulties associated with wind turbines and wind farms, and taking into consideration the practices of some overseas countries.

5. WIND TURBINES IN THE VICINITY OF AN AERODROME

5.1 CASA strongly discourages the siting of wind turbines in the vicinity of an aerodrome.

5.2 A wind turbine located sufficiently close to an aerodrome so that it penetrates an obstacle limitation surface (OLS) of the aerodrome, is defined by MOS-Part 139 Section 7.1, to be an obstacle.

5.3 If the aerodrome is to be used at night, an obstacle that penetrates an OLS should be lighted, in accordance with MOS-Part 139 Section 9.4. The top lights are required to be arranged so as to at least indicate the points or edges of the object highest above the obstacle limitation surface. For a wind turbine, these lights may be located on a separate supporting structure adjacent to the wind turbine, to overcome the difficulty associated with the highest point of the obstacle being the (moving) blades of the turbine.

> *Note:* *Obstacle limitation surfaces are a complex of imaginary surfaces associated with an aerodrome. They vary depending on number and orientation of runways, and the instrument-approach type of the runway(s). Some surfaces can extend to 15 km from an aerodrome. Aerodrome operators can provide details for their particular aerodrome.*

6. WIND TURBINES WITH A HEIGHT OF 110 m OR MORE

6.1 CASR 139.365 requires a person proposing to construct a building or structure, the top of which will be 110 m or more above ground level, to inform CASA of that intention and the proposed height and location of the proposed building or structure.

6.2 CASA will conduct an aeronautical study to determine if the wind turbine will be a hazardous object to aviation, in accordance with CASR 139.370.

6.3 If, as a result of the aeronautical study CASA finds that a proposed wind turbine will penetrate an OLS of an aerodrome, the proposal will be dealt with in accordance with 5 above.

6.4 The aeronautical study may find that even though the proposed wind turbine will not penetrate any OLS of an aerodrome, it will be a hazardous object to aviation.

6.5 The hazard that an object poses to aviation can be reduced by indicating its presence by appropriate marking and/or lighting.

> *Note:* *The marking and/or lighting does not necessarily reduce operating limitations which may be imposed by an obstacle or hazardous object.*

6.6 The advice, in 7 and 8 below, on marking and lighting of wind turbines, should be suitable for wind turbines that do not penetrate an OLS, in most cases. However, because of the variations in configurations and layout of turbines in wind farms, the aeronautical study may indicate that a variation to that advice would be appropriate for a particular wind farm. In such a case, CASA may offer suggestions for variations to the normal advice provided in 7 and 8 below.

7. MARKING OF WIND TURBINES

7.1 Experience with wind turbines installed to date, indicates that they are sufficiently conspicuous by day, due to their shape, size, and colour.

7.2 Wind turbines that are of basically a single colour, and visually conspicuous against the prevailing background, do not require to be painted in obstacle marking colours and/or patterns.

8. LIGHTING OF WIND TURBINES

8.1 In the case of a single wind turbine:

(a) two flashing red medium intensity obstacle lights should be mounted on top of the generator housing;

(b) the light fixtures should be mounted at a horizontal separation to ensure an unobstructed view of at least one of the lights by a pilot approaching from any direction;

(c) both lights should flash simultaneously; and

(d) the characteristics of the obstacle lights should be in accordance with MOS-Part 139 subsection 9.4.7.

8.2 In the case of a wind farm, sufficient individual wind turbines should be lighted to indicate the extent of the group of turbines:

(a) the interval between obstacle lights should not be less than the current extensive object standard of 900 metres, and at a distance that minimises the number of lighted wind turbine generators without diminishing appropriate aviation safety;

(b) in addition, the most prominent (highest for the terrain) turbine(s) should be lighted, if not included amongst the turbines lighted in accordance with (a) above; and

(c) the lighting of individual turbines should be in accordance with 8.1 above.

Note: *There is an overseas proposal that all lighting provided at a wind farm should flash simultaneously. This proposal is still to be validated and accepted. It is suggested that wind farm operators bear in mind that the simultaneous flashing of all lights at a wind farm could become accepted practice some time in the future.*

8.3 On completion of the project, CASA may choose to conduct a flight check to determine the adequacy of the obstacle lighting. This may result in a change (either more or fewer) to the number of obstacle lights required, to ensure the development remains conspicuous.

8.4 Where obstacle lighting is to be provided, it is recommended a monitoring, reporting and maintenance procedure be put in place to ensure outages are reported through the NOTAM system and repairs are implemented.

Bill McIntyre
Executive Manager
Aviation Safety Standards

Appendix C – Draft NSW Planning Guidelines: Wind Farms. Meeting Assessment requirements, Landscape and visual amenity

Appendix A: Meeting assessment requirements

Where a wind farm application is State significant development (SSD), specific assessment requirements are specified in Director General's Requirements (DGRs). This appendix includes information to assist applicants with assessing particular impacts from a wind farm proposal in cases where DGRs require particular impacts to be assessed. The assessment must be detailed in the proponent's EIS.

Landscape and visual amenity

The visual impact of a wind farm depends on the extent of the change to the landscape caused by the development, taking into account:

- the visibility of the development
- the locations and distances from which the development can be viewed
- landscape values and their significance
- the sensitivity of the landscape features to change

The visual impact of the development relates to:

- the number, height, scale, spacing, colour and surface reflectivity of the wind turbines
- the quantity and characteristics of lighting, including aviation obstacle lighting (subject to CASA requirements and advice)
- potential for visual clutter caused by turbine layout and ability to view through a cluster or array (visually well ordered series) of turbines in an orderly manner
- the removal or planting of vegetation
- the location and scale of other buildings and works including transmission lines and associated access roads
- proximity to sensitive areas
- proximity to an existing or proposed wind farm, having regard to cumulative visual effects.

The features of the landscape include:

- the topography of the land
- the amount and type of vegetation
- natural features such as waterways, cliffs, escarpments, hills, gullies and valleys
- visual boundaries between major landscape types
- the type, pattern, built form, scale and character of development, including roads and walking tracks
- flora and fauna habitat
- cultural heritage sites
- the skyline

Assessing landscape and visual amenity impacts

DGRs typically require a comprehensive assessment of the impact of a proposed wind farm on the landscape character, landscape values, visual amenity and any scenic or significant vistas to be undertaken. There should be a particular focus on any neighbours' houses within 2 km of a proposed wind turbine that do not host the wind farm facility. The assessment should include:

- a description of the assessment methodology and a clear justification of it including discrete justification of the methodology for assessing impacts at neighbours' houses within 2 km of a proposed wind turbine
- a description of all relevant components of the project, including turbine heights and layout – where micro-siting or a range of turbines is proposed, the assessment should be based on the 'worst case' layout and turbine height
- a description of the landscape including key features

- a description of the visibility of the development
- photomontages of the project and associated transmission lines taken from:
  - potentially affected residences (including approved but not yet developed dwellings or subdivisions with residential rights) within 2 km of a proposed wind turbine or other associated infrastructure (note that the number of photomontages may be reduced in less sensitive landscapes such as industrial areas),
  - urban settlements, and
  - significant public view points including roads, lookout points and walkways.
- identification of the zone of visual influence of the wind farm (no less than 10km)
- a description of the significance of the landscape values and character in a local and regional context
- a description of community and stakeholder values of the local and regional visual amenity and quality and perceptions of the project based on surveys and consultation.
- assessment of cumulative impacts on the landscape and any cumulative visual impacts from transmission line infrastructure and any surrounding approved or operational wind farms in the locality

Mitigating landscape and visual amenity impacts

The feasibility, effectiveness and reliability of proposed mitigation measures should be assessed. The extent of any residual impacts left over after mitigation measures have been implemented should also be described. Examples of mitigation measure that proponents can use to reduce the visual impact of a proposed wind farm include:

- where possible, locate turbines:
  - away from areas with high scenic values
  - away from areas with high visibility from local residents
- select turbines that :
  - look the same, have the same height and rotate the same way
  - are off-white or grey colouring
- minimise the removal of vegetation
- plant vegetation to provide a visual screen
- reduce impacts of night and obstacle lighting by
  - limiting lighting on towers to that required for safe operation and aviation safety and
  - use of lighting design which minimises glare
- underground electricity wires where practicable
- use alternative transmission line pole designs to minimise visual impact.

Appendix D – Andrew Homewood, curriculum vitae

GREEN BEAN DESIGN
landscape architects

Areas of Expertise

Landscape and Visual Impact Assessment
Landscape Design and Contract Documentation
Independent Verification & Landscape Management

Education

University of Sheffield, Graduate Diploma Landscape Management, 1996
University of Sheffield, BSc (Dual Hons), Landscape Architecture & Archaeology, 1995
Writtle College, National Diploma Amenity Horticulture, 1989

Registration & Memberships

Registered Landscape Architect , Australian Institute Landscape Architects (AILA)
Member Environmental Institute Australia and New Zealand (MEIANZ)
Member of the Landscape Research Group (UK)

Selected Project Experience

Landscape and Visual Impact Assessment

Wind and Solar Farms

BP Moree Solar Power Station, Status: Approved

LVIA for the Solar Flagship Moree Solar Farm site in northern New South Wales.

Boco Rock Wind Farm EA, (Wind Prospect CWP Pty Ltd) Status: Approved

LVIA for the proposed construction of up to 125 wind turbine generators in the NSW Southern Tablelands Monaro sub region, including coordination for supply of photomontage, ZVI and flicker assessment.

Sapphire Wind Farm EA (Wind Prospect CWP Pty Ltd) Status: Approved

LVIA for the proposed construction of up to 174 wind turbine generators in the NSW New England region, including coordination for supply of photomontage, ZVI and flicker assessment.

Silverton Wind Farm EA Stages 1 & 2 (Epuron Pty Ltd) Status: Approved

LVIA for a 1000MW wind farm at Silverton in the Unincorporated Area of western NSW, for up to 600 wind turbines including a 25km length of 220kV transmission line between the wind farm and Broken Hill.

Conroy's Gap Wind Farm (Epuron Pty Ltd) Status: Approved

LVIA for a DA modification for additional wind turbines to an approved development located in the southern highlands NSW.

Bango Wind Farm (Wind Prospect CWP Pty Ltd)

LVIA for the proposed construction of up to 100 wind turbines located in the southern highlands NSW.

Liverpool Range Wind Farm Stage 1 (Epuron Pty Ltd)

LVIA for the proposed construction of up to 200 wind turbines located in the Warrumbungle and Upper Hunter Shire Councils approximately 370 km north of Sydney, and a 60 km length of 330 kV line connecting to the Ulan mine site.

Rye Park Wind Farm, (Epuron Pty Ltd)

LVIA for the proposed construction of up to 120 wind turbines adjoining multiple wind farm sites in the New South Wales southern highlands.

Deepwater Wind Farm (Epuron Pty Ltd)

LVIA for the proposed construction of up to 7 wind turbines at Deepwater in north NSW.

Port Kembla Wind Farm (Epuron Pty Ltd)

LVIA for the proposed construction of up to 7 wind turbines within the Port Kembla industrial facility at Wollongong.

Eden Wind Farm, (Epuron Pty Ltd)

LVIA for the proposed construction of up to 7 wind turbines within the SEFE woodchip facility on the south coast of New South Wales.

Paling Yards Wind Farm EA, (Union Fenosa Pty Ltd)

LVIA for the proposed construction of up to 59 wind turbines including night lighting, cumulative impact assessment, detailed field assessment for shadow flicker and preparation of photomontages.

Collector Wind Farm EA, (APP/RATCH)

LVIA for the proposed construction of up to 68 wind turbines adjoining the operation Cullerin wind farm project including a detailed cumulative impact assessment.

Willatook Wind Farm EES Referral, (Wind Prospect WA Pty Ltd)

Preliminary LVIA for the proposed construction of up to 190 wind turbines within Moyne Shire Council (Victoria) including a detailed cumulative impact assessment, photomontage location selection and community consultation.

Birrema Wind Farm EA (Epuron Pty Ltd)

LVIA for the proposed construction of up to 75 wind turbines adjoining the proposed Yass Valley wind farm project development including a detailed cumulative impact assessment, photomontage location selection and community consultation.

White Rock Wind Farm EA, (Epuron Pty Ltd)

LVIA for the proposed construction of up to 100 wind turbines adjoining the proposed Sapphire and approved Glen Innes wind farm projects including a detailed cumulative impact assessment, photomontage location selection and community consultation.

Crookwell 3 Wind Farm EA, (Union Fenosa Wind Australia)

LVIA for the proposed construction of up to 35 wind turbines adjoining the approved Crookwell 2 wind farm development including a detailed cumulative impact and night time lighting assessment.

Electrical Infrastructure

22kV transmission line (Country Energy)

LVIA for a short section of electrical distribution line through central New South Wales.

Wagga North 132kV substation (TransGrid)

LVIA for a proposed 132/66kV substation and installation of transmission line connections at Wagga Wagga New South Wales.

Lismore to Dumaresq 330kV transmission line (TransGrid)

LVIA for a proposed 330kV transmission line through northern New South Wales.

Manildra to Parkes 132kV transmission line (TransGrid)

LVIA for a proposed 132kV transmission line through central New South Wales.

Mount Macquarie Communication Tower (TransGrid)

LVIA and preparation of visual simulations for proposed 80m high microwave communication tower in rural New South Wales, adjacent to the Blayney Wind Farm.

Broken Hill to Red Cliffs 220kV transmission line duplication (Epuron Pty Ltd)

LVIA for approximately 300km of 220kV transmission line duplication for the Silverton Wind Farm Concept Approval application.

Molong to Manildra 132kV transmission line (TransGrid)

View catchment mapping and visual assessment for a 28 km section of 132kV transmission line through rural landscape in central western New South Wales.

Power Generation	**Dalton Gas fired Power Plant (AGL Energy)** LVIA for gas turbine peaking power station, valve station and communication tower in rural NSW. Preparation of photomontage and 3D modelling. **Herons Creek Peaking Power Station (International Power)** LVIA for 120MW distillate-fired peaking power station in rural landscape setting. Visual assessment included preparation of visual simulations to model each of the three 40MW generating units in the existing landscape. **Parkes Peaking Power Station (International Power)** LVIA for 120MW distillate-fired peaking power station in central New South Wales, including provision of photomontages. **Buronga Peaking Power Station (International Power)** LVIA for 120MW distillate-fired peaking power station in far west New South Wales. **Leafs Gully Peaking Power Plant (AGL Energy Pty Ltd)** LVIA and landscape master plan for gas turbine peaking power station in south-west Sydney. **Bio Energy Project (SEFE)** LVIA for a 5MW bio fuel power plant located on the south of Two Fold Bay, Eden.
Professional History	Green Bean Design, Principal Landscape Architect 2006 - URS Australia Pty Ltd, Practice Leader Landscape Architecture 2005 - 2006 URS Australia Pty Ltd, Associate Landscape Architect 2003-2005 URS Australia Pty Ltd, Senior Landscape Architect, 2002 - 2003 URS Australia Pty Ltd, Landscape Planner, 2001-2002 URS, Contract Landscape Architect, 2000-2001 Blacktown City Council, Contract Landscape Planner, 2000-2001 Knox & Partners Pty Ltd, Landscape Architect, 1996-2000 Brown & Associates, Landscape Architect, 1996 Philip Parker & Associates, Graduate Landscape Architect, 1994-1995 Rendel & Branch, Landscape Assistant, 1989-1991 National Trust, Horticulturalist, 1987-1988 English Nature, Species Protection Warden, 1985-1986 Essex Wildlife Trust, Botanist, 1984-1985 Royal Society for the Protection of Birds, Voluntary Warden, 1983-1984