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Aviation Lighting Scheme

Achany Extension Wind Farm

SSE Renewables

September 2025

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ADMINISTRATION PAGE

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EXECUTIVE SUMMARY

Report Purpose

The purpose of this report is to produce an aviation lighting scheme for a proposed wind development to be located west of Lairg, Sutherland.

Guidance from the Ministry of Defence (MoD), Civil Aviation Authority (CAA), International Civil Aviation Organization (ICAO), NatureScot, and the Scottish Government has been considered. The assessment considers the type of lighting to be provided and defines which specific turbines should be lit.

The Proposed Varied Development

The Proposed Varied Development, subject to change through the design process and EIA, will comprise up to 18 wind turbines. The maximum tip and hub heights are anticipated to be up to 200 metres above ground level and 132 metres above ground level, respectively.

Aviation Lighting Requirements

The MoD lighting requirements are outlined in guidance published by the Royal Air Force (RAF) on 1 January 2020. CAA requirements are set forth in its 2017 wind turbine lighting policy statement, with additional consideration given to the CAA's unpublished 2024 draft of the seventh edition of CAP 764. Furthermore, NatureScot and the Scottish Government's joint supplementary guidance on Aviation Lighting Impact Assessments, published in November 2024, has been taken into account. Guidance from ICAO Annex 14, Chapter 6 – International Regulations and the Air Navigation Order (ANO) 2016, Article 222 has also been considered.

The priorities of various stakeholders are different, the scheme has therefore sought to meet all safety requirements while satisfying amenability considerations as much as possible. The scheme also recognises the impact of visible lighting upon the surrounding landscape and thus maintains aviation safety whilst minimising environmental effects.

Recommended Lighting Scheme

Aviation lighting will be equipped to cardinal turbines so that the Proposed Varied Development's spatial extent is discernible regardless of the approach bearing. Seven of the 18 proposed turbines have been deemed cardinal turbines, and therefore will be equipped with visible and Infra-red (IR) lighting. In determining the cardinal turbines, the following draft CAP 764 guidance criterion have been met:

- Wind turbines above the 10° plane extending from the lit nacelles are lit (paragraph 4.6.f);
- The corners of the wind farm are lit and that any change of direction of the perimeter of the wind farm can be recognised (paragraph 4.6.g);
- Maximum of 1.8km between two lit turbines (paragraph 4.6.h).

And the following have not been met:

- 900m spacing between turbines at the perimeter (paragraph 4.6.g);
- Advisory 200m perpendicular line extending from the line connecting the two outer wind turbines – only one wind turbine fails by 20m (paragraph 4.6.g **Note**[1]).

Although not all the criterion have been met, the Proposed Varied Development is not understood to be in a location with regular general aviation activity given the significant distance from any aerodromes and due to the position within the military Tactical Training Area (TTA) (see Section 2.4). This means that it will be an unappealing location for general aviation to fly, particularly under Visual Flight Rules (VFR) and at night. Therefore the identification of the Proposed Varied Development through visible lighting is less likely to be needed and it is anticipated that the reduced lighting will not materially effect aviation risk. For the same reasoning, it is proposed that no intermediate lights are installed.

The lit turbines will therefore be equipped with 2,000cd visible and IR lighting on the nacelles. A second 2,000 candela light will be fitted to the cardinal turbines, to act as a back-up in the event of failure of the main light. To further reduce lighting, visibility sensors will be employed to dim medium-intensity lights from 2,000cd to 200cd when visibility is 5km (or greater), in line with CAA policy (see Section 3.3) and NatureScot's preference.

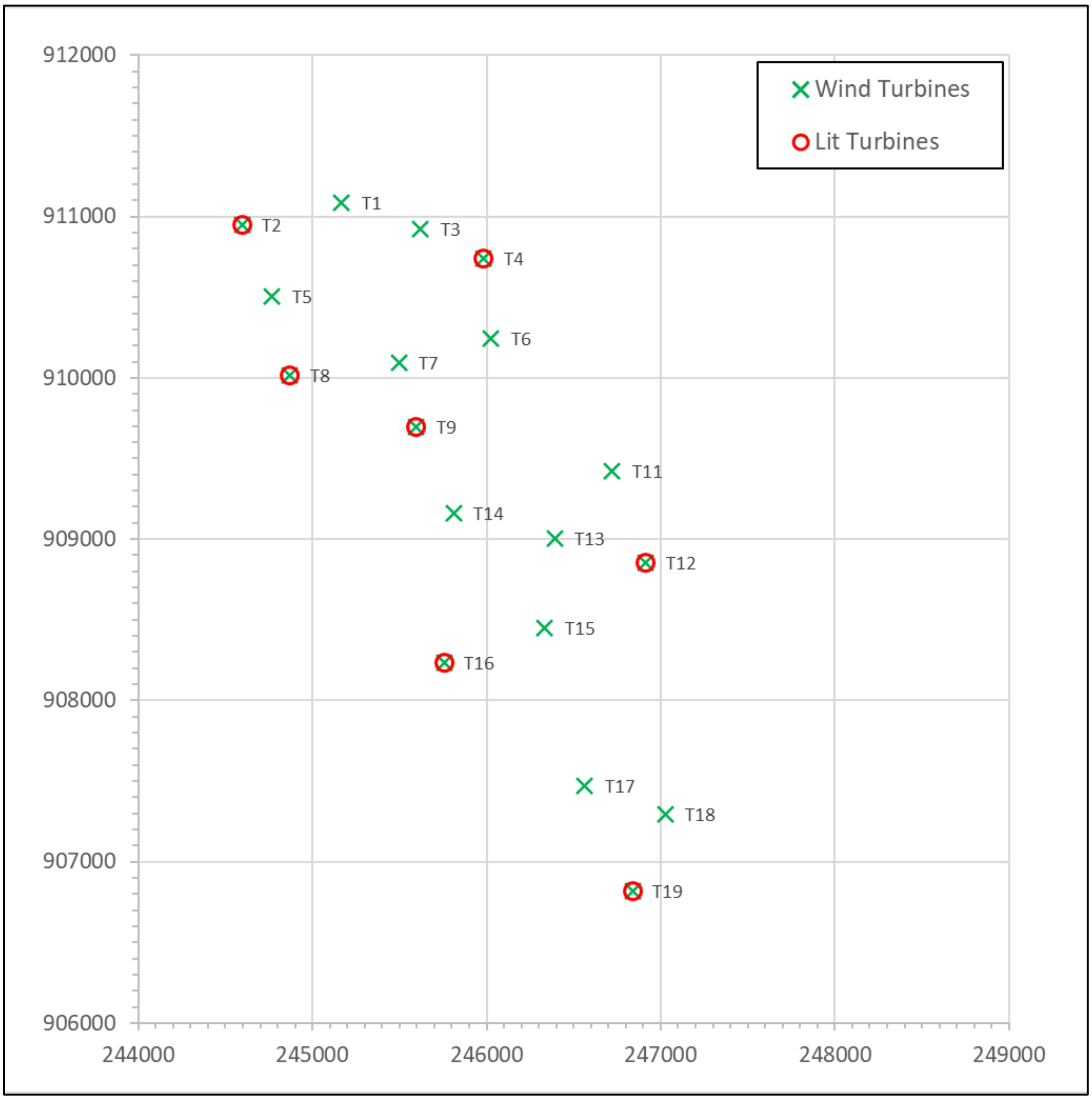
It is also recommended that light 'spill' caused by aviation lighting is minimised, as outlined in Section 4.2. Adjusting the narrow vertical beam spreads of 3° (-1° to +2°), ensures visibility to pilots at or above nacelle level while significantly reducing downward spill. Shields or optical adjustments can ensure light does not unnecessarily spill beyond required angles, maintaining compliance with the CAA and ICAO's omnidirectional horizontal visibility requirements without excessive illumination. This mitigation is subject to commitment from the developer.

By combining selective turbine lighting, intensity reduction in good visibility, as well as mitigating light 'spill', the lighting scheme aligns with aviation regulatory requirements whilst minimising lighting to address visual impact.

Lighting Plan

The wind turbine layout and proposed lighting arrangement are shown in the figure on the following page. Cardinal turbines, chosen to indicate the spatial extent of the development and highest elevated turbine, are circled in red. All other turbines will be unlit.

[1] This value comes from an advisory note to aid perimeter interpretation and is not understood to have the same importance as the other criterion.



Proposed lighting arrangement (cardinal turbines)

Lighting Schedule

The table setting out the proposed lighting schedule, including the location, type, intensity and justifications of the lighting for each wind turbine is presented in Section 5.1.2 for completeness.

Next Steps

It is recommended that this report be shared with the CAA and MoD to understand their position with respect to the proposed reduced lighting scheme.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 62 countries within Europe, Africa, America, Asia and Australasia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Overview

The purpose of this report is to produce an aviation lighting scheme for a proposed wind development to be located west of Lairg, Sutherland.

Guidance from the Ministry of Defence (MoD), Civil Aviation Authority (CAA), International Civil Aviation Organization (ICAO), NatureScot and the Scottish Government has been considered. The assessment considers the type of lighting to be provided and defines which specific turbines should be lit.

1.2 Aviation Lighting Requirement

The MoD lighting requirements are outlined in guidance published by the Royal Air Force (RAF) on 1 January 2020. CAA requirements are set forth in its 2017 wind turbine lighting policy statement, with additional consideration given to the CAA's unpublished 2024 draft of the seventh edition of CAP 764.

Furthermore, NatureScot and the Scottish Government's joint supplementary guidance on Aviation Lighting Impact Assessments, published in November 2024, has been taken into account. Guidance from ICAO Annex 14, Chapter 6 – International Regulations and the Air Navigation Order (ANO) 2016, Article 222 has also been considered.

Section 3 provides a detailed review of the guidance.

1.3 Consultation Response

The MoD has provided the following requirement in relation to lighting in their consultation response dated 01 July 2025:

To address the impact up on low flying given the location and scale of the development, the MOD would require that conditions are added to any consent issued requiring that the development is fitted with aviation safety lighting and that sufficient data is submitted to ensure that structures can be accurately charted to allow deconfliction.

The development proposed includes wind turbine generators that exceed a height of 150m agl and are therefore subject to the lighting requirements set out in the Air Navigation Order 2016. In addition to CAA requirements, the MOD will require the submission, approval, and implementation of an aviation safety lighting specification that details the installation of MOD accredited aviation safety lighting.

<u>*As a minimum the MOD would require that the cardinal turbines are fitted with MOD accredited Infra-red (IR) lighting.*</u>

2 PROPOSED VARIED DEVELOPMENT DETAILS

2.1 Proposed Varied Development Layout

The proposed turbine layout and site boundary is shown in Figure 1 below.

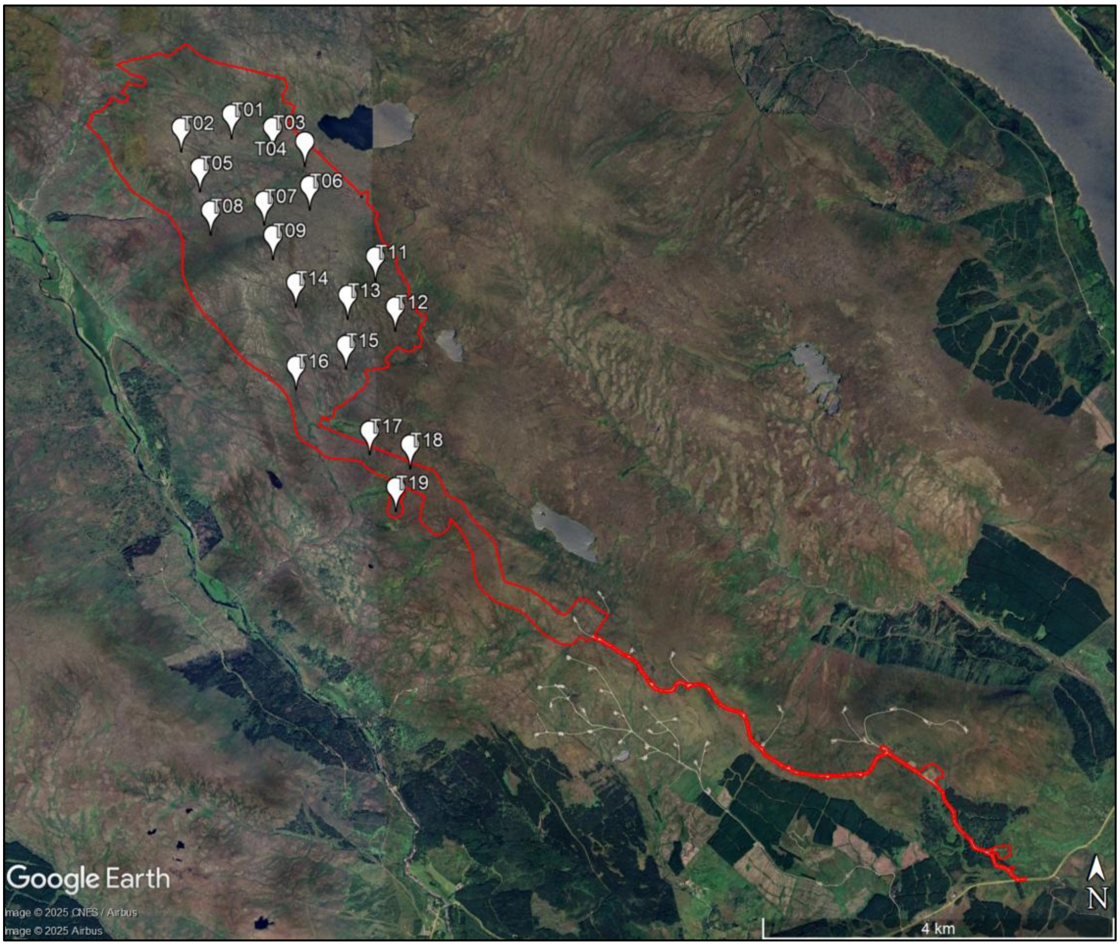


Figure 1 *Proposed wind turbine layout and site boundary*

2.2 Wind Turbine Details

The maximum wind turbine dimensions are presented in Table 1 below. The coordinate and altitude data are presented in Appendix A.

Maximum Rotor Diameter (m)	Nominal Hub Height (m agl)	Maximum Tip Height (m agl)
138	130 – 132	200

Table 1 *Assessed wind turbine details*

2.3 Inter-Turbine Distances

When determining a lighting scheme design, it is important to understand the spacing between wind turbines.

For all inter-turbine distances, the minimum nearest turbine distance is 400m (turbines 3 and 4), the maximum nearest turbine distance is 1km (turbines 15 and 17).

The full inter-turbine distances can be made available upon request.

2.4 Airspace Considerations

The Proposed Varied Development is located in the Scottish Flight Information Region (FIR), which covers all of Scotland and the northeast of England. FIR are managed by a controlling authority that ensures air traffic services are provided to the aircraft flying within it. The Civil Aviation Authority (CAA) is the controlling authority of the Scottish FIR and NATS provides Air Traffic Services (ATS) in the region for en-route aircraft.

The Proposed Varied Development is within Low Flying Area (LFA) 14T, one of the UK's Tactical Training Areas (TTA) where significant military low flying activities are undertaken.

From ground level to Flight Level (FL) 195 (approximately 19,500ft) is Class G uncontrolled airspace, where aircraft may fly when and where they like, subject to a set of simple rules. Although there is no legal requirement to do so, many pilots notify Air Traffic Control (ATC) of their presence and intentions and pilots take full responsibility for their own safety. ATC can provide pilots in Class G with Flight Information Services (FIS) to support their safe flying. An Alerting Service is also provided if necessary to notify appropriate organisations regarding aircraft in need of assistance (e.g., search and rescue).

This means that both civil and military aircraft can, in theory, fly in the area of the Proposed Varied Development. However, the Proposed Varied Development is located approximately 25.3km west of the closest aerodrome (Rogart Microlight Site) and 37.7km northwest of the closest aerodrome with 'typical' general aviation aircraft (Dornoch Airfield). It is therefore unlikely to be a location with regular general aviation activity, particularly as the site is a TTA which is often used for military low flying.

3 APPLICABLE GUIDANCE

3.1 Summary

The most relevant applicable guidance is summarised in Table 3 below.

Receptor	Stakeholder	Applicable Guidance	Date
International Civil Aviation	ICAO	ICAO Annex 14 Chapter 6 Visual Aids for Denoting Obstacles	July 2018
Civil Aviation	CAA	CAA Policy Statement – Lighting of Onshore Wind Turbine Generators in the United Kingdom with a maximum blade tip height at or in excess of 150m Above Ground Level	1 June 2017
		CAA draft CAP 764 (Seventh Edition)	March 2024
Military Aviation	Ministry of Defence	Royal Air Force Wind Turbine Lighting Guidance	1 January 2020
Landscape and Visual Impact	NatureScot	NatureScot and the Scottish Government's joint Guidance on Aviation Lighting Impact Assessment	November 2024

Table 2 *Summary of Applicable Guidance*

3.2 ICAO Annex 14 Chapter 6 – International Regulations

Relevant extracts from ICAO Annex 14 Chapter 6 are presented below.

"6.2.4 Wind turbines

Lighting 6.2.4.3 ***Recommendation.—*** *When lighting is deemed necessary, medium-intensity obstacle lights should be used. In the case of a wind farm, i.e. a group of two or more wind turbines, it should be regarded as an extensive object and the lights should be installed:*

a) to identify the perimeter of the wind farm;

b) respecting the maximum spacing, in accordance with 6.2.3.15, between the lights along the perimeter, unless a dedicated assessment shows that a greater spacing can be used;

c) so that, where flashing lights are used, they flash simultaneously; and

d) so that, within a wind farm, any wind turbines of significantly higher elevation are also identified wherever they are located.

6.2.4.4 ***Recommendation.—*** *The obstacle lights should be installed on the nacelle in such a manner as to provide an unobstructed view for aircraft approaching from any direction.*

…

6.2.3.15 Where lights are applied to display the general definition of an extensive object or a group of closely spaced objects, and

a) low-intensity lights are used, they shall be spaced at longitudinal intervals not exceeding 45 m; and

b) medium-intensity lights are used, they shall be spaced at longitudinal intervals not exceeding 900 m."

Figure 2 below and Figure *3* on the following page present ICAO Characteristics of obstacle lights and light distribution for obstacle lights.

Table 6-1. Characteristics of obstacle lights

1	2	3	4	5	6	7
			Peak intensity (cd) at given Background Luminance (b)			
Light Type	Colour	Signal type/ (flash rate)	Day (Above 500 cd/m²)	Twilight (50-500 cd/m²)	Night (Below 50 cd/m²)	Light Distribution Table
Low-intensity, Type A (fixed obstacle)	Red	Fixed	N/A	N/A	10	Table 6-2
Low-intensity, Type B (fixed obstacle)	Red	Fixed	N/A	N/A	32	Table 6-2
Low-intensity, Type C (mobile obstacle)	Yellow/Blue (a)	Flashing (60-90 fpm)	N/A	40	40	Table 6-2
Low-intensity, Type D (follow-me vehicle)	Yellow	Flashing (60–90 fpm)	N/A	200	200	Table 6-2
Medium-intensity, Type A	White	Flashing (20–60 fpm)	20 000	20 000	2 000	Table 6-3
Medium-intensity, Type B	Red	Flashing (20–60 fpm)	N/A	N/A	2 000	Table 6-3
Medium-intensity, Type C	Red	Fixed	N/A	N/A	2 000	Table 6-3
High-intensity, Type A	White	Flashing (40–60 fpm)	200 000	20 000	2 000	Table 6-3
High-intensity, Type B	White	Flashing (40–60 fpm)	100 000	20 000	2 000	Table 6-3

a) See 6.2.2.6
b) For flashing lights, effective intensity as determined in accordance with the *Aerodrome Design Manual* (Doc 9157), Part 4.

Figure 2 *ICAO Characteristics of obstacle lights*

Table 6-2. Light distribution for low-intensity obstacle lights

	Minimum intensity (a)	Maximum intensity (a)	Vertical beam spread (f)	
			Minimum beam spread	Intensity
Type A	10 cd (b)	N/A	10°	5 cd
Type B	32 cd (b)	N/A	10°	16 cd
Type C	40 cd (b)	400 cd	12° (d)	20 cd
Type D	200 cd (c)	400 cd	N/A (e)	N/A

Note.— This table does not include recommended horizontal beam spreads. 6.2.1.3 requires 360° coverage around an obstacle. Therefore, the number of lights needed to meet this requirement will depend on the horizontal beam spreads of each light as well as the shape of the obstacle. Thus, with narrower beam spreads, more lights will be required.

a) 360° horizontal. For flashing lights, the intensity is read into effective intensity, as determined in accordance with the *Aerodrome Design Manual* (Doc 9157), Part 4.
b) Between 2 and 10° vertical. Elevation vertical angles are referenced to the horizontal when the light is levelled.
c) Between 2 and 20° vertical. Elevation vertical angles are referenced to the horizontal when the light is levelled.
d) Peak intensity should be located at approximately 2.5° vertical.
e) Peak intensity should be located at approximately 17° vertical.
f) Beam spread is defined as the angle between the horizontal plane and the directions for which the intensity exceeds that mentioned in the "intensity" column.

Table 6-3. Light distribution for medium- and high-intensity obstacle lights according to benchmark intensities of Table 6-1

Benchmark intensity	Minimum requirements					Recommendations				
	Vertical elevation angle (b)			Vertical beam spread (c)		Vertical elevation angle (b)			Vertical beam spread (c)	
	0°		-1°			0°	-1°	-10°		
	Minimum average intensity (a)	Minimum intensity (a)	Minimum intensity (a)	Minimum beam spread	Intensity (a)	Maximum intensity (a)	Maximum intensity (a)	Maximum intensity (a)	Maximum beam spread	Intensity (a)
200 000	200 000	150 000	75 000	3°	75 000	250 000	112 500	7 500	7°	75 000
100 000	100 000	75 000	37 500	3°	37 500	125 000	56 250	3 750	7°	37 500
20 000	20 000	15 000	7 500	3°	7 500	25 000	11 250	750	N/A	N/A
2 000	2 000	1 500	750	3°	750	2 500	1 125	75	N/A	N/A

Note.— This table does not include recommended horizontal beam spreads. 6.2.1.3 requires 360° coverage around an obstacle. Therefore, the number of lights needed to meet this requirement will depend on the horizontal beam spreads of each light as well as the shape of the obstacle. Thus, with narrower beam spreads, more lights will be required.

a) 360° horizontal. All intensities are expressed in Candela. For flashing lights, the intensity is read into effective intensity, as determined in accordance with the *Aerodrome Design Manual* (Doc 9157), Part 4.
b) Elevation vertical angles are referenced to the horizontal when the light unit is levelled.
c) Beam spread is defined as the angle between the horizontal plane and the directions for which the intensity exceeds that mentioned in the "intensity" column.
Note.— An extended beam spread may be necessary under specific configuration and justified by an aeronautical study.

Figure 3 *ICAO Light distribution for obstacle lights*

3.3 CAA Guidance

CAA Policy Statement – Lighting of Onshore Wind Turbine Generators in the United Kingdom with a maximum blade tip height at or in excess of 150m Above Ground Level – Extracts

2. The UK statutory requirements for the lighting of en–route obstacles (i.e. those away from the vicinity of a licensed aerodrome) are set out in Article 222 of the UK Air Navigation Order (ANO) 2016. This article requires medium intensity (2000 candela) steady red aviation warning lights to be mounted as close as possible to the top of all structures at or above 150 meters above ground level (AGL). In terms of requirement for lighting wind turbines generators in accordance with the ANO, the CAA considers the top of a wind turbine generator to be the maximum blade tip height. In terms of positioning of aviation obstruction lighting on wind turbine generators with a maximum height of 150m AGL or above onshore, the CAA interprets 'as close as possible to the top of the obstacle' as the fitting of lights on the top of the supporting structure (the nacelle) rather than the blade tips.

4. Under Article 222 (5), the CAA may direct that an en-route obstacle must be fitted with and must display such additional lights in such positions and at such times as it may specify. In addition, under Article 222 (6) a permission may be granted for the purposes of this article for a particular case or class of cases or generally. Accordingly, the following policy shall apply to all UK land based wind turbine generators which have a maximum blade tip height at or above 150m AGL:

a. The person in charge of the wind turbine generator must ensure that it is fitted with a medium intensity (2000 candela) red light positioned as close as practicable to the top of the fixed structure. A second light serving as an alternative should be provided in case of failure of the operating light.

b. The lights required by paragraph (a) must be so fitted to show when displayed in all directions without interruption.

c. Additionally, at least three (to provide 360 degree coverage) low-intensity Type B lights (32 candela) lights should be provided at an intermediate level of half the nacelle height.

d. Subject to sub-paragraphs (e) and (f), the person in charge of a wind turbine generator must ensure that any light required to be fitted by this article is displayed.

e. Lights should be operated by an acceptable control device (e.g., photocell, timer, etc.) adjusted so the lights will be turned on whenever illuminance reaching a vertical surface falls below 500 LUX. The control device should turn the lights off when the illuminance rises to a level of 500 LUX or more.

f. In the event of the failure of any light which is required by this policy statement to be displayed, the person in charge of a wind turbine generator must repair or replace the light as soon as practicable. For any outage that is expected to be or is greater than 12 hours, the operator shall request a NOTAM to be issued by informing the NOTAM Section ...

g. If the horizontal meteorological visibility in all directions from every wind turbine generator in a group is more than 5 km, the intensity for the light positioned as close as practicable to the top of the fixed structure required to be fitted to any generator in the windfarm and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type.

Point 'g' suggests that a dimming of aviation lights under suitable visibility conditions is a possibility. There are technologies for implementation of such a solution, set out later in this section. Consultation with the CAA would be required if deviation away from the legislation presented in the ANO was sought.

This report has also considered extracts from paragraphs 4.4 to 4.10 from the draft CAP 764 (Seventh Edition)[2], dated March 2024, which, although intended for publication in 2024, has not yet been released. Extracts from which are detailed below:

4.6. In accordance with Article 222(6) of the ANO (2016) as amended and considering ICAO Annex 14 Volume 1 Chapter 6, the CAA has determined the following specific lighting requirements apply to wind turbines:

a. *The requirement to fit lights is based on the maximum height from the ground to the tip of the blades, but the requirement for the positioning of lights is based on the fixed structure (nacelle and tower).*

b. *One medium intensity (2000 candela) red light must be placed on the nacelle of the turbine; a second 2000 candela red light serving as an alternate should be provided in case of failure of the operating light.*

c. *At least three (to provide 360 degree coverage) low-intensity Type B lights (32 candela) lights must be provided at an intermediate level of half the nacelle height ± 10 m.*

d. *The lights required by sub-paragraphs 5.6(b) and 5.6(c) above must be so fitted to show when displayed in all directions without interruption.*

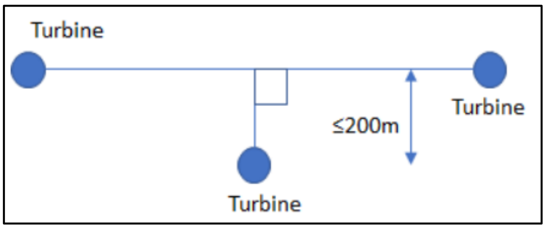
e. *For a group of two or more wind turbines, obstacle lighting must be fitted and operated when required to identify the corners and perimeter of the wind farm.*

f. *Additionally, if the height of other turbine nacelle(s) in the wind farm exceed the height of a plane extending at an elevation of 10 degrees above the horizontal from the nacelle of a turbine that is required to be lit, then obstacle lighting must be fitted and operated in accordance with sub-paragraphs 5.6(b) and 5.6(c) on these wind turbines.*

g. *Obstacle lighting may be omitted on the perimeter of the wind farm if it can be demonstrated that the maximum distance between lit turbines does not exceed 900 metres, the corners of the wind farm are lit and that any change of direction of the perimeter of the wind farm can be recognised.*

Note*: An intermediate wind turbine can be considered to lie along the perimeter if it is at a distance equal to or less than 200 m of a perpendicular line extending from a line connecting the two outer wind turbines, protruding outwards from the wind farm, as per the following diagram:*

[2] Draft CAP 764 Wind Turbine Policy Consultation, March 2024. Accessed 18/08/2025.



h. *Any wind turbine that is located at a distance greater than 1800 m from the nearest lit turbine must also be lit.*

i. *Lights may be operated by a suitable control device (e.g., photocell, timer, etc.). In the event that a photocell is used, in lieu of the 30 minutes after sunset until 30 minutes before sunrise requirement, the CAA will accept a solution that turns the lights on whenever illuminance reaching a vertical surface falls below 500 LUX. The control device should turn the lights off when the illuminance rises to a level of 500 LUX or more.*

j. *If visibility in all directions from every wind turbine generator in a group is more than 5 km, the light intensity for any visible light required by article 222 of the ANO (2016) to be fitted to any generator in the windfarm and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type.*

k. *….*

l. *Developers may apply to the CAA for other specific obstacle lighting designs/layouts. Any lighting scheme that reduces the overall lighting provision requires additional justification for such a layout, consideration of the airspace and types of operation in that airspace at night as well as possible additional mitigation measures issues*.

3.4 MoD Obstruction Lighting Guidance

Excerpts from the RAF 2020 guidance are reproduced below:

1. *… The proliferation of wind turbines across the UK has caused the MOD concern with regard to military night flying training … MOD considers that there is an absolute requirement for the lighting … to enhance the probability of the obstruction being acquired visually by the crew.*
2. *MOD will request some form of lighting in all but exceptional circumstances …*
3. *…*
4. *MOD's standard aviation obstacle lighting standards are … 2000cd steady red lights (for obstacles >45m and (150m) … the proliferation of wind turbines, lighting pollution is an issue and so MOD has addressed this public concern for onshore developments by revising the aerodrome standard to suit the en-route requirement.*
    a. ***Infra-Red (IR) Lighting**. MOD is cognisant that the majority of military night low flying is now conducted with the aid of aircrew night vision goggles (NVGs) … the specification required is detailed Appendix 1 to this Annex. When requesting lighting on turbines, MOD will specify IR lighting as an option **wherever possible** in the interests of public amenity.*
    b. ***Visible Lighting**. There are circumstances where IR lighting is incompatible with the military operations … in such cases visible lighting will be requested …*

        (1) MOD will request either 25cd or 200cd flashing red lighting (depending on the circumstances). This is a deviation from ICAO stds but flashing permits visual

acquisition at a greater range (in excess of 5nm in the case of 25cd) and compensates for the reduction in intensity. 25cd will be requested wherever circumstances permit, but in some locations a brighter 200cd (still low intensity) light will be needed. These areas will be close to elementary/basic flying training schools.

(2) Occasionally, these lights will also be required to mark the corners/cardinals of large wind farm sites where circumstances might reduce the pilot's ability to quickly identify the full size of the site if marked with less intense lights. The specification recommended for visible lighting is detailed in Appendix 1 to this Annex.

*c. **Combi Lighting**. In some locations it may be appropriate to combine IR and 25cd elements. The combination increases the probability of early detection. Combi lighting is appropriate in low flying choke points or on the cardinal turbines of large wind farms where circumstances might reduce the pilot's ability to quickly identify the full size of the site if marked with less intense lights ..*

Lighting Layouts

8. For sites of more than 2 turbines it may not be necessary to light all turbines. Indeed, on the larger sites it may only be necessary to light the perimeter turbines or, for tightly packed sites with smaller turbines, every other perimeter turbine. Combi lights will be requested to define the 'ends' of turbine lines or the cardinal/corner turbines on the largest sites. Full details of lighting layout requirements are at Appendix 3.

Dark Skies Parks

15. MOD recognises that requesting visible lighting elements within Dark Skies Parks (DSP) conflicts with other national policies. Visible lighting, where requested in these areas, will almost exclusively be a 25cd element on combi lights fitted to selected turbines of a large site.

16. Since the UK SAR capability has been contracted out the MOD lighting requirement for DSP's may be reduced to IR only, this will be reflected in lighting request to LPA's.

17. This reduction in requirement for the DSP's should not be interpreted as a precedent for other lighting restrictions. The reduction in these specific areas will require careful management by establishment of navigation warning and some aircraft will have to avoid the areas. To extend reduced lighting to the wider low flying system would significantly reduce available training areas and will not be countenanced.

APPENDIX 3

LIGHTING LAYOUTS

Location	**Individual (1-2 turbines)**	**Small Sites (3-10 turbines)**	**Medium Sites (11-15 turbines)**	**Large Sites (15+ turbines)**
Standard Request	25cd **or** IR on individual turbines	25cd **or** IR on perimeter turbines	25cd **or** IR on perimeter turbines	25cd or IR **COMBI** on perimeter turbines
Vicinity of RW fg trg (see note 4)	200cd **VISIBLE** on individual turbines	200cd **VISIBLE** on perimeter turbines	200cd **VISIBLE** on perimeter turbines	200cd **VISIBLE** on perimeter turbines
Flow choke area	25cd/IR **COMBI** on lead turbine. Other lighting std.	25cd/IR **COMBI** on lead turbine. Other lighting std.	25cd/IR **COMBI** on lead turbine. Other lighting std.	25cd/IR **COMBI** on lead turbine. Other lighting std.
Offshore	200cd/IR **COMBI** on individual turbines.	200cd/IR **COMBI** on perimeter turbines		
Dark Skies Parks	25cd **or** IR on individual turbines	25cd **or** IR on perimeter turbines	25cd **or** IR on perimeter turbines	25cd **or** IR on perimeter turbines

Notes:

1. Where perimeter turbines are located close together, alternate turbines only may be lit, provided the distance between lit turbines does not misrepresent the layout, eg a large gap that might indicate a space between 2 different developments. As a guideline this gap should be no more than 500m.
2. The lead turbine is the first turbine to be encountered in the flow choke point. Traffic flow may be one way or 2 ways and this will determine which turbines should be lit.
3. For offshore turbines, MOD requirement is far exceeded by CAA and Trinity House requirements. Developers should ensure that the selected lighting meets all stakeholder requirements.
4. Visible lighting will be requested around Shawbury in all cases to support use of field landing sites (down to surface) and general LF (down to 150' agl).

Figure 4 *Appendix 3 to MoD Wind Farm Lighting Guidance*

3.5 NatureScot's Guidance on Aviation Lighting Impact Assessment

NatureScot's guidance on aviation lighting for onshore wind turbines addresses the regulatory and technical requirements for lighting schemes on turbines exceeding 150m, emphasising compliance with aviation safety while mitigating visual and environmental impacts. Their guidance was written as a joint venture with the Scottish Government and has been informed by the Aviation Lighting Working Group[3] whom members include representatives from the MoD, the CAA, and NatureScot. It outlines statutory obligations under the UK Air Navigation Order (ANO) 2016, requiring medium-intensity red lights on nacelles and supplementary low-intensity lights at mid-tower heights for visibility. The guidance highlights opportunities for mitigation, such as:

- *Automatic dimming: Sensor controlled lighting that allows for a reduction in brightness, from 2000 cd to 200 cd, in conditions of good meteorological visibility.*

[3] https://www.gov.scot/groups/aviation-lighting-guidance-working-group/. Accessed November 2024.

- *Vertical directional intensity (narrow vertical beam spread - sometimes called 'narrow vertical beam spread' or 'angle intensity mitigation'): Specification of aviation warning light design that allows for reduction in brightness when viewed from certain elevations above and below the horizontal plane of the nacelle.*
- *Reduced lighting scheme: This mitigation comprises project-specific agreement from the CAA that only cardinal or specific turbines, rather than all, can be fitted with visible lighting. Such reduced lighting schemes can also include the potential removal of mid-tower low-intensity (32 cd) visible lights.*

The guidance also outlines the evolving mitigation measure in the form of Aircraft Detection Lighting Systems (ADLS). This is a developing mitigation solution that is yet to gain a legal basis in the UK. Therefore, this lighting scheme has focused on the mitigation options outlined above.

Developers are encouraged to incorporate these measures early in the design process to balance aviation safety with landscape preservation, ensuring assessments align with established environmental impact standards. The document also provides a structured methodology for evaluating nighttime effects, advising a proportionate approach tailored to specific landscapes and receptors, particularly in sensitive areas like Dark Sky Parks and Wild Land Areas.

4 VISIBLE LIGHTING REDUCTION OPTIONS

4.1 Overview

This section provides an overview of the potential mitigation options available to reduce visible aviation lighting. Multiple solutions can be utilised in combination to inform the complete scheme.

4.2 Not Lighting Every Turbine

4.2.1 Justification

Not lighting every turbine is reflected in the MoD's guidance, as detailed in Section 3.4 of this report, including Figure 4 on page 19, which references Appendix 3 of the MoD guidance. The MoD guidance refers to spacings of no more than 500m and *"For sites of more than 2 turbines it may not be necessary to light all turbines. Indeed, on the larger sites it may only be necessary to light the perimeter turbines or, for tightly packed sites with smaller turbines, every other perimeter turbine. Combi lights will be requested to define the 'ends' of turbine lines or the cardinal/corner turbines on the largest sites. Full details of lighting layout requirements are at Appendix 3."*

Similarly, the draft CAP 764 and ICAO guidance refers to reduced lighting possibilities such that where *"medium-intensity lights are used, they shall be spaced at longitudinal intervals not exceeding 900 m."* However, both the draft CAP 764 and ICAO guidance do note that this maximum spacing be adhered to *"unless a dedicated assessment shows that a greater spacing can be used"*.

Cardinal turbines are chosen to indicate the spatial extent of the development and the highest elevated turbine. The cardinal turbines will be identified based on their visibility when the site is viewed from any bearing, specifically those that appear at the highest elevation and are the furthest left and right from the observer's perspective, providing a representation of its spatial extent regardless of the approach bearing. The guidance outlined in paragraph 4.6.g of the draft CAP 764 (see Section 3.3) provides guidance to the selection of cardinal turbines, specifying that: *an intermediate wind turbine can be considered to lie along the perimeter if it is at a distance equal to or less than 200 m of a perpendicular line extending from a line connecting the two outer wind turbines, protruding outwards from the wind farm*.

4.2.2 Implementation

The aviation lighting scheme has been designed so that only the cardinal wind turbines will be equipped with aviation lighting to comply with the ANO, CAA guidance, and the request made by the MoD.

The cardinal wind turbines have been identified using the guidance in draft CAP 764 where wind turbines will be considered part of the perimeter if they extend less than 200m out from a perpendicular line between the two outer wind turbines.

4.3 Light Designed to Minimise Light 'Spill'

4.3.1 Justification

Nacelle aviation warning lights are designed to be visible to aircraft flying level with the nacelle and above. To minimise light spill while ensuring compliance with aviation lighting requirements, lights are designed to significantly restrict downward light radiation while remaining visible to pilots. This mitigation can be achieved through the selection of lights with specific optical characteristics or the use of shields that block light below a certain angle from the horizontal.

According to ICAO guidelines as detailed in Section 3.2, for *medium- and high-intensity obstacle lights* (Table 6-3 shown in Figure 3 on page 14), the *2000 cd* benchmark intensity has specific requirements for visibility and beam spread. For this benchmark, the minimum intensity of *1500 cd* at the specified angles ensures compliance. This mitigation is achieved through narrow vertical beam spreads of *3°*, typically ranging from -1° to +2°, as reiterated in NatureScot's guidance. Achieving precise intensity reductions at different angles of elevation may require careful choice of light fittings and dimming technology. However, in this context, developers need not seek additional approval from the CAA as long as the lights meet ICAO's minimum intensity and vertical beam spread requirements.

The ICAO guidance also emphasises the need for *360° horizontal* visibility around obstacles, which can be achieved by placing light fixtures to ensure no part of the structure, such as turbine hubs, obstructs visibility from approaching aircraft. Vertical directional intensity mitigation can be an effective way to reduce light impact on receptors, especially at lower elevations, ensuring that the lighting is sufficiently visible to pilots at vertical angles without excessive light spill above or below the specified angles.

4.3.2 Implementation

Visible aviation lighting will be implemented that minimises light spill downwards whilst satisfying 2,000cd lighting ICAO requirements of 1,500cd at the height of the nacelle and 750cd one degree below the nacelle.

4.4 Reduced Light Intensity in Good Visibility

4.4.1 Justification

As detailed in Section 3.3 of this report, paragraph 4g of the UK CAA Policy Statement means that wind farms can be fitted with a visibility sensor that reduces the intensity of the nacelle lights significantly when the visibility meets the specified criteria (greater than 5km). Effectively this allows Medium Intensity Lights (2000 Candela) to be reduced to Low Intensity Lights (200 Candela) during good visibility:

"If the horizontal meteorological visibility in all directions from every wind turbine generator in a group is more than 5 km, the intensity for the light positioned as close as practicable to the top of the fixed structure required to be fitted to any generator in the windfarm and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type."

4.4.2 Implementation

Any wind turbines with visible lighting implemented will employ this feature, ensuring that lighting intensity is reduced when visibility conditions permit, thereby minimising potential visual impacts.

4.5 Infra-Red Lighting

4.5.1 Justification

Infra-red (IR) light is invisible to the naked eye but can be detected using equipment like night-vision goggles, which are commonly used by military pilots during night time training flights. As outlined in Section 3.4, the MoD states that:

*a. **Infra-Red (IR) Lighting**: MOD is cognisant that the majority of military night low flying is now conducted with the aid of aircrew night vision goggles (NVGs) … the specification required is detailed Appendix 1 to this Annex. When requesting lighting on turbines, MOD will specify IR lighting as an option **wherever possible** in the interests of public amenity.*

***Visible Lighting**: There are circumstances where IR lighting is incompatible with the military operations.*

The MoD has also specifically requested that cardinal turbines are fitted with MoD-accredited IR lighting (see Section 1.3).

4.5.2 Implementation

The lighting scheme will propose that the cardinal wind turbines are fitted with IR lighting alongside the visible aviation lighting to comply with MoD requirement.

4.6 Controlled Lighting

4.6.1 Aircraft Detection Lighting Systems

For Aircraft Detection Lighting Systems (ADLS), also known as Radar Controlled Lighting, a bespoke radar is typically installed at an elevated location in or near to the wind development such that it can detect approaching aircraft. The radar can differentiate between the turbines and the aircraft. If the radar detects an aircraft near to the wind development at night time the lights are turned on. The lights are then turned off when the aircraft moves beyond a specified distance from the wind development.

This is a rapidly developing field for mitigating the effects of nighttime aviation lighting. A strategy like this would significantly reduce the anticipated lighting impacts, as lights would only be triggered infrequently for rural developments. However, radar-controlled lighting is a costly solution and while it is worth investigating, the necessary legislation and technology may not yet be viable for use as a mitigation strategy for the Proposed Varied Development.

As this mitigation solution is yet to gain a legal basis in the UK, the lighting scheme has focused on the mitigation options in the prior sections. However, this approach could be explored post-consent should it become a more feasible solution in the UK, as it would minimise light pollution as much as possible whilst ensuring aviation safety. The CAA has indicated with previous developments that it is minded to accept a case for such a system to be employed if the technology is approved for use within the required timescales.

For reference, providers of radar-controlled lighting are detailed in subsections 4.6.2 to 4.6.5.

4.6.2 Terma

The Terma solution utilises[4] an X Band SCANTER radar to detect aircraft approaching the windfarm, illuminating the turbines when required. Terma states that its solution is certified for deployment in the USA, Germany and Denmark[5]. The system is installed and operational at a wind farm in Brandenburg[6] with six 200 metre turbines.

4.6.3 Vestas InteliLight

The Vestas InteliLight solution utilises[7] a radar with an instrumented range of up to 36 kilometres. Approaching aircraft distance, speed and heading are analysed to facilitate an automatic assessment of whether to switch the aviation lights on.

4.6.4 PARASOL

The PARASOL solution utilises[8] broadcast signal from DVB-T2, comparing the original signal and the received signal to determine whether a plane is in the area. The system is reported to have received accreditation from German Air Traffic Control (DFS).

4.6.5 DeTect

DeTect has developed[9] the HARRIER Aircraft Detection Lighting System, which provides 360 degree radar surveillance to activate aviation lighting when required. The DeTect system claims to meet or exceed all regulatory requirements of the Federal Aviation Administration in the USA.

4.6.6 Pilot Activated Lighting (PAL)

Pilot Activated Lighting (PAL), also referred to as Pilot Controlled Lighting (PCL) is a lighting solution that allows for pilots to control lighting located at an airport or on wind turbines or any other obstruction. PAL would require input from a pilot, whereas radar-controlled lighting is a technology solution that does not require human input and can be automated.

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[4] Information taken from Terma website, accessed December 2021.

[5] It is Pager Power's understanding that Terma is the closest supplier to getting approval in the UK.

[6] Rasmussen, K, *First Wind Farm Obstruction Light Control project from Terma approved and operational*, International Cooperation on Airport Surveillance (last accessed December 2021, http://www.icas-group.org/wp/first-wind-farm-obstruction-light-control-project-from-terma-approved-and-operational/)

[7] Information taken from Vestas website, accessed December 2021.

[8] Information taken from a press release via the Fraunhofer website, accessed December 2021.

[9] Information taken from DeTect website, accessed December 2021.

5 RECOMMENDED LIGHTING SCHEME

5.1 Recommended Lighting Scheme

As per Section 4.1, lighting will be implemented on selected cardinal turbines so that the Proposed Varied Development's spatial extent is discernible regardless of the approach bearing. Seven of the 18 proposed turbines have been deemed cardinal turbines, and will therefore be equipped with visible and IR lighting. In determining the cardinal turbines, the following draft CAP 764 guidance criterion have been met:

- Wind turbines above the 10° plane extending from the lit nacelles are lit (paragraph 4.6.f);
- The corners of the wind farm are lit and that any change of direction of the perimeter of the wind farm can be recognised (paragraph 4.6.g);
- Maximum of 1.8km between two lit turbines (paragraph 4.6.h).

And the following have not been met:

- 900m spacing between turbines at the perimeter (paragraph 4.6.g);
- Advisory 200m perpendicular line extending from the line connecting the two outer wind turbines – only one wind turbine fails by 20m (paragraph 4.6.g **Note**[10]).

Although not all the criterion have been met, the Proposed Varied Development is not understood to be in a location with regular general aviation activity given the significant distance from any aerodromes and due to the position within the TTA (see Section 2.4). This means that it will be an unappealing location for general aviation to fly, particularly under VFR and at night, and the identification of the Proposed Varied Development through visible lighting is less likely to be needed and it is anticipated that the reduced lighting will not materially affect aviation risk.

The lit turbines will therefore be equipped with 2,000cd visible and IR lighting on the nacelles. A second 2,000 candela light will be fitted to the cardinal turbines, to act as a back-up in the event of failure of the main light. To further reduce lighting, visibility sensors will be employed to dim medium-intensity lights from 2,000cd to 200cd when visibility is 5km (or greater), in line with CAA policy (see Section 3.3) and NatureScot's preference.

Given that the Proposed Varied Development is understood to be situated away from areas of regular general aviation activity, the reduced lighting scheme excludes the mid-tower low-intensity (32 cd) lights. This approach aligns with NatureScot guidance, developed jointly with the Scottish Government and informed by the Aviation Lighting Working Group, which includes representatives from the MoD and the CAA.

It is also recommended that light 'spill' caused by aviation lighting is minimised, as outlined in Section 4.2. Adjusting the narrow vertical beam spreads of 3° (-1° to +2°), ensures visibility to

[10] This value comes from an advisory note to aid perimeter interpretation and is not understood to have the same importance as the other criterion.

pilots at or above nacelle level while significantly reducing downward spill. Shields or optical adjustments can ensure light does not unnecessarily spill beyond required angles, maintaining compliance with the CAA and ICAO's omnidirectional horizontal visibility requirements without excessive illumination. This mitigation is subject to commitment from the developer.

By combining selective turbine lighting, intensity reduction in good visibility, as well as mitigating light 'spill', the lighting scheme aligns with aviation regulatory requirements whilst minimising lighting.

5.1.1 Lighting Plan

The wind turbine layout and proposed lighting arrangement are shown in Figure 5 below. Cardinal turbines, chosen to indicate the spatial extent of the development and highest elevated turbine (T9), are circled in red. All other turbines will be unlit.

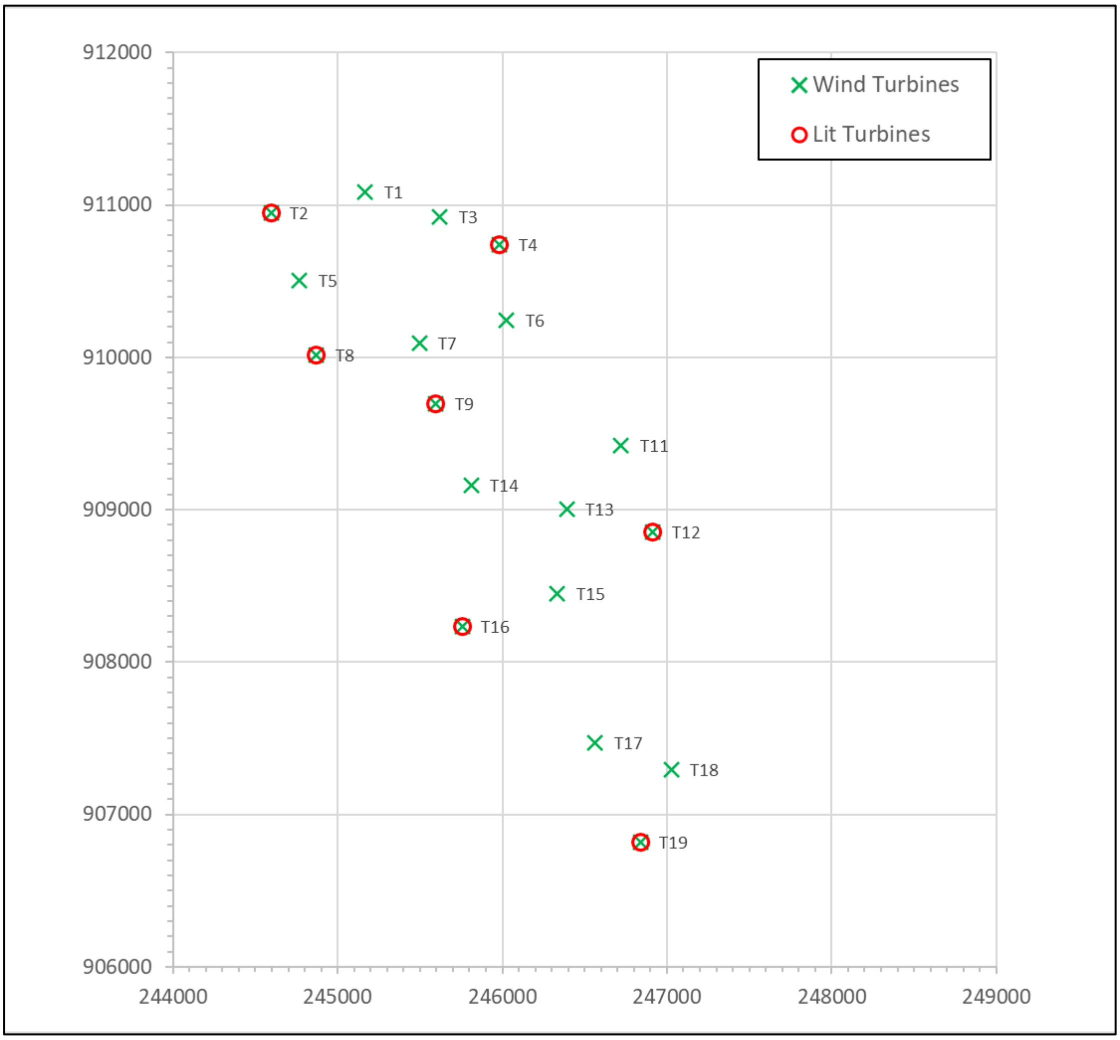

Figure 5 *Proposed lighting arrangement (cardinal turbines)*

The 3D representation of the aviation lighting plan is shown in Figure 6 to Figure 9 on the following pages.

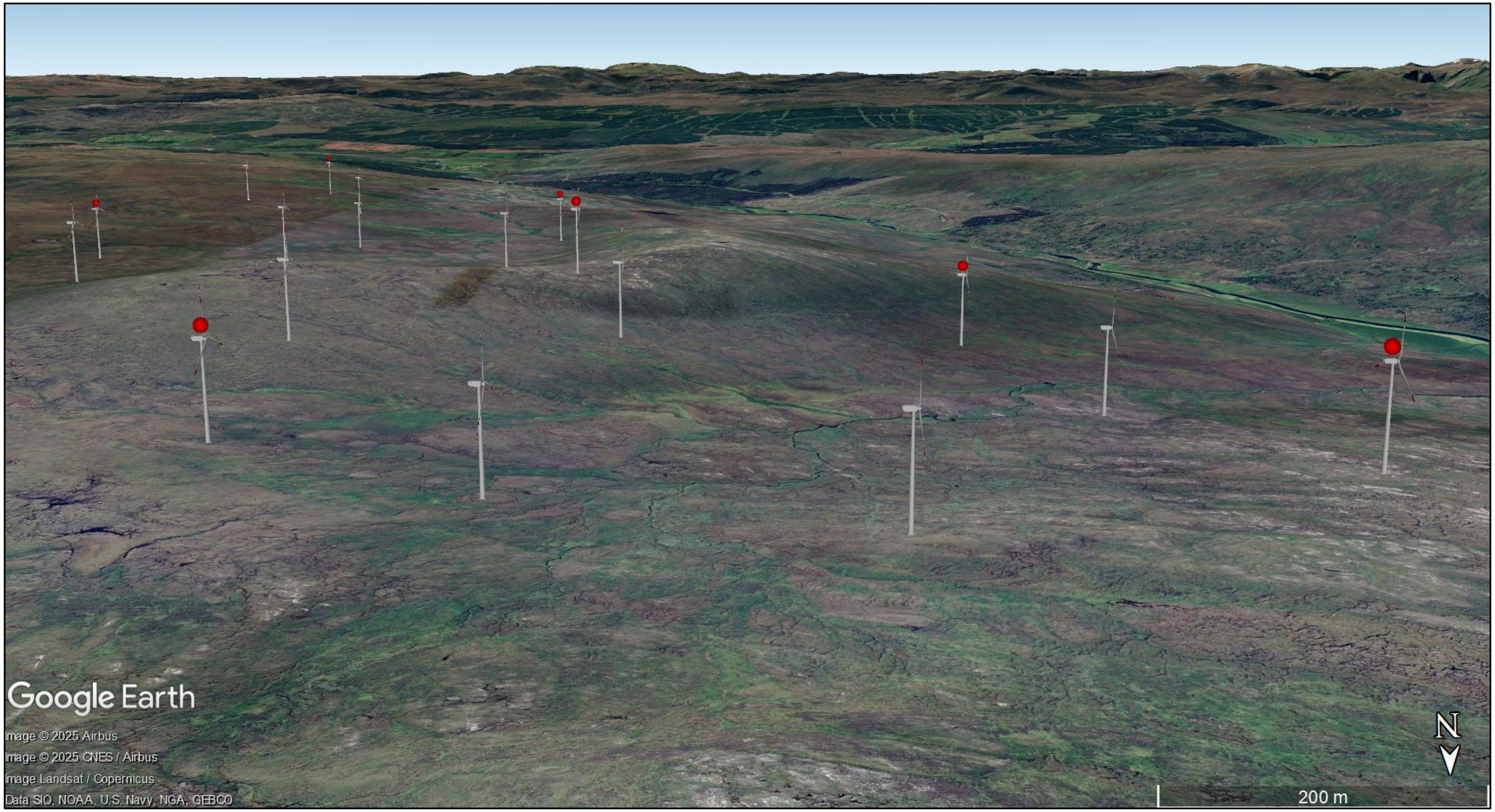

Figure 6 *Lighting plan 3D representation – north*

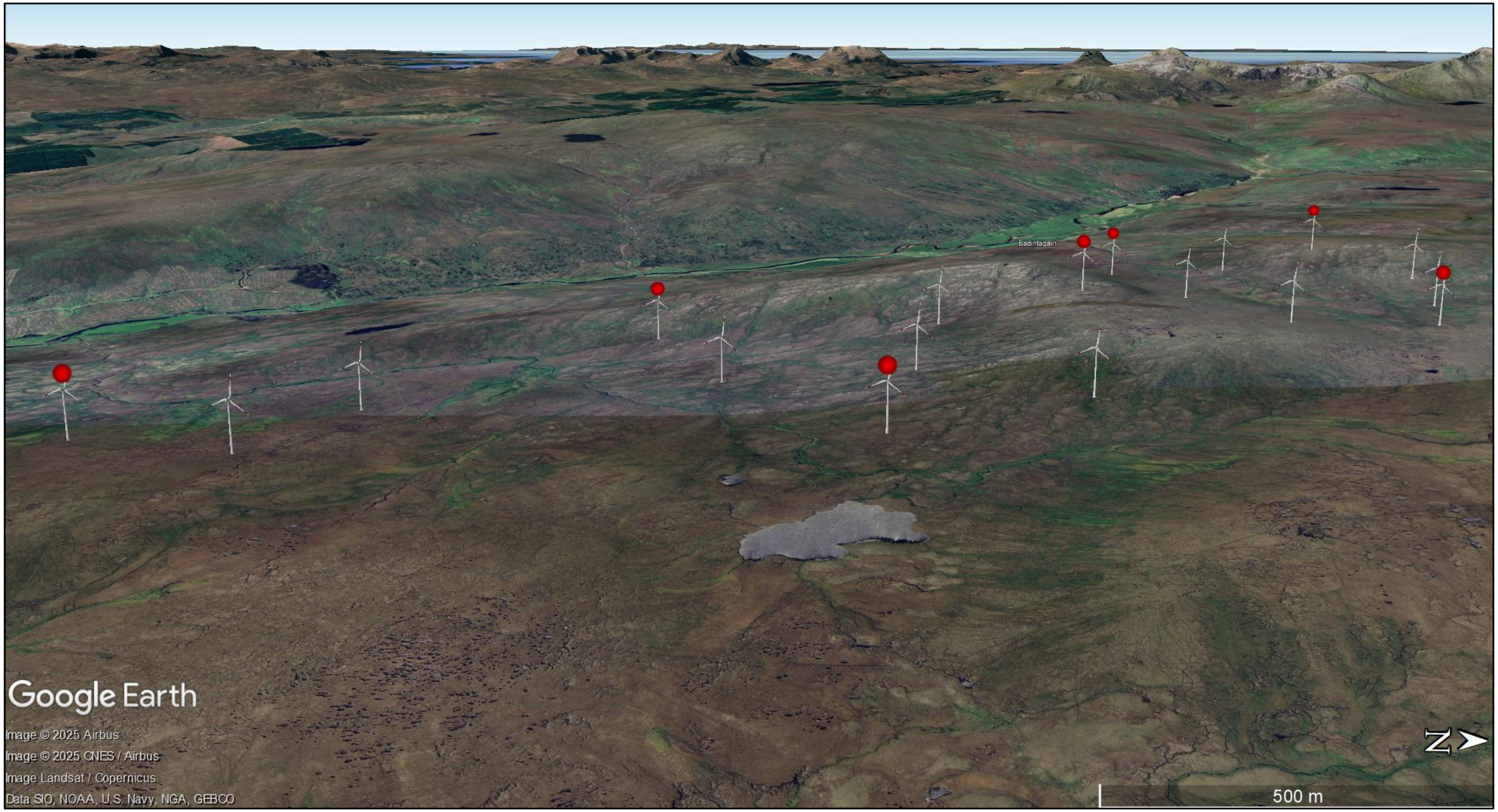

Figure 7 *Lighting plan 3D representation – east*

Figure 8 *Lighting plan 3D representation – south*

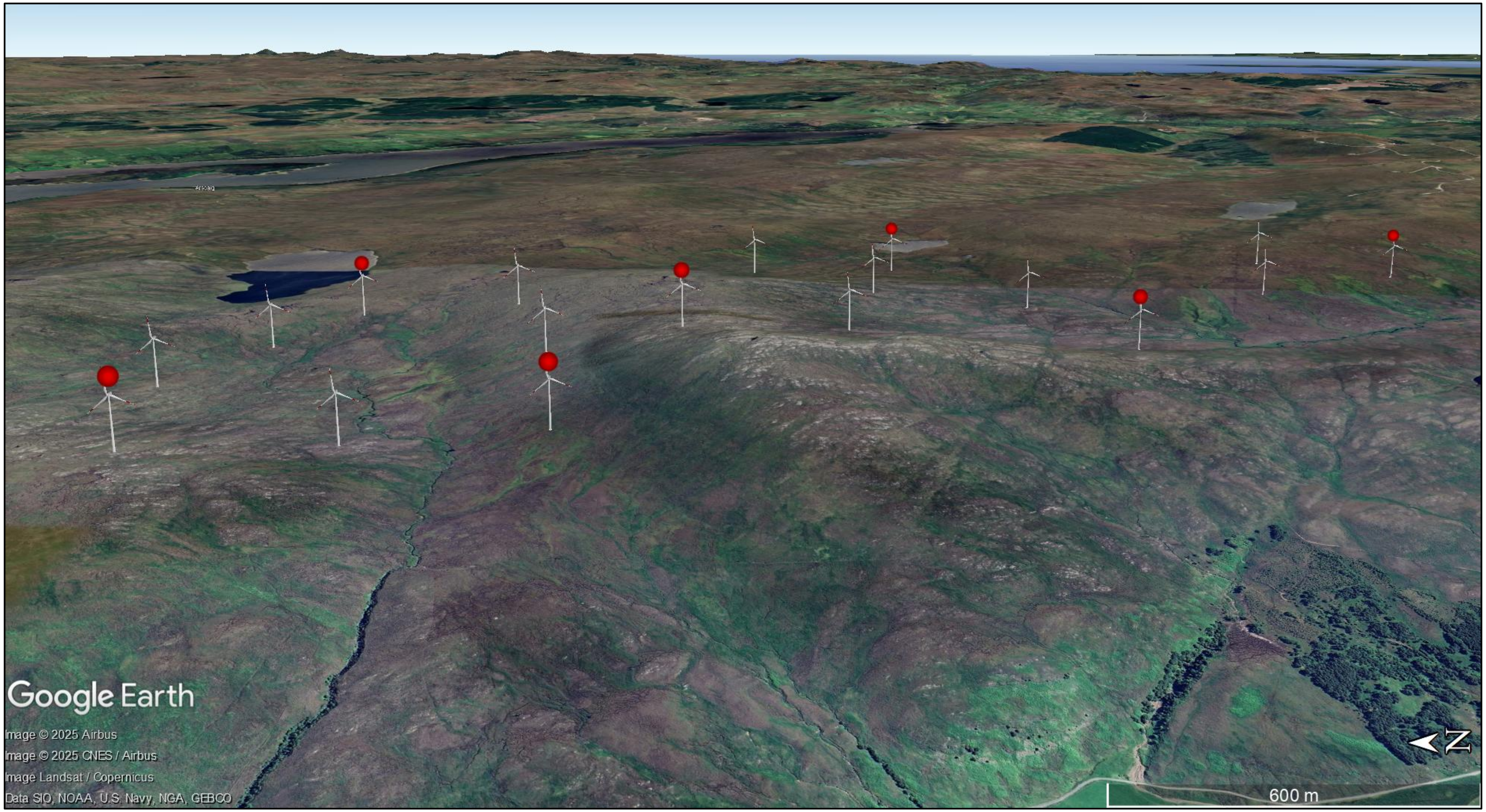

Figure 9 *Lighting plan 3D representation - west*

5.1.2 Lighting Schedule

Table 3 below and on the following pages presents the proposed lighting schedule, including the location, type and intensity of the lighting for each wind turbine.

Turbine	Classification	Justification	Nacelle	Tower
T1	Interior	Although T1 is positioned beyond the lateral extents of T2 and T3, it has been designated as an interior wind turbine as the perpendicular line extending from the line connecting the wind turbines is 218m Although greater than 200m recommendation in CAA guidance, the airspace in which the Proposed Varied Development is located is not predicted to be sensitive given that the closest aerodrome is a microlight site 25.3km to the east. The vertical prominence test (10° plane above the horizontal from the lit nacelles) is met	Nil	Nil
T2	Cardinal	Marks the western extent for aircraft approaching from the north and northern extent for aircraft approaching from the west	2,000cd red steady Reducing to 200cd red steady when visibility is 5km (or greater)[11] IR lighting	

[11] It is recommended that visibility sensors are installed at the north, south, east, and west of the Proposed Varied Development to determine visibility.

Turbine	Classification	Justification	Nacelle	Tower
T3	Interior	Although T3 is positioned beyond the lateral extents of T2 and T4, it has been designated as an interior wind turbine as the perpendicular line extending from the line connecting the wind turbines is less than 200m	Nil	
T4	Cardinal	Marks the eastern extent for aircraft approaching from the north	2,000cd red steady Reducing to 200cd red steady when visibility is 5km (or greater) IR lighting	Nil
T5	Interior	Does not mark the extent of the Proposed Varied Development for aircraft approaching in any direction The distance between the two closest lit wind turbines (T2 and T8) is less than 1.8km	Nil	
T6	Interior	Does not mark the extent of the Proposed Varied Development for aircraft approaching in any direction The distance between the two closest lit wind turbines (T4 and T9) is less than 1.8km		

<table>
<tr><th>Turbine</th><th>Classification</th><th>Justification</th><th>Nacelle</th><th>Tower</th></tr>
<tr><td>T7</td><td>Interior</td><td>Does not mark the extent of the Proposed Varied Development for aircraft approaching in any direction
The distance between the surrounding lit wind turbines (T4, T8 and T9) is less than 1.8km</td><td></td><td></td></tr>
<tr><td>T8</td><td>Cardinal</td><td>Marks the western extent for aircraft approaching from the north</td><td>2,000cd red steady
Reducing to 200cd red steady when visibility is 5km (or greater)
IR lighting</td><td rowspan="3">Nil</td></tr>
<tr><td>T9</td><td>Cardinal</td><td>The turbine with the highest elevation and therefore marking the vertical extent of the Proposed Varied Development
Ensures the distance between a number of turbines is less than 1.8km</td><td>2,000cd red steady
Reducing to 200cd red steady when visibility is 5km (or greater)
IR lighting</td></tr>
<tr><td>T11</td><td>Interior</td><td>Although T11 is positioned beyond the lateral extents of T4 and T12, it has been designated as an interior wind turbine as the perpendicular line extending from the line connecting the wind turbines is less than 200m</td><td>Nil</td></tr>
</table>

Turbine	Classification	Justification	Nacelle	Tower
T12	Cardinal	Marks the eastern extent for aircraft approaching from the north	2,000cd red steady Reducing to 200cd red steady when visibility is 5km (or greater) IR lighting	
T13	Interior	Does not mark the extent of the Proposed Varied Development for aircraft approaching in any direction The distance between the surrounding lit wind turbines (T11, T12 and T16) is less than 1.8km	Nil	Nil
T14	Interior	Does not mark the extent of the Proposed Varied Development for aircraft approaching in any direction The distance between the surrounding lit wind turbines (T9, T11 and T16) is less than 1.8km		
T15	Interior	Does not mark the extent of the Proposed Varied Development for aircraft approaching in any direction The distance between the two closest lit wind turbines (T12 and T16) is less than 1.8km		

<table>
<tr><th>Turbine</th><th>Classification</th><th>Justification</th><th>Nacelle</th><th>Tower</th></tr>
<tr><td>T16</td><td>Cardinal</td><td>Marks the western extent for aircraft approaching from the south</td><td>2,000cd red steady
Reducing to 200cd red steady when visibility is 5km (or greater)
IR lighting</td><td></td></tr>
<tr><td>T17</td><td>Interior</td><td>Does not mark the extent of the Proposed Varied Development for aircraft approaching in any direction
The distance between the two closest lit wind turbines (T16 and T18) is less than 1.8km</td><td>Nil</td><td rowspan="3">Nil</td></tr>
<tr><td>T18</td><td>Cardinal</td><td>Marks the eastern extent for aircraft approaching from the south</td><td rowspan="2">2,000cd red steady
Reducing to 200cd red steady when visibility is 5km (or greater)
IR lighting</td></tr>
<tr><td>T19</td><td>Cardinal</td><td>The southernmost wind turbine marking the southern extent for aircraft approaching from the south, east and west</td></tr>
</table>

Table 3 *Proposed lighting schedule*

APPENDIX A – WIND TURBINE DATA

Wind Turbine Data

The wind turbine locations and assessed altitudes are presented in the table below.

Ref	Easting	Northing	Current Wind Turbine Altitude (m amsl)
T01	245163.952	911082.989	528.5
T02	244595.048	910949.995	537.3
T03	245617.670	910921.998	519.2
T04	245979.918	910739.931	534.5
T05	244768.059	910506.254	486.3
T06	246023.000	910241.000	562.3
T07	245495.008	910094.972	528.7
T08	244871.843	910017.815	487.5
T09	245597.429	909695.303	578.1
T11	246722.000	909421.000	521.5
T12	246915.000	908855.000	492.9
T13	246390.000	909004.000	513.7
T14	245810.499	909163.287	506.7
T15	246333.995	908448.012	462.3
T16	245756.009	908236.996	444.8
T17	246564.000	907472.000	455.2
T18	247025.000	907297.000	489.2
T19	246838.006	906821.004	465.2

Assessed wind turbine data

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