Technical Appendix 13.1: Glentarken Turbine Site: Basic Lighting Report

Wind Farm Low Flying Aviation Consultants Ltd

Glentarken Turbine Site: Basic Lighting Report

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Date 22 August 2024

Introduction

SSE is proposing to build a wind farm on the hills 4km to the north of Loch Earn in Perthshire. The site is located on the south western slopes of Creag Ruadh which borders Glen Tarken leading to Loch Earn.

From a Civilian perspective the Glentarken site is not close to any airports/airfields and sits in unrestricted (Class G) airspace. Conversely, from a Military standpoint this proposed location is within MOD Low Flying Area (LFA) 14. At night this area converts to Night Allocated Region (NAR) 1A which is a busy training area primarily reserved for low flying fast jets in the hours of darkness. Fast jet and tactical transport aircraft will operate down to 250ft (75m) above ground level (agl), and helicopters down to 30ft, (9m).

Helicopters operating in the Loch Earn vicinity will use the A85 valley for transit by day and night. These helicopters will include: Police, Ambulance, HEMS, Coast Guard and various Military formations. Due to the Glentarken location in NAR 1A, and close to the A85, the turbine site will require a comprehensive obstruction lighting arrangement that includes both visible and infra-red obstruction lights.

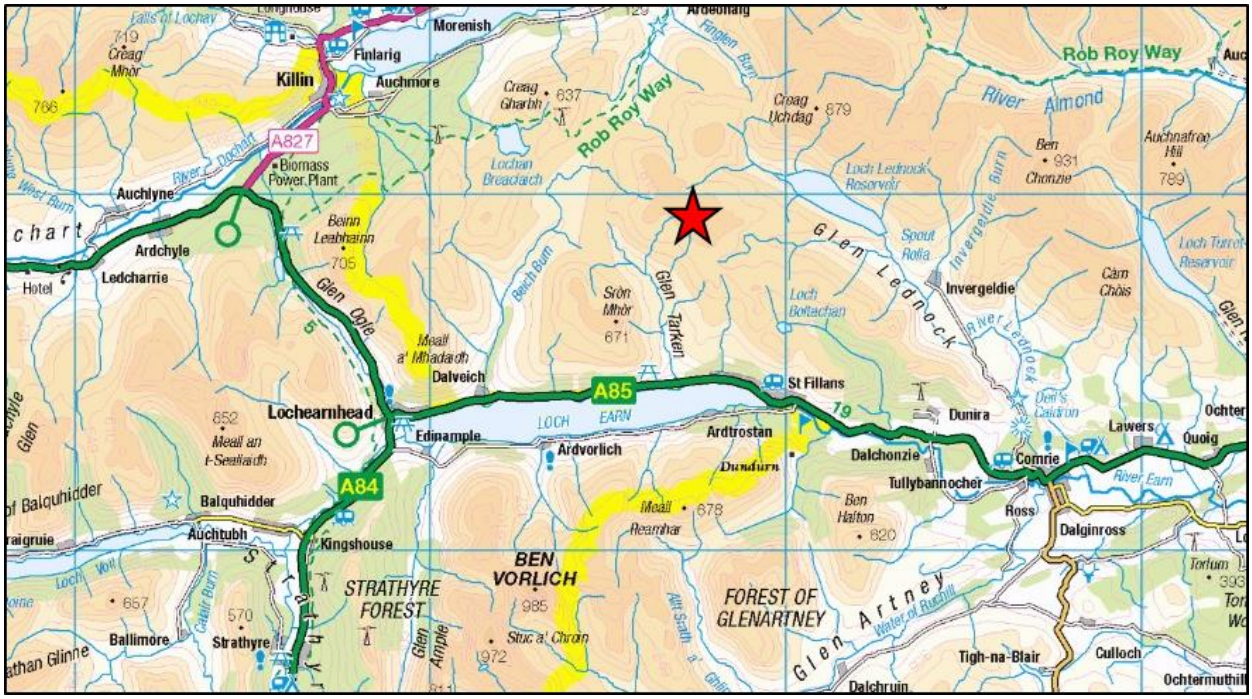

Figure 1: Glentarken Turbine Site Location

Proposed Lighting Situation

The purpose of this Lighting Report is to generate an Obstruction Lighting Proposal which meets the twin requirements, as below:

- To keep the visible ANO lighting element as low as is safe to do so in order to minimise the light impact on the local environment.
- Introduce a comprehensive Infra-Red lighting arrangement for military and civilian low-flying aircraft and helicopters operating at night.

Glentarken Wind Turbine Site

Glentarken Turbine Table					
Turbine	Easting	Northing	Hub Ht	Rotor Dia	Tip Ht
T01E	265223	729628	99m	162m	180m
T02E	266658	730054	99m	162m	180m
T03E	267291	729514	99m	162m	180m
T04E	266515	729589	99m	162m	180m
T05E	266047	730060	99m	162m	180m
T06E	266176	728779	99m	162m	180m
T08E	267965	727717	99m	162m	180m
T10E	267615	728614	99m	162m	180m
T11E	265270	730141	99m	162m	180m
T16E	265826	729610	99m	162m	180m
T20	267133	728410	99m	162m	180m
T21	266664	728991	99m	162m	180m

Figure 2: Glentarken Turbine Details

Starting Assumptions and Lighting Criteria

- Glentarken will be assessed as below/in Class G 'en route' airspace insofar as ANO visible obstruction lighting is concerned.
- Local airspace constraints will be considered for their potential impact on the site.
- Expected CAA and MOD dispensations will be assessed for the site.
- The visible lighting component of the lighting proposal will be developed in accordance with the latest (draft update) CAA CAP 764.
- To accommodate MOD requirements, and other lower airspace night operators, the site will be assessed for NVG compatible lighting in accordance with MOD published obstruction lighting specifications.
- Where possible, the recommended lighting configuration will be optimised to reduce light impact on the local area.
- The Glentarken wind turbine proposal is for twelve wind turbines up to 180m to tip.

CAA-ANO Red 2000/200cd Lighting

The CAA requires:

- That all 'string perimeter' (see black dotted line) turbines be lit unless removing a light will leave a gap of less than 900m total between the remaining lit turbines (This distance is sometimes negotiable/extendable by application to the CAA).

- That any turbine within/behind 200m of a 'string perimeter' be lit unless the distance between adjacent turbines is less than 900m total (Again, this distance/requirement is negotiable by application to the CAA).

- That any unlit turbine does not exceed a 10° up-slope from adjacent lit turbines. Note: all unlit turbines conform to this requirement.

Applying these criteria, <u>without expected dispensations</u>, dictates that nine turbines will require ANO lighting.

Turbines with 2000/200cd Lights: T01E, T02E, T03E, T05E, T06E, T08E, T10E, T11E and T20

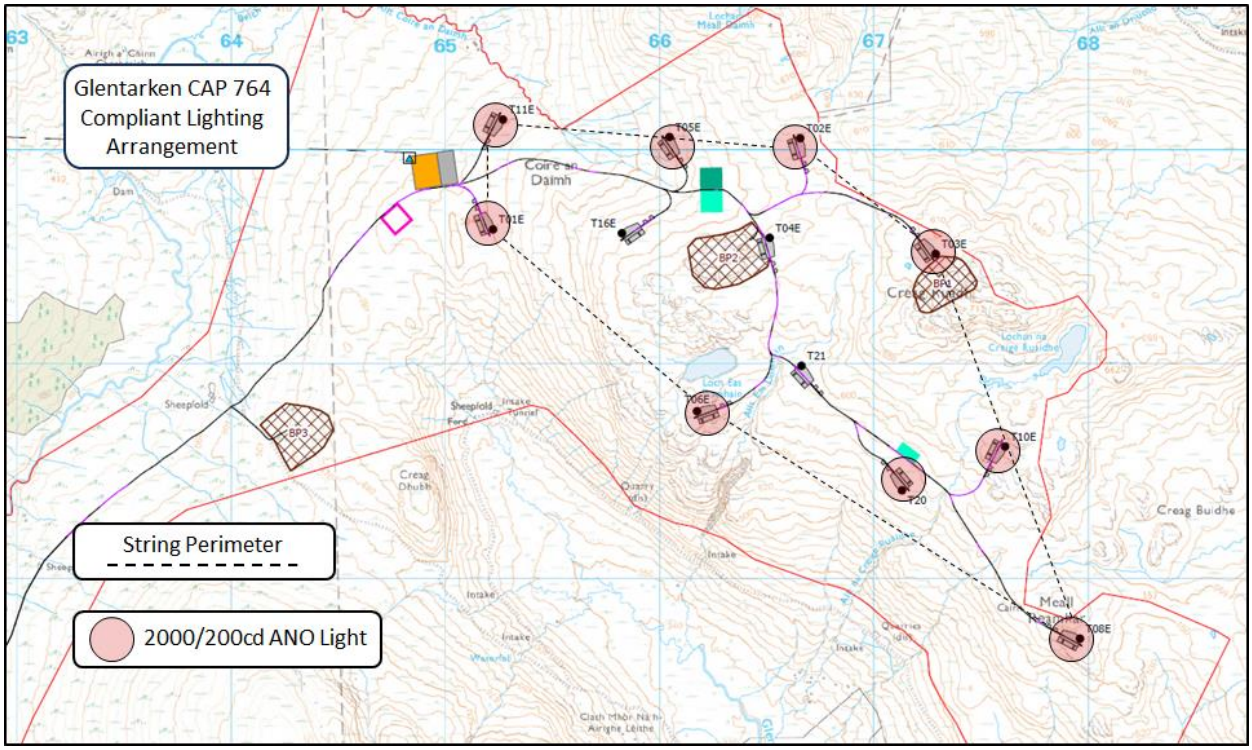

Figure 3: CAA-ANO Visible Red Lighting Requirements.

CAA-ANO Red 2000/200cd Lighting - Reduced Lighting Option

The military have operated at low level at night for many decades now using night vision equipment. In more recent times, the last decade or so, more civilian operators have moved to night low level using suitable night vision equipment: night vision goggles (NVGs) etc. Such civilian operators include Coast Guard (CSAR), Police, Helicopter Emergency Medical Services (HEMS) and Air Ambulance.

Although, in the past, some night operators would fly at night at low level without night equipment (on carefully pre-planned exercises pre-flown by day) such events have been overtaken by the ever-widening use of night vision equipment. As a result, operators who now night fly without night vision equipment will fly at or above 'safety altitude' when not under the guidance of Air Traffic Control.

Aircraft operating at safety-altitude or above, and depending upon the protocol adopted or phase of flight, the safety-altitude used will be 1000ft (300m), 1500ft (450m) or 2000ft (600m) above the local terrain/highest obstacle, this includes the turbine tip heights. Aircraft/helicopters flying as such, will only need enough visible lights to define the wind farm and its size/shape/perimeter.

Accordingly, the regular outline of the Glentarken turbine site could be identified with four visible red lights on turbines T03E, T06E, T08E and T11E forming an irregular diamond.

Turbines with 2000/200cd Lights: T03E, T06E, T08E and T11E

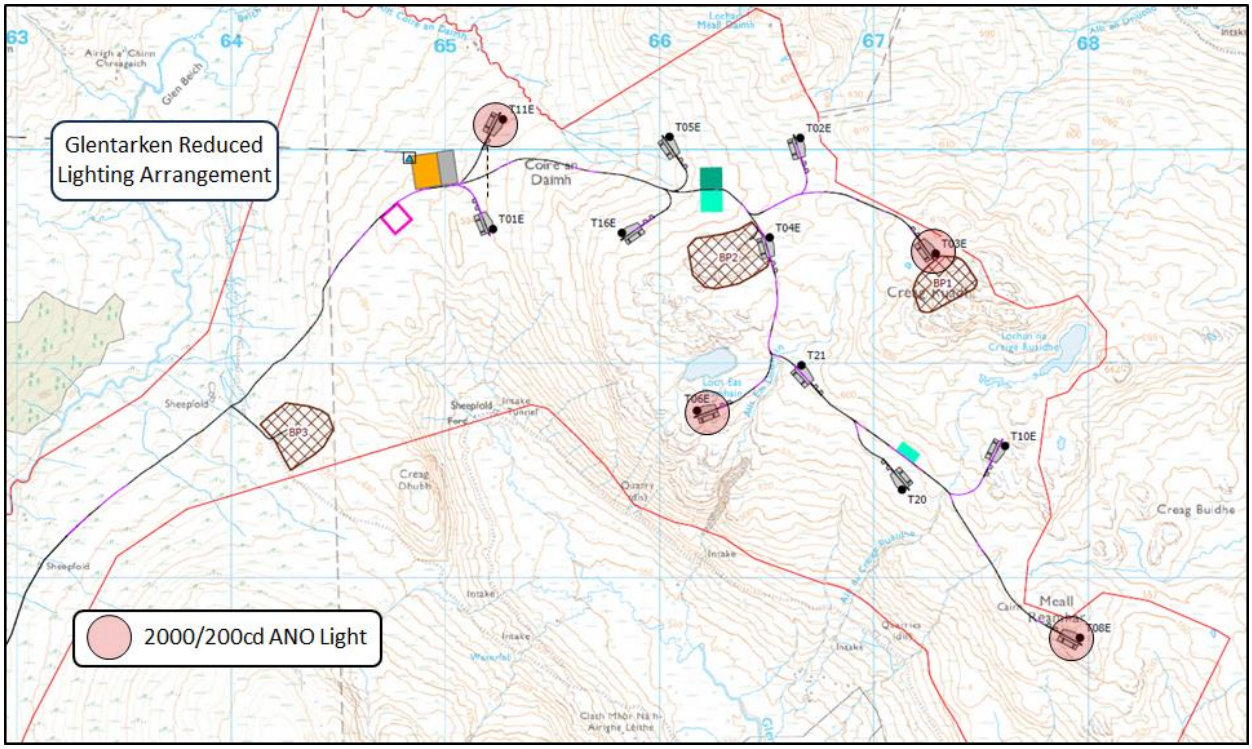

Figure 4: CAA-ANO Visible Red - Reduced Lighting.

MOD IR Lighting

The MOD requires:

- That all 'compound-perimeter' turbines (see diagram blue dotted line) be lit unless removing a light will leave a gap of less than 500m between the remaining perimeter lit turbines. Note: At this site, the CAA 'string' and MOD 'compound' perimeters differ only slightly.

- That any dominant turbine, by location or height, be lit. Note: here, the corner and highest turbines are lit. Indeed, all turbines are lit.

- Glentarken does not meet the MOD small site criterion which caters for approaching 'site-depth-perception' and helicopters passing through larger turbine sites, as opposed to going around. Accordingly, Glentarken central turbine (T04E) will also require lighting.

Applying this criterion dictates that all turbines of the Glentarken site will require IR lighting. Twelve turbine hub lights in total.

Infra-Red Lighting on: T01E, T02E, T03E, T04E, T05E, T06E, T08E, T10E, T11E. T16E, T20 and T21

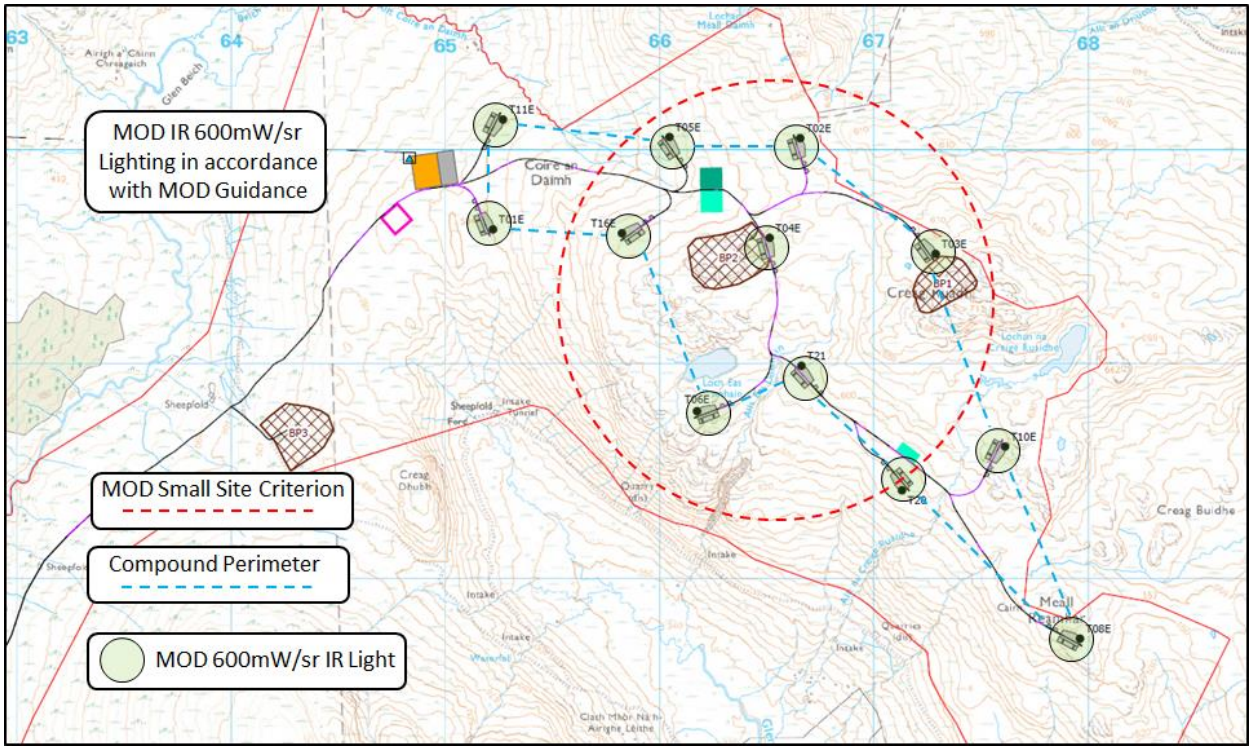

Figure 5: MOD IR Lighting Requirements.

Night Vision Goggles/Devices (NVG/D) will automatically adjust their internal-gain if they 'see' lots of IR light. This prevents 'blooming and flare-up' of the image presented to the pilot. However, turning down the gain means unlit objects fade into the background; this can be terrain, trees, hills etc; most undesirable and clearly auto-gain-down is best avoided. Nonetheless, pilots/crews train to work through such events. Where there is a high concentration of IR lights, or closely set IR lights, the MOD may request fewer IR lights to help avoid gain-down. However, although potentially relevant here, MOD is not expected to apply this reduction at Glentarken.

Combined CAA ANO and MOD IR Lighting Proposal for Glentarken

Glentarken Turbine Table							
Turbine	Easting	Northing	Hub Ht	Rotor Dia	Tip Ht	CAA ANO	MOD IR
T01E	265223	729628	99m	162m	180m		600mW/sr
T02E	266658	730054	99m	162m	180m		600mW/sr
T03E	267291	729514	99m	162m	180m	2000/200cd	600mW/sr
T04E	266515	729589	99m	162m	180m		600mW/sr
T05E	266047	730060	99m	162m	180m		600mW/sr
T06E	266176	728779	99m	162m	180m	2000/200cd	600mW/sr
T08E	267965	727717	99m	162m	180m	2000/200cd	600mW/sr
T10E	267615	728614	99m	162m	180m		600mW/sr
T11E	265270	730141	99m	162m	180m	2000/200cd	600mW/sr
T16E	265826	729610	99m	162m	180m		600mW/sr
T20	267133	728410	99m	162m	180m		600mW/sr
T21	266664	728991	99m	162m	180m		600mW/sr

Figure 6: Final Lighting Table.

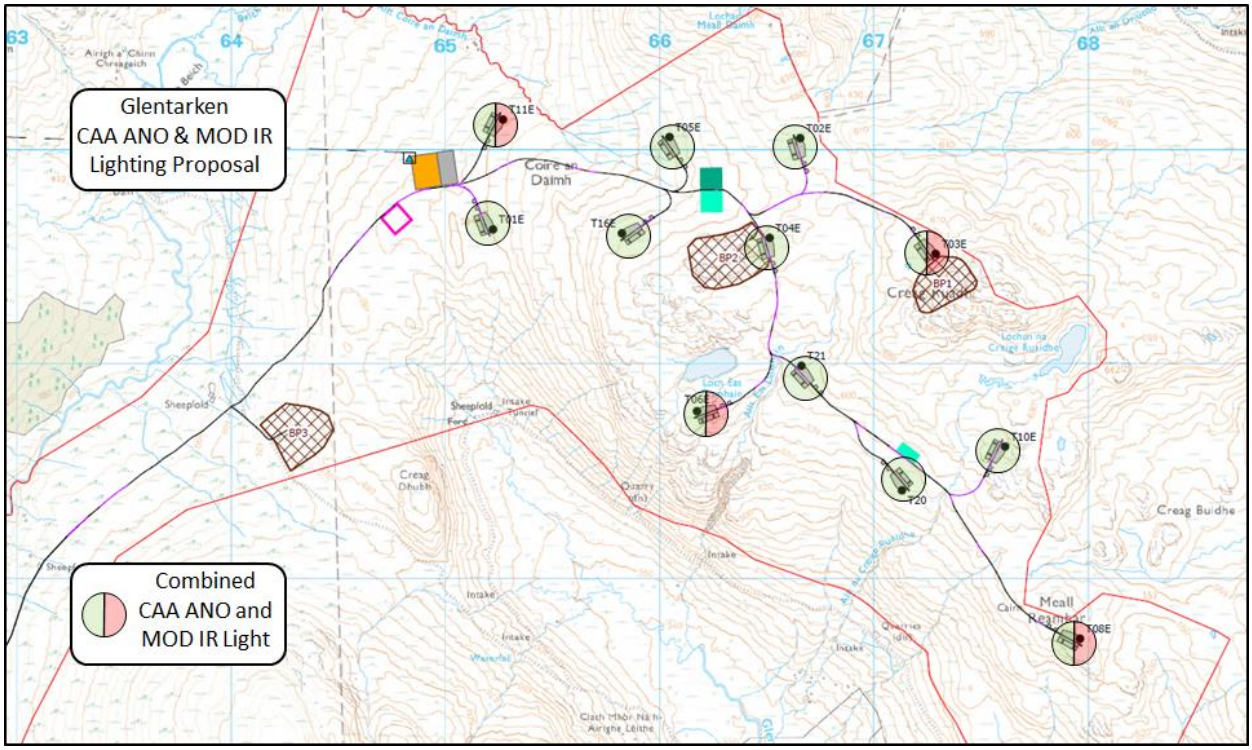

Figure 7: Final Lighting Proposal.

ANO Light Specifications

Medium Intensity Hub Mounted Lights

The ANO 2000/200cd Lights will conform to the ICAO specification as set-out in Annex 14 Table 6-3.

The lights will also be controlled such that when the met visibility is greater than 5km in all directions from all turbine hubs, the lights will be reduced to 200cd (10% of normal power).

It is suggested that visibility meters be fitted to turbines T08E and T11E at opposite ends of the site.

This reduction in power will not apply to MOD IR Lights.

ICAO Annex 14 Table 6-3 (excerpt)

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)
2000	2000	1500	750	3°	750	2500	1125	75	N/A	N/A

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.

Figure 8: ICAO Annex 14 Table 6-3 Medium Intensity Lighting Specifications.

Low Intensity Mid-Mast Lights

WFLFAC will request that the CAA set-aside the guidance requirement for 32cd (Type B) mid mast lights for the Glentarken turbines.

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.

Figure 9: ICAO Annex 9 Table 6-2 Low Intensity Obstacle Lights.

IR Light Specifications

The IR lights will conform to the MOD specification as set-out in MOD Lighting Guidance below.

MOD Specification IR.

IR wavelength – 750 to 900nm.
But ideally concentrated within 800 to 850nm for optimum detection by all military NVG types.

IR intensity – 600mW/sr minimum at peak flash but not above 1200mW/sr.
(Note: Typically a 300mW/sr steady burn LED IR light will generate 600mW/sr at peak flash)
This will generate a 7-8 nm NVG pick-up range - remaining above 5nm as the light ages.

Horizontal Pattern – unrestricted 360 deg.

Vertical Pattern – Minimum flash intensity of 600 mW/sr between +30 deg and -15 deg elevation.
– up to 50% reduction between +25 to +30 deg and -10 to -15 deg is acceptable.
– Maximum intensity of 1200 mW/sr for all angles of elevation.
– Vertical overspill is acceptable.

Flash Pattern – 60 flashes per min at 100-500 ms duration (ideally 250ms)

Synchronisation – all lights to be visually synchronised across a wind farm site

Figure 10: MOD Specification for IR Obstacle Lights.

Timings

The lights (IR and ANO) will be switched-on between Evening Civil Twilight and Morning Civil Twilight in accordance with the UK Almanac. Approximately 11 hours per day averaged over the year. Conversely, the lights can be switched-on/off by a suitable Lux Meter when the sun light falling on a vertical surface drops below 500 Lux. Note: this Lux Meter is different to the Met Visibility Meters mentioned earlier.

Intensity Reduction (ANO Lighting: 2000cd down to 200cd)

It is possible to take advantage of the CAA SARG Policy Statement dated 01/06/2017 and incorporate the option to reduce the hub height lighting to not less than 10% of the minimum peak intensity specified for the installation in good weather. In essence, reducing the 2000cd obstruction lights to 200cd in meteorological visibilities greater than 5km.

Note: This concession is not applicable to MOD specification IR lighting.

Accordingly, if it is possible to assess how much time the met visibility will be below 5km, it will be possible to assess how much time the lights would spend at 200cd as opposed to 2000cd. To assess historical visibility in the Glentarken area, the closest meteorological stations are at Edinburgh and Glasgow Airports. The visibility will not be identical at these three locations, but similar. They will invariably be in the same air-mass and the airports, more-or-less, bracket Glentarken by position.

Edinburgh issues historical meteorological data in the 'Met Office' format which displays the data using block graph tables. Over the page is a Met Office table of visibilities at Edinburgh across the year and averaged over a 30-year period.

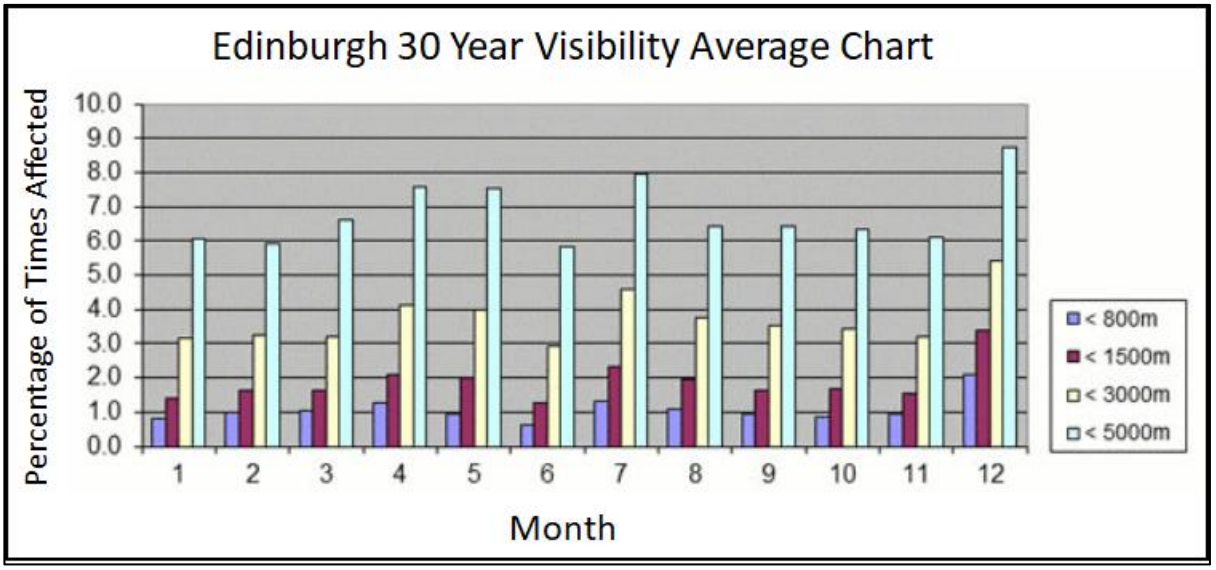

Figure 11a: Visibility Table for Edinburgh Airport (Light Blue is 5km Indicator)

This Met Office table shows us that the visibility is below 5km for an average of 7% of the times measured.

This suggests that the lights will be at **2000cd for 7% of the time and 200cd for 93% of the time**.

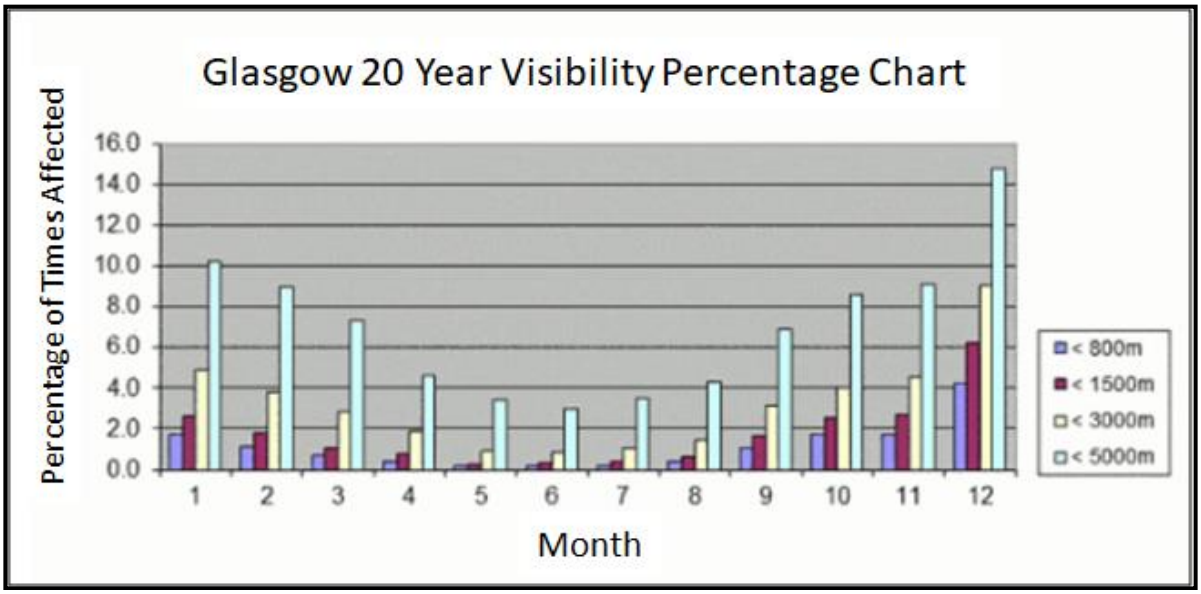

Figure 11b: Visibility Table for Glasgow Airport (Light Blue is 5km Indicator)

Similar to Edinburgh, Glasgow issues historical meteorological data across the year and averaged over a 20-year period. This Met Office table shows us that the visibility is below 5km for an average of 7% of the times measured.

This suggests that the lights will be at **2000cd for 7% of the time and 200cd for 93% of the time**.

Both Edinburgh and Glasgow record the same percentage-time figure for visibility below 5km.

Whist Edinburgh and Glasgow are not Glentarken visibilities will generally be similar in the three locations. Moreover, met visibility improves with height since the concentration of particles (dust, haze)

and liquid droplets (water) reduces with height and the air also becomes thinner. It could be argued that the Glentarken visibility would be better than that at Edinburgh and Glasgow. In addition, cloud will play its part in the observability of the obstruction lights at Glentarken. This can also be obtained from Met Office data.

Weather Obscuration.

On occasion, the visibility in the area of Glentarken will drop significantly due to the presence of cloud on the hills. If the Glentarken turbines are in cloud, then the obstruction lights will not be seen. In a similar vein, if the turbines are partially shrouded in cloud, then the light intensity will be much reduced.

Note: All heights and elevations in aviation are measured and presented in feet and not metres.

The turbines will carry the CAA/ANO lights on the turbine hub. The average height at the base of these turbines is around 1600-2300ft above mean sea level (amsl). The hub heights, for the proposed turbines will be around 330ft above ground level (agl) giving hub heights averaging around 1930-2630ft amsl.

Using these heights, it is possible to compare the light altitudes amsl with the actual cloud bases recorded by the Met Office at Edinburgh and Glasgow (over a 20/30-year period) as shown below in Figures 12a+b.

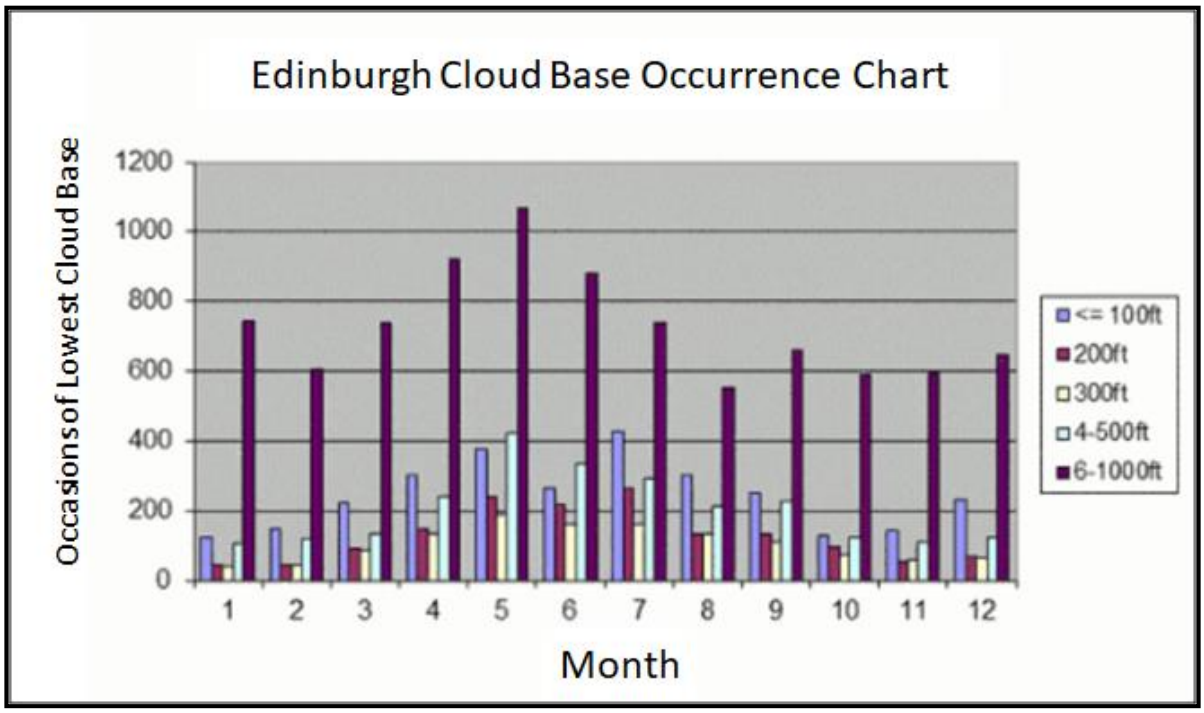

Figure 12a: Average Cloud-Base Table for Edinburgh Airport

The darker red columns (600-1000ft amsl) indicate that, on around 800 occasions a month, the cloud-base will be well below the turbine base heights and up to 2000ft below the hub light. In addition, the combined blue, red and yellow columns indicate that on a further 1000 times a month the weather would be such that the cloud would be so low that the turbines/lights would only be visible to people on the hills when very close to the turbines.

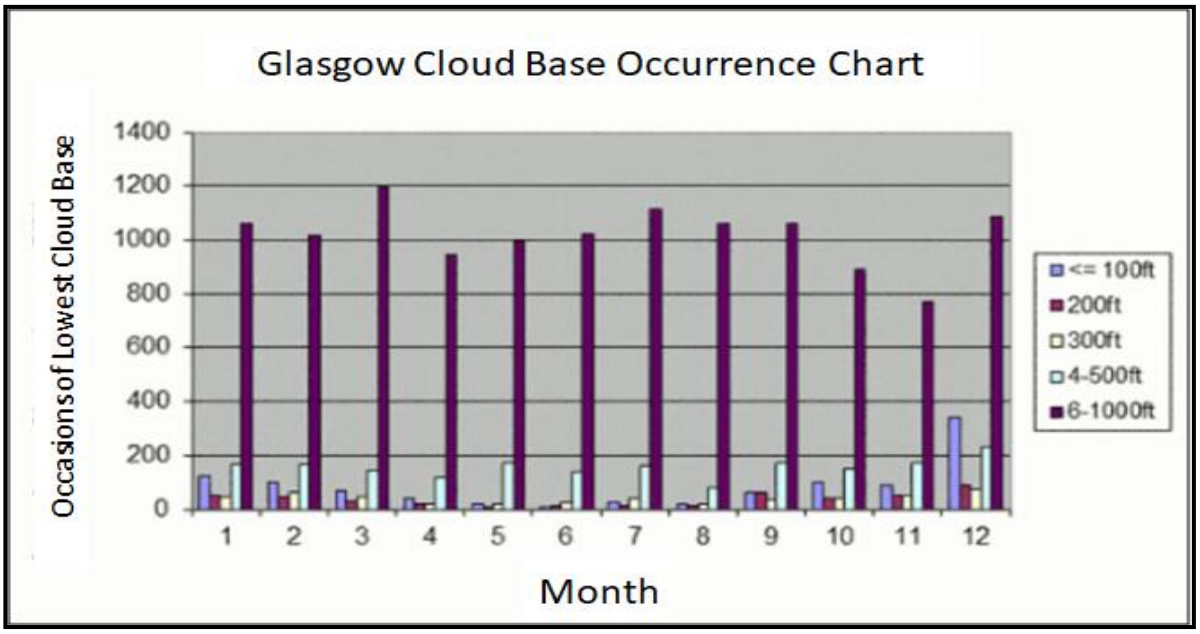

Figure 12b: Average Cloud-Base Table for Glasgow Airport

Similar to Edinburgh, the darker red columns (600-1000ft amsl) indicate that, on around 1000 occasions a month, the cloud-base will be well below the turbine base heights and up to 2000ft below the hub light. In addition, the combined blue, red and yellow columns indicate that on a further 400 times a month the weather would be such that the cloud would be so low that the turbines/lights would only be visible to people on the hills when very close to the turbines.

Edinburgh and Glasgow are not Glentarken; nonetheless, the three sites will sit, for-the-most-part, in the same air mass. In addition, meteorological statistics and science show that cloud-bases reduce in the region of hills. It could be argued that, at Glentarken, the cloud-base would, on the whole, be lower than at Edinburgh and Glasgow, thus providing even greater degree of light obscuration on more occasions per month.

Weather Obscuration Conclusion

It is most important not to try and combine the two different observations, visibility and cloud-base, into a single statement. Informal advice direct from Met Office and Airport forecasters indicates the information so gathered, should be presented as follows:

> *Meteorological observations suggest that the turbine hubs/lights will be obscured on 1000 or more occasions a month by cloud.*
>
> *When not obscured by cloud, the visibility in the area of the turbines can be expected to exceed 5km for 93% of the time and the lights will be switched down to 200cd.*

Mid-Mast Lighting

Mid mast lighting was originally intended to give an attitude/range reference (horizon indication) to pilots flying at night in the days before NVGs. A tip/hub light with a mid/mast light will give a vertical reference (from which a horizontal reference can be gauged) when fitted to a single vertical structure. In contrast, a single light on a single structure will not be able to give a vertical or horizontal reference or indication of range, range-rate and sight-line spin values or changes to an approaching pilot. However, a series of single tip/hub lights, on a group of structures, will provide a good horizon reference together with range, range-

rate and sight line spin clues to a pilot. Accordingly, the requirement for mid-mast lights is much diminished if not made redundant in the case of lit multiple vertical structures such as wind farms.

All of the current commercially available 32cd (supposedly focused) lights are over-engineered (up to 70cd between -30deg and +40deg) to fit a multitude of aviation and marine applications. As a result, they induce a disproportionately large environmental impact, often significantly more than the focused hub 2000/200cd lights especially in the downward direction. WFLFAC will request that the CAA guidance requirement for 32cd (Type B) mid mast lights be removed for Glentarken.

Conclusion/Notes

The purpose of this Lighting Brief is to identify an obstruction lighting arrangement that is environmentally friendly but at the same time is aviation safe, in particular, for night low level operators. This has been accomplished by using a combination of CAA ANO and MOD IR lights.

Applying the CAP 764 Draft criteria, for visible obstruction lighting, results in nine turbines carrying a hub mounted ANO red light. However, by initially applying CAA dispensations, coupled with the recently added 1800m criterion and adding IR lighting, a more environmentally friendly arrangement is achieved, as follows:

4 x ANO Red 2000/200cd lights and 12 x MOD IR 600mW/sr lights across Glentarken.

Furthermore, the site is in an area where it will benefit from 90% light-intensity-dimming in good-weather and obscuration of both turbines and the visible ANO lighting in poor-weather. These dimming and obscuration benefits are potentially significant.

The lights will be regularly obscured by cloud and when not obscured set at the lower 200cd for approximately 93% of the time.

The formal WFLFAC lighting proposal shown in Figures 6 (Table) & 7 (Map) will require CAA Wind Farm Policy and MOD DIO/LFOS approval.

[redacted]

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For WFLFAC
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