Shadow Flicker Assessment Summary

SECTION 12

12.1 Introduction

Due to their height, wind turbines can cast shadows on surrounding areas at a significant distance from the base of the wind turbine tower. Coupled with this, the moving blades create moving shadows. When viewed from a stationary position, the moving shadows appear as a flicker giving rise to the phenomenon of 'shadow flicker'. When the sun is low in the sky the length of the shadows increases, increasing the shadow flicker affected area around the wind turbine.

A shadow flicker assessment has been prepared by GL-GH to determine and illustrate the potential impact of shadow flicker on surrounding view locations. The detailed shadow flicker assessment for the Crookwell 3 wind farm is included at **Appendix A**.

A shadow flicker assessment may over estimate the actual number of annual hours of shadow flicker at a particular location due to a number of reasons including:

- The probability that the wind turbines will not face into or away from the sun all of the time;
- The occurrence of cloud cover;
- The amount of particulate matter in the atmosphere (moisture, dust, smoke etc…) which may diffuse sunlight;
- The presence of vegetation; and
- Periods where the wind turbine may not be in operation due to low winds, or high winds or for operational or maintenance reasons.

12.2 Residents

As there are no guidelines by which to assess the impact of shadow flicker in New South Wales, the shadow flicker assessment prepared by GL-GH has adopted the Victorian Planning Guidelines which state:

"*The shadow flicker experienced at any dwelling in the surrounding area must not exceed 30 hours per year as a result of the operation of the wind energy facility*".

The results of the shadow flicker assessment for the Crookwell 3 wind farm determined that four residential view locations may be subject to some levels of shadow flicker and include:

- House ID 18, Wollondilly (associated residence);
- House ID 79, Leeston (associated residence);
- House ID66, Little Vale (non associated residence); and
- House ID 63, Rocky Corner (non associated residence).

The Leeston residence that adjoins the Crookwell 3 East site has been determined as the only residence that may be subject to levels of shadow flicker in excess of 30 hours, and is an associated landowner. A summary of the GL-GH shadow flicker results are outlined in the **Table 25** below:

Table 25- Flicker Assessment Summary for the Crookwell 3 wind farm layout

			Theoretical				Predicted Actual[3]	
House ID	Easting[1] [m]	Northing[1] [m]	At Dwelling [hr/yr]		Max Within 50m of Dwelling[2] [hr/yr]		Max Within 50m of Dwelling[2] [hr/yr]	
			At 2 m	At 6 m	At 2 m	At 6 m	At 2 m	At 6 m
Limit			30	30	30	30	10	10
18	736232	6171276	0	0	28	28	10	10
63	741181	6173622	0	0	13	13	4	4
66	743524	6174343	0	0	9	12	3	4
79	740830	6174323	28	32	36	38	11	12

[1] MGA Zone 54 (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

The Leeston residence is located amongst mature tree plantings which screen the majority of views from the residence toward the Crookwell 3 East wind turbines. As there are likely to be limited views toward wind turbines from the residence, it is anticipated that Leeston will not experience the level of shadow flicker predicted in the assessment (which may over estimate the actual number of annual hours of shadow flicker at a particular location for the reasons outlined above).

None of the surrounding residential view locations were determined to have the potential to exceed the maximum theoretical duration of shadow flicker of greater than 30 hours per year for the Crookwell 3 South site.

The 'predicted actual' in **Table 25** combines the probability of shadow flicker, taking into account the occurrence of various wind directions, rather than assuming the worse case assumption of the turbine always facing the sun.

12.3 Photosensitive Epilepsy

The Canadian Epilepsy Alliance (http://www.epilepsymatters.com) defines photosensitivity as '*a sensitivity to flashing or flickering lights, usually of high intensity, which are pulsating in a regular pattern – and people with photosensitive epilepsy can be triggered into seizures by them'*. Both the Canadian Epilepsy Alliance and Epilepsy Action Australia (http://www.epilepsy.org.au) estimate that less than 5% of people with epilepsy are photosensitive.

Epileptic seizures caused by photosensitive epilepsy may be triggered by a range of electronic devices including material broadcast by televisions, computer screens or strobing and flashing lights in nightclubs. Seizures may also be triggered by natural light shining off water, through tree leaves or by flickering caused by travelling past railings. Not all flashing or flickering light will trigger a seizure in people with photosensitive epilepsy, and the potential to trigger a seizure may also be dependent on the frequency of flashing or flicker, and the duration and intensity of light.

Epilepsy Action Australia suggest that the frequency of flashing or flickering light most likely to trigger seizures occurs between 8 to 30Hz (or flashes/flickers per second), although this may vary between individuals. It also suggests that 96% of people with photosensitive epilepsy are sensitive to flicker between 15 to 20Hz.

The majority of three bladed wind turbines are unlikely to create a flicker frequency greater than 1Hz (or 1 flicker per second). The flicker frequency for a three blade wind turbine can be calculated by multiplying the hub rotation frequency (in revolutions per second) by the number of blades. As the maximum rotational speed for the Crookwell 3 wind turbines would be around 20 revolutions per minute (rpm), the hub rotation frequency would be 20rpm divided by 60 seconds resulting in 0.3 revolutions per second. Multiplying 0.3 revolutions per second by three blades equals around 1Hz (or 1 flicker per second).

Given the low flicker frequency associated with the Crookwell 3 wind turbines, which falls below the range suggested by Epilepsy Action Australia as a potential trigger for photosensitive epileptic seizures, it is unlikely that the Crookwell 3 wind turbines would present a risk to people with photosensitive epilepsy.

12.4 Motorists

Motorists can experience shadow flicker sensations whilst driving as a result of shadows cast on the road from roadside or overhead objects such as trees, poles or buildings. Under certain conditions the sensation of shadow flicker may cause annoyance and may impact on a driver's ability to operate a motor vehicle safely.

The photograph in **Plate 7** illustrates a typical situation where shadow flicker may be experienced whilst driving along a road where trees cast shadows.

Plate 7. *Potential shadow flicker created by trees filtering sunlight across road.*

There are no specific guidelines to address the potential impact of shadow flicker on motorists cast by wind turbines across roads, although there are lighting standards that can be applied to minimise the adverse effects of flicker caused by roadside or overhead objects. These standards include AS 1158:5:2007 (Lighting for roads and public spaces – Part 5: Tunnels and underpasses), section 3.3.8 and CIE 88:2004 (Guide for lighting of roads tunnels and underpasses, 2nd ed.), section 6.14. The standards suggest that the flicker effect will be noticeable and possibly cause annoyance between 2.5 and 15Hz (2.5 to 15 flickers per second), and that a flicker effect between 4 and 11Hz should be avoided for longer than 20 seconds.

As the potential flicker frequency for the Crookwell 3 wind turbines is likely to be around 1Hz, it is unlikely that the flicker effect will cause annoyance or impact on a driver's ability to operate a motor vehicle safely whilst travelling along local roads surrounding the wind farm.

12.5 Blade Glint

Glint is a phenomenon that results from the direct reflection of sunlight (also known as specular reflection) from a reflective surface that would be visible when the sun reflects off the surface of the wind turbine at the same angle that a person is viewing the wind turbine surface. Glint may be noticeable for some distance, but usually results in a low impact.

The surfaces of the wind turbines, including the towers and blades, are largely convex, which will tend to result in the divergence of light reflected from the surfaces, rather than convergence toward a particular point. This will reduce the potential for blade glint.

Blade glint can also be further mitigated through the use of matt coatings which, if applied correctly, will generally mitigate potential visual impacts caused by glint.

Night Time Lighting

SECTION 13

13.1 Introduction

The Crookwell 3 wind farm may require obstacle marking and lighting at night time or during periods of reduced visibility. The requirement for lighting would be subject to the advice and endorsement of the Civil Aviation Safety Authority (CASA). CASA is currently undertaking a safety study into the risk to aviation posed by wind farms and may develop a new set of guidelines to replace the Advisory Circular with regard to lighting for wind turbines that was withdrawn by CASA in mid 2008.

However, in order to ensure that a full assessment was undertaken, the Proponent commissioned an independent aviation safety expert to conduct an Aeronautical Impact Assessment, to first determine the risks posed to aviation activities by the Crookwell 3 wind farm. The Aeronautical Impact Assessment expert carried out an Obstacle Lighting Assessment and stipulated a turbine lighting layout which would mitigate risks to aviation.

The lighting design has recommended that a total of 12 turbines be lit at night (3 within the Crookwell 3 South site and 9 within the Crookwell East site). The Crookwell 3 South and East turbines have been lit to identify the perimeter of the wind at longitudinal intervals not greater than 900m.

In accordance with the CASA Advisory Circular two red medium intensity obstacle lights were required on specified turbines at a distance not exceeding 900m and all lights were to flash synchronously. To minimise visual impact some shielding of the obstacle lights below the horizontal plane was permitted.

Lighting for aviation safety may also be required prior to and during the construction period, including lighting for large equipment such as cranes.

Potential visual impacts associated with obstacle marking and lighting at night time have not been extensively researched or tested in New South Wales, although some site investigations have been carried out at existing wind farms in Victoria. Investigations have generally concluded that although night time lighting mounted on wind turbines may be visible for a number of kilometres from the wind farm project area, the actual intensity of the lighting appears no greater than other sources of night time lighting, including vehicle head and tail lights.

Previous investigations have also suggested that replacing the more conventional incandescent lights with light emitting diodes (LED) may help to minimise the potential visual impact of the wind turbine lights (Epuron 2008).

Site investigations and anecdotal evidence from a number of local residents confirm that the Cullerin wind farm lights were visible from the Crookwell 3 site, which is located approximately 30km's from the general locality of the Cullerin wind farm site. A series of night time photographs were taken toward the Cullerin wind farm in order to illustrate the visual effect of turbine mounted lighting. These were taken at distances of 500m, 3.5km and 17km and are illustrated in **Figures 71, 72** and **73**. Each night time view is presented below a corresponding day time photograph taken from the same location. It should be noted that following community consultation, and the preparation of an aviation risk assessment, Origin Energy have removed night time lighting from the Cullerin wind turbines.

13.2 Existing light sources

A small number of existing night time light sources occur in the vicinity of the Crookwell 3 wind farm, and includes residential and road lighting.

Localised lighting is associated with a small number of dispersed homesteads located within the project boundary, but lighting is unlikely to be visually prominent and does not emit any significant illumination beyond immediate areas surrounding residential and agricultural buildings.

Lights from vehicles travelling along the local roads provide dynamic and temporary sources of light.

An Aeronautical Impact Assessment was carried out for the approved Crookwell 2 wind farm and determined that up to 23 turbines would be lit with obstacle lighting. These turbines are illustrated in **Figure 2**.

The Gullen Range wind farm would not have obstacle lighting installed on wind turbines and there is no obstacle lighting installed on the operational Crookwell 1 wind farm.

Figure 71
Night Lighting Cullerin wind farm at 500m

DAY TIME VIEW FROM HUME HIGHWAY TOWARD
CULLERIN WIND FARM AT AROUND 500M

NIGHT TIME VIEW FROM HUME HIGHWAY TOWARD
CULLERIN WIND FARM AT AROUND 500M

CULLERIN WIND FARM NIGHT TIME LIGHTING .
VIEW WEST FROM HUME HIGHWAY AT AROUND
500M DISTANCE.

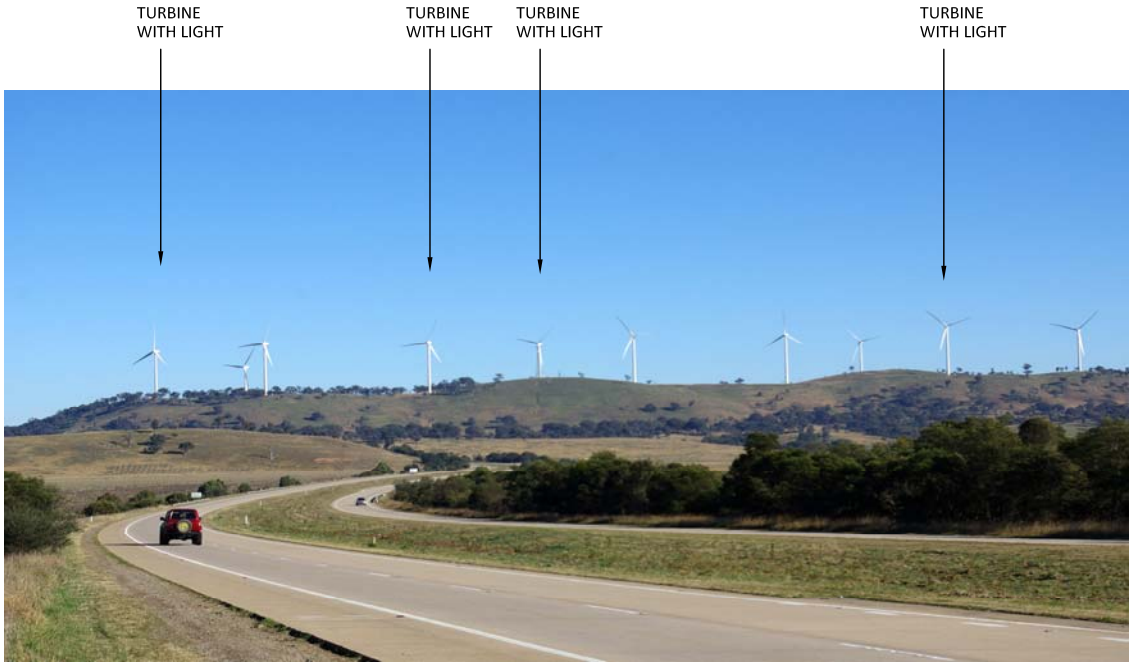
UNION FENOSA
WIND AUSTRALIA
gasNatural fenosa

CROOKWELL DEVELOPMENT
PTY LTD

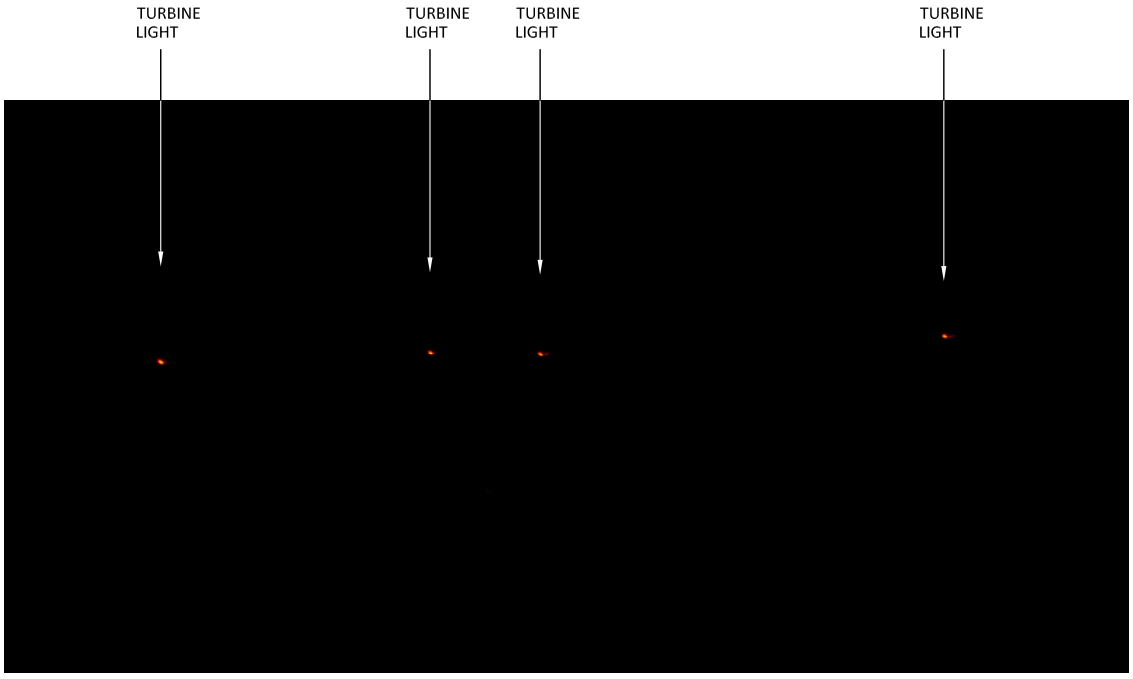
CROOKWELL 3 WIND FARM

GREEN BEAN DESIGN
landscape architects

Figure 72
Night Lighting Cullerin wind farm at 3.5km



DAY TIME VIEW FROM HUME HIGHWAY TOWARD CULLERIN WIND FARM AT AROUND 3.5KM



NIGHT TIME VIEW FROM HUME HIGHWAY TOWARD CULLERIN WIND FARM AT AROUND 3.5KM

CULLERIN WIND FARM NIGHT TIME LIGHTING . VIEW WEST FROM HUME HIGHWAY AT AROUND 3.5KM DISTANCE.

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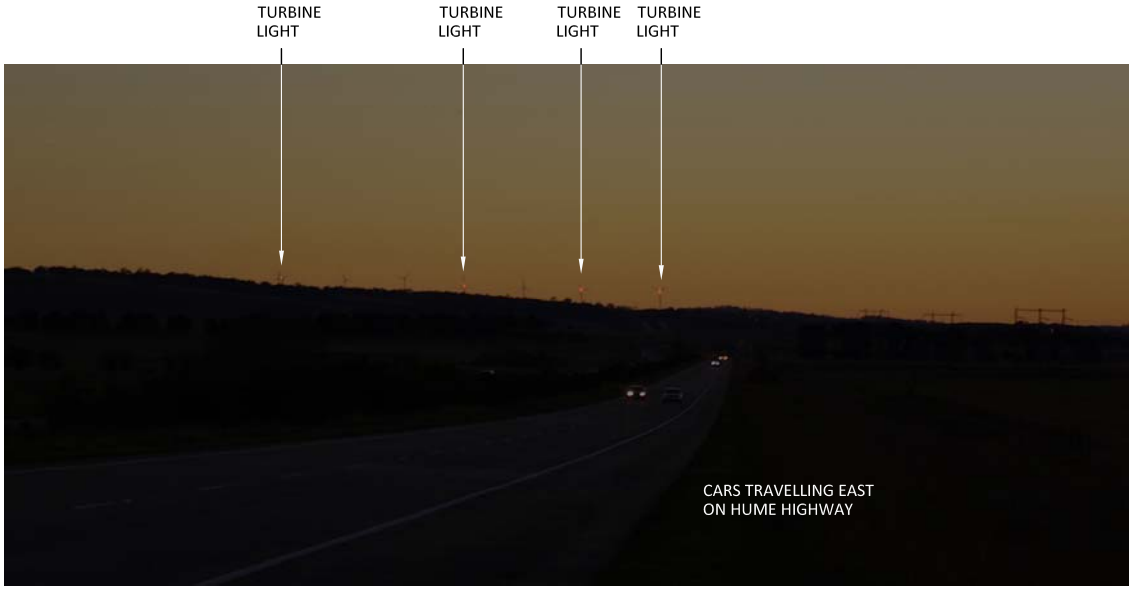
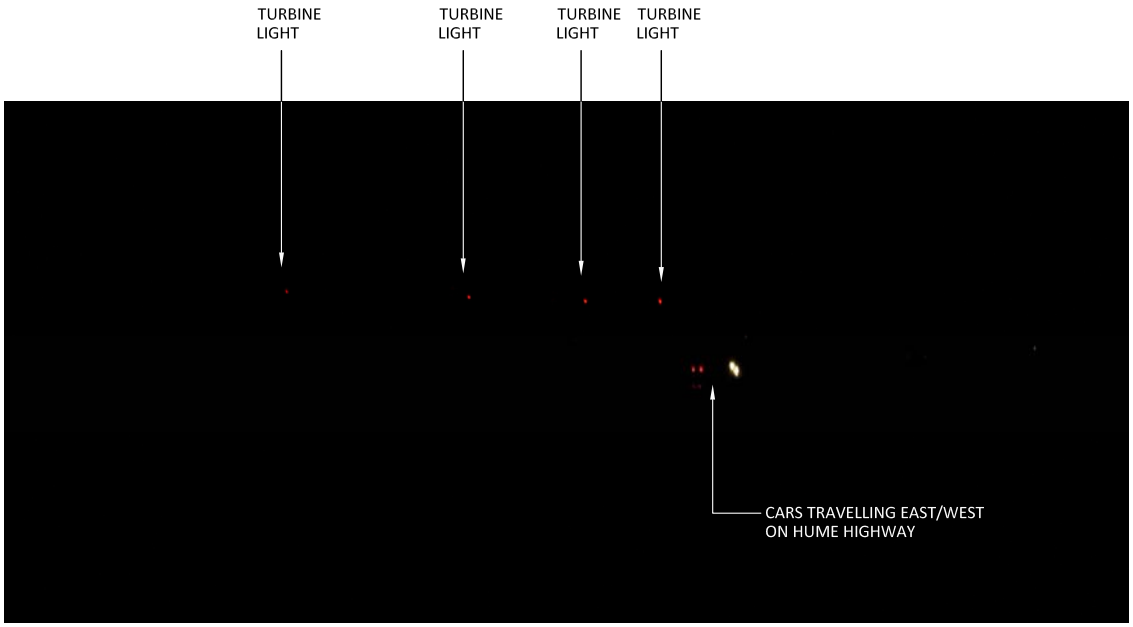
CROOKWELL 3 WIND FARM

GREEN BEAN DESIGN
landscape architects

Figure 73
Night Lighting Cullerin wind farm at 17km



VIEW WEST AT DUSK FROM HUME HIGHWAY TOWARD CULLERIN WIND FARM AT AROUND 17KM



VIEW WEST AFTER DARK FROM HUME HIGHWAY TOWARD CULLERIN WIND FARM AT AROUND 17KM

CULLERIN WIND FARM NIGHT TIME LIGHTING .
VIEW WEST FROM HUME HIGHWAY AT AROUND 17KM DISTANCE.

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GREEN BEAN DESIGN
landscape architects

13.3 Potential light sources

The main potential light sources associated with the Crookwell 3 wind farm would include night time obstacle lights on wind turbines. Lighting may also be required for scheduled or emergency maintenance around the wind turbine areas.

13.4 Potential views and impact

The categories of potential views that may be impacted by night time lighting generally include residents and motorists.

Night time lighting associated with the wind farm is likely to have an impact on a number of the residential view locations at both the Crookwell 3 South and East sites.

Irrespective of the total number of visible lights, safety lighting is more likely to be noticeable from exterior areas surrounding residences rather than from within residences where at night time room lights tend to reflect and mirror internal views in windows, or curtains and blinds tend to be drawn.

Although visible from distances which would exceed the Crookwell 3 wind farm 10km viewshed, the intensity of night time lighting would tend to diminish over 3 to 4km from the lit turbines, and would be more likely to be screened by topography and vegetation surrounding individual residential dwellings.

In the event that night time lighting were to be installed on the Crookwell 3 South and East turbines, a relatively small number of residential dwellings within 3km of the lit turbines would experience some degree of potential visual impact, together with a increased cumulative impact from view locations that afford views toward the turbines lit within the Crookwell 2 wind farm site.

Night time lighting associated with the wind farm is unlikely to have a significant visual impact on the majority of public view locations. Whilst safety lighting would be visible to motorists travelling along the local roads, the duration of visibility would tend to be very short and partially screened by undulating landform along some sections of local road corridors.

14.1 Potential visual impacts

There are potential visual impacts that may occur during both pre-construction and construction phases of the project. The wind farm construction phase is likely to occur over a period of around 12 to 15 months, although the extent and nature of pre-construction and construction activities will vary at different locations within the project area.

Plate 8. *Illustrating general construction activities at the Capital Hill wind farm site, including views toward cranes, partial construction of towers and laydown areas.*

The key pre-construction and construction activities that may be visible from areas surrounding the proposed wind farm include:

- Ongoing detailed site assessment including sub surface geotechnical investigations;
- Various civil works to upgrade local roads and access point;
- Construction facilities, including portable structures and laydown areas;
- Various construction and directional signage;
- Mobilisation of rock crushing and concrete batching plant (if required);
- Excavation and earthworks; and
- Various construction activities including erection of wind turbines, monitoring masts and associated electrical infrastructure works.

The majority of pre-construction and construction activities, some of which would result in physical changes to the landscape (which have been assessed elsewhere in this LVIA report), are generally temporary in nature and for the most restricted to various discrete areas within or beyond the

immediate wind farm project area. The majority of pre-construction and construction activities would be unlikely to result in an unacceptable level of visual impact for their duration and temporary nature.

Perception and Public Consultation

SECTION 15

15.1 Perception

People's perception of wind farms is an important issue to consider as the attitude or opinion of individual people adds significant weight to the level of potential visual impact.

The opinions and perception of individuals from the local community and broader area were sought and provided through a range of consultation activities. These included:

- Door knocking within the Crookwell 3 wind farm 3 to 5km viewshed;
- Leaflet drops and local media presentations;
- Dedicated project web site including feedback provisions; and
- Individual stakeholder meetings.

The attitudes or opinions of individuals toward wind farms can be shaped or formed through a multitude of complex social and cultural values. Whilst some people may accept and support wind farms in response to global or local environmental issues, others may find the concept of wind farms completely unacceptable. Some may support the environmental ideals of wind farm development as part of a broader renewable energy strategy but do not consider them appropriate for their regional or local area. It is unlikely that wind farm projects will ever conform or be acceptable to all points of view; however, research within Australia as well as overseas consistently suggests that the majority of people who have been canvassed do support the development of wind farms.

Wind farms are generally easy to recognise in the landscape and to take advantage of available wind resources are more often located in elevated and exposed locations. The geometrical form of a wind turbine is a relatively simple one and can be visible for some distance beyond a wind farm, and the level of visibility may be accentuated by the repetitive or repeating pattern of multiple wind turbines within a local area. Wind farms do have a significant potential to alter the physical appearance of the landscape, as well as change existing landscape values.

15.2 Public Consultation

A door knock exercise was carried out by the proponent for all residential dwellings within a 3 to 5km radius of the Crookwell 3 wind farm.

The Crookwell 3 design layout is the culmination of several meetings with residents in the local community, and has taken into account a number of issues and concerns relating to potential visual impacts from individual view locations.

The Proponent held a number of meetings with stakeholders in the area surrounding the windfarm, including individual meetings with adjoining landowners potentially impacted by the wind farm development.

A public consultation 'Information Day' will be held once the EA is placed on public exhibition.

15.3 Quantitative Research

Whilst published Australian research into the potential landscape and visual impacts of wind farms is limited, there are general corresponding results between the limited number that have been carried out when compared with those carried out overseas.

A recent survey was conducted by ARM Interactive on behalf of the NSW Department of Environment, Climate Change and Water (September 2010). The survey polled 2022 residents across the six Renewable Energy Precincts established by the NSW Government. The key findings of the survey indicated that:

- *97% of people across the Precincts had heard about wind farms or turbines, and 81% had seen a wind farm or turbine (in person or the media);*
- *85% of people supported the construction of wind farms in New South Wales, and 80% within their local region;*
- *79% supported wind farms being built within 10km of residences and 60% of people surveyed supported the construction of wind turbines within 1 to 2kmfrom their residences.*

These results are reflected in other surveys including the community perception survey commissioned by Epuron Pty Ltd for the Gullen Range Wind Farm Environmental Assessment (August 2008). The

results of the survey, which targeted a number of local populations within the Southern Tablelands, suggested that around 89 % of respondents were in favour of wind farms being developed in the Southern Tablelands, with around 71 % of respondents accepting the development of a wind farm within one kilometre from their residential dwelling.

The study targeted people living in a number of small urban and rural communities located in the area immediately surrounding the proposed Gullen Range wind farm as well as other communities surrounding potential future wind farm development sites. The results of the survey suggested that almost 89% of respondents were in favour of wind farms being developed in the Southern Tablelands, with around 71% of respondents accepting the development of a wind farm within one kilometre from their residential dwelling.

These general levels of support for wind farm developments have also been recorded for a number of wind farm developments around Australia as well as overseas.

Auspoll research carried out in February 2002 on behalf of a wind farm developer for a wind farm project in Victoria included just over 200 respondents. The results indicated that:

- *Over 92% of respondents agreed that wind farms can make a difference in reducing greenhouse emissions and mitigating the effects of global warming.*
- *Over 88% disagreed with the statement that wind farms are ugly.*
- *Over 93% of respondents identified 'interesting' as a good way to describe wind farms, over 73% nominating 'graceful' and over 55% selecting attractive.*
- *Over 79% of respondents thought that the wind farm would have a good impact on tourism, with 15% of respondents believing that the wind farm would make no difference.*
- *Over 40% of respondents believed that the impact of the wind farm on the visual amenity of the area would be good, with 40% believing that it would make no difference.*

A September 2002 MORI poll of 307 tourists conducted in Argyll (United Kingdom) indicated that:

- *43% maintained that the presence of wind farms had a positive impression of Argyll as a place to visit.*

- *43% maintained that the presence of wind farms had an equally positive or negative effect.*
- *Less than 8% maintained it had a negative effect.*
- *91% of tourists maintained that the presence of wind farms in Argyll made no difference to the likelihood of them visiting the area.*

There is no published Australian research on community attitudes to the impact of wind farms on landscape and visual issues before and after construction. However, overseas research in the United Kingdom conducted by MORI in 2003 indicated that:

- *Prior to construction 27% of people polled thought problems may arise from wind farm impact on the landscape*
- *Following construction the number of people who thought the landscape has been spoiled was 12%.*

The majority of research carried out to date has focussed on public attitudes to wind farms and does not provide any indication for acceptable or agreed thresholds in relation to numbers and heights of turbines, and the potential impact of distance between turbines and view locations.

15.4 The Broader Public Good

Whilst visual perceptions and attitudes of local communities toward wind farm developments are an important issue, and need to be assessed locally in terms of potential landscape and visual impacts, there is also an issue of the greater potential public benefit provided by renewable energy production. Wind farms are expected to make a contribution toward meeting the Government's commitment that 20% of Australia's electricity supply comes from renewable energy sources by 2020.

In the 2006 Land and Environment Court decision to confirm, on an amended basis, consent for the construction of a wind farm at Taralga, Chief Judge Justice Preston said in his prologue to the judgement:

"The insertion of wind turbines into a non-industrial landscape is perceived by many as a radical change which confronts their present reality. However, those perceptions come in different hues. To residents, such as members of the Taralga Landscape Guardians Inc. (the Guardians), the change is

stark and negative. It would represent a blight and the confrontation is with their enjoyment of their rural setting".

"To others; however, the change is positive. It would represent an opportunity to shift from societal dependence on high emission fossil fuels to renewable energy sources. For them, the confrontation is beneficial – being one much needed step in the policy settings confronting carbon emission and global warming".

"Resolving this conundrum – the conflict between the geographically narrower concerns of the guardians and the broader public good of increasing the supply of renewable energy – has not been easy. However, I have concluded that, on balance, the broader public good must prevail".

Whilst the exact circumstances between the Taralga wind farm and the proposed Crookwell 3 wind farm may differ, the comments provided by the Chief Judge make it clear that, in the circumstances of that case, there was a need for the broader public good to be put before the potential negative impacts on some members of the local community. Similar reasoning can be applied to the Crookwell 3 wind farm.

16.1 Mitigation Measures

The purpose of mitigation is to avoid, reduce, or where possible remedy or offset any significant negative impact arising from the Crookwell 3 wind farm. Where reasonable and feasible, mitigation measures would reduce the potential visual impact of the Crookwell 3 wind farm in one of two ways:

- firstly, by reducing the visual prominence of the wind turbines and associated structures by minimising the visual contrast between the wind turbines and the landscape in which they are viewed; and
- secondly, by screening views toward the wind turbines from specific view locations.

In relation to the first form of mitigation, the design of the turbine structures has been highly refined over a number of years to maximise their efficiency. The height of the supporting towers and dimensions of the rotors are defined by engineering efficiency and design criteria. Consequently, modification of the turbine design to mitigate potential visual impacts is not considered a realistic option.

Colour is one aspect of the wind turbine design that does provide an opportunity to reduce visual contrast between the turbine structures and the background against which they are viewed. The white colour that is used on a majority of turbine structures provides the maximum level of visual contrast with the background. This maximum level of visual contrast could be reduced through the use of an appropriate off white or grey colour for the turbines where the visual contrast would be reduced when portions of the turbine were viewed against the sky as well as for those portions viewed against a background of landscape. The final colour selection will also be subject to the availability of turbine models on the market at the time of ordering and to aviation safety requirements.

The potential visual impact of the Crookwell 3 wind farm from specific view locations could be mitigated by planting vegetation close to the view locations. For instance, tree or large shrub planting close to a residence can screen potential views to individual or groups of turbines. Similarly roadside

tree planting can screen potential views of turbines from particular sections of road provided the turbine is not located some distance from the road.

The location and design of screen planting used as a mitigation measure is very site specific and requires detailed analysis of potential views and consultation with landowners. Planting vegetation may not provide effective mitigation in all circumstances and can reduce the extent of existing views available from residences or other view locations.

There is greater potential to mitigate the visual prominence for some of the ancillary structures and built elements associated with the wind farm through the appropriate selection of materials and colours, together with consideration of their reflective properties.

The potential visual impacts of vehicular tracks providing access for construction and maintenance can be mitigated by:

- minimising the extent of cut and fill in the track construction;
- re-vegetating disturbed soil areas immediately after completion of construction works; and
- using local materials as much as possible in track construction to minimise colour contrast.

16.2 Summary of Mitigation Measures

Table 26 - Visual Assessment: Summary of Mitigation Measures

Safeguard	Implementation			
	Design	Site Preparation	Construction	Operation
Consider options for use of colour to reduce visual contrast between turbine structures and background, e.g. use of off white rather than white, and use matt finish to avoid reflected sunlight.	✓			
Avoid use of advertising, signs or logos mounted on turbine structures, except those required for safety purposes.			✓	✓
If necessary, design and construct site control building and facilities building sympathetically with nature of	✓		✓	

Table 26 - Visual Assessment: Summary of Mitigation Measures

Safeguard	Implementation			
	Design	Site Preparation	Construction	Operation
locality.				
Enforce safeguards to control and minimise fugitive dust emissions.		✓	✓	
Restrict the height of stockpiles to minimise visibility from outside the site.		✓	✓	
Minimise activities that may require night time lighting, and if necessary use low lux (intensity) lighting designed to be mounted with the light projecting inwards to the site to minimise glare at night.			✓	✓
Minimise cut and fill for site tracks and revegetate disturbed soils as soon as possible after construction.		✓	✓	
Maximise revegetation of disturbed areas to ensure effective cover is achieved.				✓
Consider options for planting screening vegetation in vicinity of nearby residences and along roadsides to screen potential views of turbines. Such works to be considered in consultation with local residents and authorities.	✓	✓		
Undertake revegetation and off-set planting at areas around the site in consultation and agreement with landholders.	✓	✓	✓	

Conclusion

SECTION 17

17.1 Summary

In summary, this LVIA has determined that the Crookwell 3 wind farm would have an overall Low to Moderate visual impact on the majority of non-associated residential view locations as well as views from public locations, including view locations from the main highways and local road network identified in this LVIA.

This LVIA determined the overall landscape character sensitivity to be Medium with some characteristics of the landscape likely to be altered by the wind farm, although the landscape will have some capability to accommodate change. This capability is largely derived from the large scale and open landscape character identified in this part of the Southern Tablelands, together with the relatively low density of people located within the immediate and surrounding area of the wind farm viewshed.

The Landscape Character Areas identified and described in this LVIA are generally well represented throughout the Upper Lachlan Shire and Goulburn Mulwaree Council areas and more generally within the New South Wales Southern Tablelands. This LVIA has determined that the landscape surrounding the Crookwell 3 wind farm would have the ability to accommodate the physical changes associated with the wind farm and its associated structures. Wind farm developments have been previously approved in the New South Wales Southern Tablelands region and in areas of similar landscape character, including the Gullen Range and Crookwell 2 wind farms.

This LVIA determined that the Crookwell 3 South turbines would have:

- a potential High or Moderate to High visual impact on 10 residential view locations (or 8% of residential view locations within the 5km viewshed);
- a potential Moderate or Low to Moderate visual impact on 13 residential view locations (or 11% of residential view locations within the 5km viewshed); and
- a potential Low or Nil visual impact on 100 residential view locations (or 81% of residential view locations within the 5km viewshed).

This LVIA determined that the Crookwell 3 East turbines would have:

- a potential High or Moderate to High visual impact on 18 residential view locations (or 14.5% of residential view locations within the 5km viewshed);
- a potential Moderate or Low to Moderate visual impact on 18 residential view locations (or 14.5% of residential view locations within the 5km viewshed); and
- a potential Low or Nil visual impact on 87 residential view locations (or 71% of residential view locations within the 5km viewshed).

GBD understand that none of the associated landowners have expressed concerns with regard to the potential visual impact of the proposed wind farm, including the potential visibility of wind turbines from within, or immediately surrounding their residential dwellings.

The majority of residential dwellings surrounding the wind farm are strategically situated within the landscape to mitigate exposure to inclement weather, or have adopted measures to reduce these impacts by planting and maintaining windbreaks around dwellings. The extent of windbreak planting reduces the potential visibility of the windfarm from a number of residential view locations surrounding the wind farm area.

This LVIA identified and assessed 16 public view locations, the majority from road corridors. This LVIA determined that the Crookwell 3 wind farm would not have a High or Moderate impact on views from any of the public view locations. The majority of the public view locations are dynamic (motorists travelling along local roads) and include contextual views that will potentially change in reasonably quick succession within the spatial qualities of the surrounding landscape.

GBD acknowledge that the Crookwell 3 wind farm may have the potential to impact people engaged in predominantly farming or recreational activities, where views toward wind turbines occur from surrounding and non-associated agricultural areas. Ultimately the level of impact would depend on the type of activities engaged in as well as the location of the activities together with the degree of screening provided by local landform or vegetation within individual properties. Whilst views toward the turbines will occur from a wide area of surrounding rural agricultural land, this LVIA has

determined that the sensitivity of visual impacts is less for those employed or carrying out work in rural areas compared to potential views from residential dwellings.

The shadow flicker assessment, prepared by GL-GH, concluded that the Crookwell 3 wind farm would potentially impact one residential view location (an associated landowner) by exceeding a cumulative 30 hours of shadow flicker per year. Views toward the wind turbines from this residential view location are largely screened by mature tree planting surrounding the residence. As there are effectively no views toward the turbines, it is unlikely that shadow flicker would be experienced within or surrounding the curtilage of the residence.

It is unlikely that potential wind turbine shadow flicker would have any significant adverse impacts on people with photosensitive epilepsy or upon motorists travelling along local roads surrounding the Crookwell 3 wind farm.

The Crookwell 3 wind farm would not have a significant impact on the character of the Crookwell Township, where views toward the wind farm from the majority of residential view locations would be screened by adjoining residences, tree cover and landform.

The Crookwell 3 wind farm would be visible from a number of local roads including the Goulburn Crookwell and Woodhouselee Roads. This LVIA has determined that views toward the Crookwell 3 wind farm would generally result in a Low visual impact for the majority of motorists travelling through the area.

Both pre-construction and construction activities are unlikely to result in an unacceptable level of visual impact due to the temporary nature of these activities, together with proposed restoration and rehabilitation strategies. The preferred location for some of the construction activities, including the on-site concrete batch plant and rock crusher, would generally be located away from publicly accessible areas, with the closest residential view location generally comprising associated landowners.

Although some mitigation measures may be considered appropriate to minimise the visual impact for a number of the elements associated with the wind farm, it is acknowledged that the degree to which the wind turbines may be visually mitigated is limited by their scale and position within the landscape

relative to surrounding view locations. Despite this, the Proponent has engaged in ongoing consultation with local residents and made a number of adjustments to the location of individual turbines to minimise visual impacts where possible.

Subject to DoP&I assessment and determination, and any conditions of approval, the proponent would consider implementing landscape treatments to screen and mitigate the potential visual impact of the wind farm for individual neighbouring properties within an appropriate and agreed distance from the wind farm project area, subject to consultation and agreement with individual property owners.

Appendix A – Garrad Hassan Flicker Assessment

GL Garrad Hassan

SHADOW FLICKER AND BLADE GLINT ASSESSMENT FOR THE PROPOSED CROOKWELL 3 WIND FARM

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CONTENTS

1 EXECUTIVE SUMMARY

Garrad Hassan Pacific Pty Ltd (GH) has been commissioned by Green Bean Design on behalf of Crookwell Development Pty Ltd (CDPL) to independently assess the shadow flicker in the vicinity of the proposed Crookwell 3 Wind Farm. The results of the work are reported here. This document has been prepared pursuant to the GH proposal P953/PP/01 Issue C, dated 10 February 2010, and is subject to the terms and conditions contained therein.

The Director-General's Requirements for the proposed Crookwell 3 wind farm, based on the Section 75F of the Environmental Planning and Assessment Act 1979, state the following with regard to shadow flicker and blade glint caused by the wind farm.

"Visual Impacts – the EA must assess the impact of shadow "flicker", blade "glint" and night lighting from the wind farm."

This document assesses the potential impact of shadow flicker and blade glint from the wind farm.

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 Crookwell 3 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 assessment of the probable degree of conservatism associated with the analysis has also been conducted.

CDPL has supplied a turbine layout for the wind farm consisting of 30 REpower 3.XM turbines [4] and surveyed locations of 113 houses in the vicinity of the wind farm [3]. These have been assessed 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 [2] which recommend a shadow flicker limit of 30 hours per year in the area immediately surrounding a dwelling.

In addition, there are Draft National Wind Farm Development Guidelines [5] which 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 actual hours by taking into account two of the factors (turbine orientation and cloud cover) which reduce the shadow flicker duration below the theoretical values.

The modelling shows that based on the methodology recommended in the Draft National Wind Farm Development Guidelines, there are four existing dwellings that are predicted to

experience some shadow flicker. One of these dwellings is predicted to experience a theoretical shadow flicker duration in excess of 30 hours per year, and an actual shadow flicker duration in excess of 10 hours per year, however the owner of the property is participating in the project and has an agreement with CDPL. The three remaining dwellings are predicted to experience theoretical shadow flicker durations of 30 hours or below and actual shadow flicker durations of 10 hours or below.

Therefore, compliance with both the Victorian Planning Guidelines, and also the Draft National Wind Farm Development Guidelines is predicted to be achieved at all non-participating dwellings.

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 Crookwell 3 site is located approximately 15 km southeast of Crookwell, in New South Wales. 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 and Figure 4.

The town of Crookwell is situated some 180 km west-southwest of Sydney and 40 km north-northwest of the nearest major regional centre, Goulburn. The proposed wind farm is located on a series of undulating hills that vary in elevation between approximately 750 m and 900 m.

The vegetation in the region is predominantly open farmland, with some moderately sized areas of dense bush within 10 km.

2.2 House locations

A list of co-ordinates of dwellings to be considered as shadow flicker receptors has been provided by CDPL [3]. Only houses within 2.1 km of the wind farm have been considered in the current analysis, and are shown in Table 1.

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

2.3 Proposed Wind Farm layout

CDPL has supplied the layout of the wind farm, which is composed of 30 REpower 3.XM turbines. A hub height of 105 m and a rotor diameter of 104 m were considered for the shadow flicker modelling.

A list of co-ordinates of proposed turbine locations has been provided by CDPL [4], with the grid coordinates given in MGA Zone 55 (GDA94 datum). These co-ordinates, together with the identifiers which have been supplied by CDPL are shown in Table 2.

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

3 PLANNING GUIDELINES

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 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 2009 [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 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* 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 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."

* The maximum blade chord is the thickest part of the blade.

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 variable factors as follows:

- Direction of the property relative to the turbine;
- Distance from turbine (the further the observer is from the turbine, the less pronounced the effect would 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 height of the sun in the sky);
- Weather conditions (cloud cover reduces the occurrence of shadow flicker).

4.2 Shadow Flicker Assessment Methodology

The 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 shadow flicker calculations have been undertaken using a computational model of the wind farm. 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;
- The sun is modelled as a disc.

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

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 mounted horizontal points, representing the worst case scenario, as real windows would be facing a particular direction. The 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 minutes of shadow flicker.

As discussed in section 3, it is generally accepted that shadow flicker from wind turbines is unlikely to cause annoyance at distances greater than approximately 10 rotor diameters, or 265 times the maximum blade chord, from a wind turbine. Considering the REpower 3.XM turbines, the most conservative value corresponds to 10 rotor diameters, or 1040 m.

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 dependant 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 Impact of Shadow Flicker on Road Users

The Draft National Guidelines state the following with regard to distraction of vehicle drivers by shadow flicker:

"There is a negligible risk associated with distraction of vehicle drivers who experience shadow flicker, for the following reasons:

- *Shadow flicker is little different for a vehicle in motion that the effect of shadows from trees on the side of the road or high passing vehicles, neither of which represent a significant risk in terms of road transport.*
- *In spite of extensive searches, no references to motor vehicle accidents caused by this phenomenon have been found."*

In addition, based on the shadow flicker map shown in Figure 3, there are only a small number of locations where shadows from wind turbines with an intensity sufficient to cause annoyance is likely to fall on significant roads.

Therefore it is expected that risk associated with distraction of road users from shadow flicker caused by wind turbines at the Crookwell 3 site is likely to be minimal.

4.5 Current Shadow Flicker Analysis

The modelling of shadow flicker at the proposed Crookwell 3 wind farm has been conducted for a 30 turbine layout and house locations provided by CDPL, using the method described in section 4.2 above. The wind turbine has been modelled assuming all wind turbines are disc objects oriented perpendicular to the sun-turbine vector, representing 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 a 50 m radius of each house location.

An assumption has been made regarding the maximum length that a shadow cast by a wind turbine is likely to cause annoyance due to shadow flicker. The UK wind industry considers that 10 rotor diameters is appropriate [6], while the Danish wind industry suggests this distance is between 500 m and 1 km [7]. 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. The maximum turbine rotor diameter being considered for the proposed Crookwell 3 wind farm is 104 m and GH has assumed that the maximum distance a shadow can be cast that will cause annoyance for an observer is equal to 10 rotor diameters, or a distance of 1040 m.

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 five Bureau of Meteorology (BoM) station located in proximity to the considered site. These stations are:

- 068045 Moss Vale (Located approximately 65 km from the site) [8];
- 068102 Bowral (Located approximately 65 km from the site) [9];
- 070080 Taralga Post Office (Located approximately 15 km from the site) [10];
- 070091 Yass (Located approximately 65 km from the site) [11];
- 070263 Goulburn TAFE (Located approximately 20 km from the site) [12].

The reduction in shadow flicker duration was calculated using the monthly average cloud cover from the five stations listed above.

The average results show that the average annual cloud cover obtained from readings at 9 am and 3 pm is approximately 4.3 oktas. This means that, on average, 4.3/8 or approximately 54% of the sky in the vicinity of the wind farm is covered with cloud at those times of day. 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 59 % 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 two masts, Charley Hill and Red Hill, on the adjoining Crookwell 2 site has been supplied to GH. The averaged 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 20 to 40% 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.

4.6 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 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 Crookwell 3 wind farm are presented in Table 3. The maximum predicted theoretical shadow flicker durations within 50 m of receptors are also presented in Table 3. The results are presented in the form of a shadow flicker maps at 2 m and 6 m above ground in Figure 3 and Figure 4, respectively.

These results indicate that four dwellings are predicted to experience some shadow flicker. Of these four dwellings, one is expected to experience theoretical shadow flicker durations of more than 30 hours per year. It is understood that this dwelling, House 79, has agreements with CDPL regarding this project. The three remaining dwellings are all predicted to experience theoretical shadow flicker durations of less 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 the predicted actual shadow flicker duration in Table 3. It can be seen in this table that consideration of turbine orientation and cloud cover reduces the predicted shadow flicker duration by 65% to 70%.

After the application of these factors, the predicted actual shadow flicker durations at House 79 remains above the limit of 10 hours recommended in the Draft National Guidelines.

5.1 Mitigation Options

Should shadow flicker become 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, or the use of turbine control strategies which shut down turbines when shadow flicker is likely to occur.

6 CONCLUSION

An analysis has been conducted to determine the duration of shadow flicker experienced at shadow receptors in the vicinity of the proposed Crookwell 3 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 and Figure 4. The shadow flicker results for each receptor identified to GH are also listed in Table 3.

The assessment of theoretical shadow flicker hours shows that all except one of the dwellings identified by CDPL 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 are also presented in Table 3 and show that the same dwelling that is predicted to experience theoretical shadow flicker duration in excess of 30 hours per year, is likely to experience more than the recommended limit of 10 actual shadow flicker hours per year. It is understood that this property is owned by a participating landowner with an interest in the project.

Note 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, and therefore the adjusted values may still be regarded as a conservative assessment.

It is expected that the risks associated with distraction of vehicle drivers by shadow flicker from the Crookwell 3 wind farm are likely to be minimal.

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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House ID	Easting [m][1]	Northing [m][1]	Distance to nearest turbine [km]	Nearest turbine
8	733838	6172296	1.07	A26
17	736692	6171234	1.26	A33
18	736232	6171276	0.95	A33
19	735698	6171835	1.07	A32
20	735970	6172727	2.00	A32
58	741473	6171450	1.26	A23
59	741415	6171733	1.27	A23
61	741369	6171908	1.32	A23
62	741337	6172055	1.37	A23
63	741181	6173622	1.00	A6
64	740395	6174100	1.10	A1
65	740315	6174217	1.04	A1
66	743524	6174343	1.03	A15
67	743724	6174675	1.18	A5
68	739684	6175594	1.33	A1
69	740191	6175752	0.99	A1
70	739339	6175736	1.71	A1
79	740830	6174323	0.62	A6
80	741434	6172956	1.28	A10
106	742601	6176175	1.37	A4

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

Table 1. House locations in the vicinity of Crookwell 3 Wind Farm.

Turbine ID	Easting [m][1]	Northing [m][1]	Elevation [m A.S.L.]
A1	740910	6175065	911
A2	741318	6175038	911
A3	741739	6174961	919
A4	742142	6174888	923
A5	742545	6174793	916
A6	741385	6174600	905
A8	741992	6174487	911
A9	742420	6174375	913
A10	742163	6174009	900
A12	742793	6173382	886
A13	743466	6173101	868
A15	744163	6173538	889
A16	743023	6172812	871
A17	743851	6172845	880
A18	744369	6173123	903
A19	744768	6173016	930
A20	743049	6172311	880
A21	743818	6172439	896
A22	743634	6172076	904
A23	742689	6171800	861
A24	743097	6171718	872
A25	743605	6171669	933
A26	733928	6171235	825
A27	734391	6171227	791
A28	733966	6170569	799
A29	734365	6170720	819
A30	734198	6170212	810
A31	734648	6170173	824
A32	735268	6170853	803
A33	735649	6170525	799

[1] Turbine coordinates are in MGA Zone 55 (GDA94 datum)

Table 2. Proposed turbine layout for the Crookwell 3 Wind Farm.

House ID	Easting[1] [m]	Northing[1] [m]	Theoretical				Predicted Actual[3]	
			At Dwelling [hr/yr]		Max Within 50m of Dwelling[2] [hr/yr]		Max Within 50m of Dwelling[2] [hr/yr]	
			At 2 m	At 6 m	At 2 m	At 6 m	At 2 m	At 6 m
Limit			30	30	30	30	10	10
18	736232	6171276	0	0	28	28	10	10
63	741181	6173622	0	0	13	13	4	4
66	743524	6174343	0	0	9	12	3	4
79	740830	6174323	28	32	36	38	11	12

[1] MGA Zone 54 (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 3. Theoretical and predicted actual shadow flicker durations.

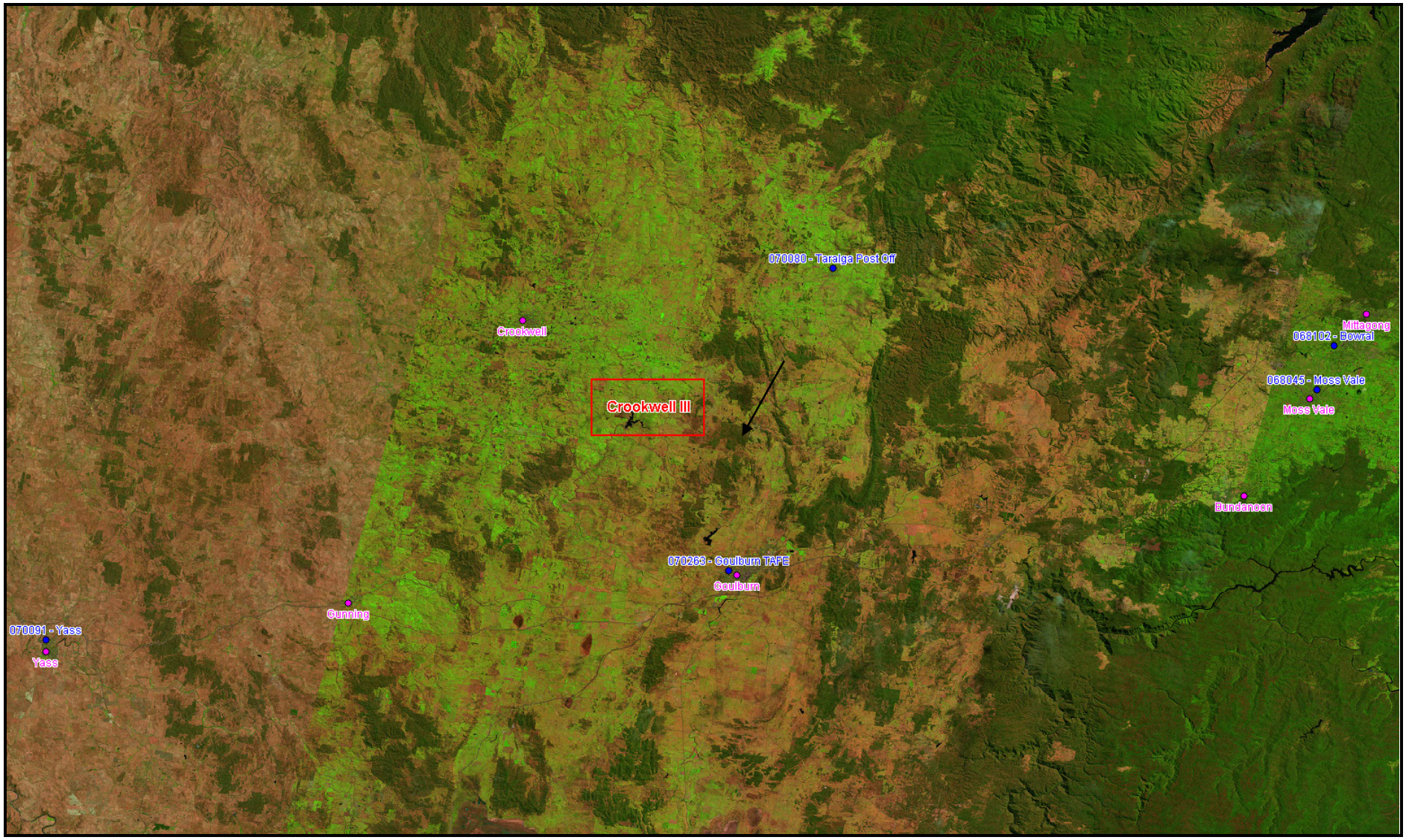

Figure 1. Location of the proposed Crookwell 3 Wind Farm site (blue circles represent BoM stations and pink circles represent towns).

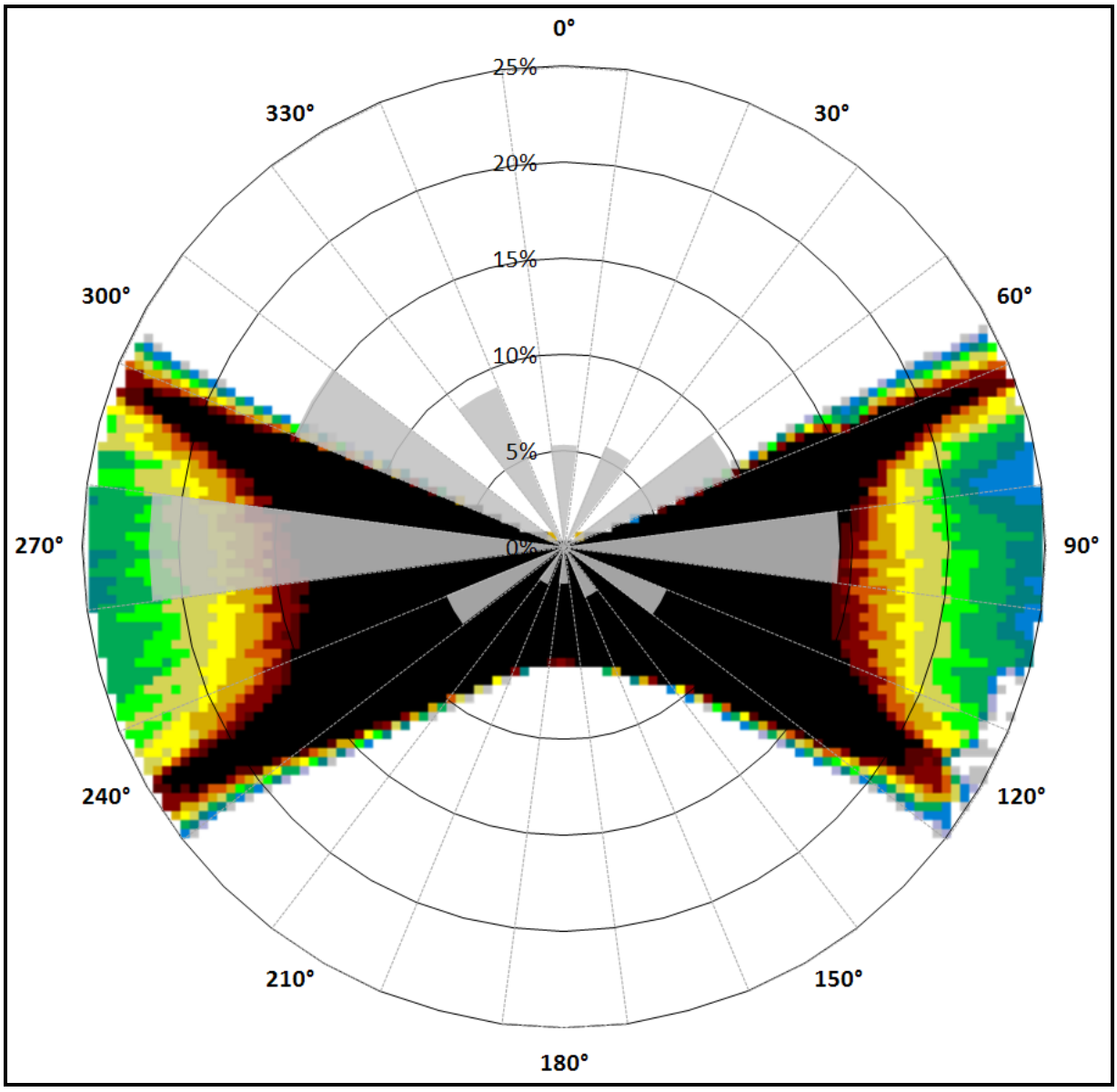

Figure 2. Indicative shadow flicker map with wind direction frequency overlaid.

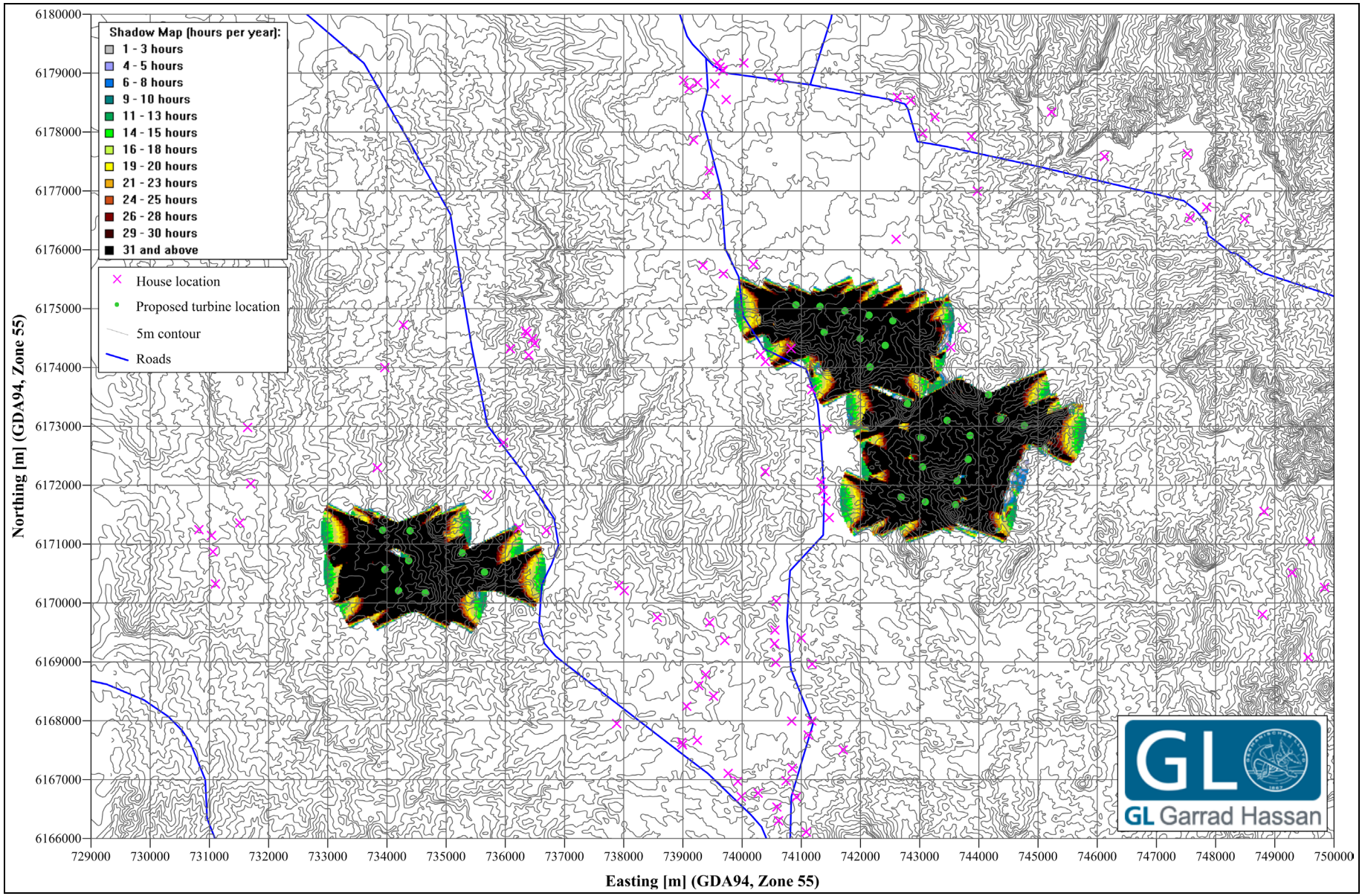

Figure 3. Map of Crookwell 3 Wind Farm showing turbine, house locations and theoretical annual shadow flicker duration at 2 m.