

# ***AARDVaRC Ltd***

***Aviation Analysis, Renewables Development & Visualisation, and Radio Communications***

## **Aviation Lighting and Marking Requirements**

**for the**

***Neart-na-Gaoithe***

**Offshore Wind Farm**

Prepared for EMU Ltd  
by Charles Morelli BEng

2 December 2011

AARDVaRC Ltd, PO Box 10785, Sudbury, Suffolk, CO10 3AY  
T: +44 (0) 1787 468539 E: charles@aardvarc.ltd.uk W: www.aardvarc.ltd.uk

Copyright © 2011 AARDVaRC Ltd. All rights reserved.

## Summary

Mainstream Renewable Power is developing the Neart-na-Gaoithe offshore wind farm in the Forth of Firth, with 0.5GW generating capacity and various options for turbine size, number and layout. AARDVaRC Ltd has been retained through EMU Ltd to advise on the requirement for aviation lights to be fitted to the turbines and to propose a suitable lighting scheme for approval by the Civil Aviation Authority (CAA) prior to construction.

This report considers the significant aviation stakeholders, their needs, legal requirements, policy and guidance in order to propose a lighting scheme for the operational phase of the Neart-na-Gaoithe wind farm. This scheme should be agreed by the CAA prior to construction.

A scheme covering the construction phase should be agreed separately: ideally this would be based on the lighting scheme for the operational phase, but it is not possible to develop such a scheme until the construction plan is finalised. This is discussed briefly later in the report.

The principles discussed for construction also apply to decommissioning, and should be considered at the appropriate time. However, that is many years away.

### Conclusions

The MoD and CAA are the only significant aviation stakeholders representing interests in a lighting or marking scheme.

There is no requirement to mark the turbines for aviation conspicuity other than by using the proposed RAL7035 colour. Civil Aviation Publication (CAP) 437 – Chapter 10, Paragraph 2 and sub-paragraphs detail guidance for the marking scheme on the top of the nacelle to support helicopter winching operations.

The following are proposed for the wind farm's operational phase (see References section for detailed specifications, and details of selected turbines in Appendices 2A and 2B):

- Selected turbines should be fitted with 2 medium intensity red lights to the tops of the nacelles, spaced so as to minimise the likelihood of blades temporarily obscuring both lights simultaneously in any direction. There may be a requirement for these lights to flash 'W' Morse code simultaneously and repeatedly, however, at the time of writing, the requirement is for steady red lights.
- All turbines should be fitted with a low intensity green light to indicate when the turbine rotor is locked in a safe position for a helicopter to approach and commence winching operations.
- Turbines not fitted with medium intensity red lights should be fitted with low intensity red lights to support helicopter winching operations.
- There is a separate proposal for each layout in the Rochdale Envelope. Where this allows for turbine locations to be omitted it may be necessary to revise the proposed lighting scheme to accommodate changes, even if only unlit turbines are omitted.

The construction phase will need its own lighting scheme to be developed. Ideally, this should be based on the scheme for the operational phase but can only be developed once the construction plan is known. It may be desirable to amend the proposed operational lighting scheme once the construction plan is known to simplify the transition from construction to operation.

Similarly, a lighting scheme for decommissioning will be required, although that is many years off.

Finally, the Civil Aviation authority should approve any lighting scheme before it is implemented.

## References

### Legal

Air Navigation Order 2009, Amendment 1/2010 (reproduced in CAP393 – see below)

Article 220 (reproduced at Appendix 1)

### Policy

Civil Aviation Authority (CAA): Directorate of Airspace Policy (DAP)

*The Lighting of Wind Turbine Generators in United Kingdom Territorial Waters*  
dated 2 August 2010

### Guidance

Civil Aviation Publications (CAP)

CAP393 *Air Navigation: The Order and the Regulations*

Section 1 *The Air Navigation Order 2009*

Part 28 *Lights and Lighting*

Article 220 *Lighting of wind turbine generators in United Kingdom territorial waters*

(Articles 218, 219, 221 and 222 are also pertinent)

CAP437 *Offshore Helicopter Landing Areas - Guidance on Standards*

Chapter 10 *Helicopter Winching Areas on Vessels and on Wind Turbine Platforms*

Paragraph 2 (and sub-paragraphs) *Helicopter Winching Areas on Wind Turbine Platforms*

CAP764 *CAA Policy and Guidelines on Wind Turbines*

Chapter 3 *Safeguarding Considerations*

Paragraph 5 (and sub-paragraphs) *Obstructions, Lighting and Marking*

Ministry of Defence (MoD): Low Flying Operations Squadron

WITT/605/LFOPS *MOD Specification for IR and Low Intensity Red Vertical Obstruction Lighting*  
dated 17 December 2010.

## Contents

Aviation Lighting and Marking Requirements .....	1
Summary .....	2
References .....	3
Contents .....	4
Aviation Lighting and Marking Requirements .....	5
Introduction .....	5
Background .....	5
Stakeholders .....	5
Wind Turbine Marking .....	6
Wind Turbine Aviation Lighting.....	6
Summary of Proposed Lights .....	8
Lighting in the Construction Phase.....	9
Conclusions .....	10
Appendix 1 .....	A1-1
Appendix 2A .....	A2A-1
Appendix 2B .....	A2B-1

# Aviation Lighting and Marking Requirements

## Introduction

Mainstream Renewable Power is developing the Neart-na-Gaoithe offshore wind farm in the Forth of Firth, with 0.5GW generating capacity and various options for turbine size, number and layout. AARDVaRC Ltd has been retained through EMU Ltd to advise on the requirement for aviation lights to be fitted to the turbines and to propose a suitable lighting scheme for approval by the Civil Aviation Authority (CAA) prior to construction.

This report considers the significant aviation stakeholders, their needs, legal requirements, policy and guidance in order to propose a lighting scheme for the operational phase of the Neart-na-Gaoithe wind farm. This scheme should be agreed by the CAA prior to construction.

A scheme covering the construction phase should be agreed separately: ideally this would be based on the lighting scheme for the operational phase, but it is not possible to develop such a scheme until the construction plan is finalised. This is discussed briefly later in the report.

The principles discussed for construction also apply to decommissioning, and should be considered at the appropriate time. However, that is many years away.

## Background

Guidance for aviation marking and lighting requirements is found in Civil Aviation Publication (CAP) 764 *CAA Policy and Guidelines on Wind Turbines*. This refers to the legal requirements found in: Article 220 of the *Air Navigation Order 2009* – amendment 1/2010 (this Article is reproduced in full at Appendix 1); the latest DAP Policy Statement: *The Lighting of Wind Turbine Generators in United Kingdom Territorial Waters*, dated 02 August 2010; and CAP437 *Offshore Helicopter Landing Areas - Guidance on Standards*.

The MoD commonly requests use of infrared lights for onshore wind farms (although not usually in addition to medium intensity red lights). These are discussed later, and should the MoD request them, the Low Flying Operations Squadron has produced a specification for such lights: MoD reference WITT/605/LFOPS, *MOD Specification for IR and Low Intensity Red Vertical Obstruction Lighting*, dated 17 December 2010.

The law requires appropriate aviation lighting to be fitted to offshore structures taller than 60m within UK territorial waters – i.e., 12nm (22.2km) from land. Where more than 4 turbines are located together, only those on the periphery of the wind farm need be illuminated as described later in this report.

Normally these would be steady red lights, however, recent experience with some large offshore wind farms has raised concerns from the marine community regarding the potential for confusion with marine lights so the requirement may change between the time of writing and final agreement of the lighting scheme with the CAA. The most likely change will be to have all aviation lights on the wind farm flashing the Morse code signal for 'W' (i.e., '· – –') simultaneously and repeatedly. Until such time as the policy changes, the requirement is for steady red lights.

## Stakeholders

The following stakeholders have been considered.

Edinburgh Airport. Edinburgh Airport has made no objection on the development, and has made no comment on lighting. Due to this and its distance from the wind farm site, it is not a significant stakeholder and will not be considered further.

Search and Rescue Units. Search and Rescue (SAR) flying units are important stakeholders as the potential requirement to mount an airborne rescue from within an offshore wind farm has been recognised for some time with trials conducted and guidance published. Both the MoD and CAA take an interest in this matter and will ensure that SAR interests are accommodated, so there is no need for separate consideration of SAR operations.

NATS. NATS has expressed no request or requirement for lighting since its main concern is the safeguarding of its technical infrastructure. Therefore it is not a significant stakeholder in this matter.

MoD. Consultations with the MoD are on-going, although no specific requests have been made that would not be accommodated by other requirements. However, it is noted that it is common for the MoD to request low intensity red lights, and/ or infrared lights, to be fitted to large onshore wind turbines. This will be considered later in this report.

CAA. The CAA is the principle stakeholder as far as compliance with the law, other stakeholder requests, and published guidance is concerned. It will need to approve the aviation lighting scheme prior to construction, and in doing so will consider advice from the above stakeholders.

Other Stakeholders. No other significant stakeholders have been identified with respect to aviation lighting for the Neart-na-Gaoithe wind farm.

Therefore only the MoD and CAA will be considered further.

## Wind Turbine Marking

There is no guidance for the specific marking of offshore wind turbines within UK territorial waters for purposes of aviation conspicuity.

It is noted that the International Civil Aviation Organisation (ICAO) guidance for the colour of onshore wind turbines deemed to be aviation obstacles is that the upper two-thirds of the structure should be 'white' and the CAA adheres to this guidance for onshore turbines. It appears that the typical wind turbine colour (RAL7035) – as proposed for turbines at Neart-na-Gaoithe – is generally accepted as satisfying this guidance.

However, there is extant guidance for the marking of helicopter winch areas on the tops of offshore wind turbine nacelles, although this is not for purposes of general conspicuity. The guidance is detailed and specific so is not repeated here: it should be taken from the source document: CAP 437 *Offshore Helicopter Landing Areas - Guidance on Standards*, Chapter 10 *Helicopter Winching Areas on Vessels and on Wind Turbine Platforms*, Paragraph 2 *Helicopter Winching Areas on Wind Turbine Platforms* (and sub-paragraphs).

## Wind Turbine Aviation Lighting

### Lighting Principles

There are three types of lighting that should be fitted to some or all of the wind turbines, and a fourth type that may be requested. The first three types are: *medium intensity red* lights, *low intensity green* lights, and *low intensity red* lights. The fourth type that may be requested is *low intensity infrared* (i.e., invisible to the eye) lighting.

The legal requirement for offshore wind turbine lighting is stipulated in Article 220 of the Air Navigation Order 2009 (reproduced in CAP393 *Air Navigation: The Order and the Regulations*), with other documents providing further policy information and guidance.

It is noted that the Air Navigation Order only requires lighting to be fitted to turbines on the periphery of a group of turbines (Article 220, Paragraph (2) – see Appendix 1); from this and Paragraph (12)(c), it is implicit that situating a light on the periphery every 3-4km should be adequate as a *maximum* separation.

The lighting schemes proposed by AARDVaRC place medium intensity lights somewhat closer than this maximum; it also places some in the interior of the wind farm. This is based on the author's own military flying experience, and on past recommendations from the MoD requesting some lights inside wind farms to indicate the 'depth' of the wind farm to pilots. The author's opinion is that the lighting schemes proposed are a sensible balance between legal requirements, provision of reasonable warning to pilots, and excessive lighting.

The requirement for these lights is discussed in the following paragraphs. The required and optional specifications for the lights are detailed and are left to the source documents, with appropriate references given (see References section).

### **Medium Intensity Red Lights**

Medium intensity red lights as specified in Article 220 of the Air Navigation Order 2009 have a brightness of 2,000 candela (cd) – see CAA Policy Statement: *The Lighting of Wind Turbine Generators in United Kingdom Territorial Waters*, dated 02 August 2010.

These should be lit during the hours of darkness and in poor visibility (on a good visibility night, the brightness may be reduced).

- Top Lights.

When used, top lights on wind turbines are typically fitted in pairs at the top of the nacelle (although the Air Navigation Order only mandates 'at least one' light). They are normally mounted as far apart as practicable in order to minimise the possibility of a passing blade simultaneously obscuring both lights in any particular direction.

It is proposed that 2 such lights are fitted to selected turbines (see Appendices 2A and 2B for selected turbines). This also allows for some redundancy in the event of failure.

- Intermediate Lights.

Intermediate aviation lights have a similar specification to the top lights, but when used are spaced at regular intervals – not exceeding 52m – below the top lights.

At the time of writing, no UK offshore wind farm developments are known to have required fitting of intermediate aviation lights. It is not expected that these will be required at Neart-na-Gaoithe and it is not proposed to fit any.

### **Low Intensity Green Lights**

There may be a requirement during the wind farm's operational life for helicopter winch operations to be conducted to any or all of the wind turbines for maintenance or Search and Rescue (SAR) operations. For these purposes, guidance is provided in CAP437 for marking of the winching area, and in the current CAA Policy Statement for all wind turbines to be equipped with a low intensity – 16-60 cd – steady green light to indicate to a pilot that it is safe to operate (i.e., that the wind turbine nacelle and rotor are locked in a safe position).

Every wind turbine should be fitted with a low intensity green light. The light only illuminates when the blades of that specific turbine are locked in a safe position as a signal to the pilot that the turbine is safe to approach.

### Low Intensity Red Lights

To further support winching and SAR operations within the wind farm in poor visibility or at night, low intensity red lights – 50-200 cd – should be fitted to turbines (unless already fitted with medium intensity red lights). Note there is no requirement for these lights to be visible below the horizontal plane.

The lights only need to be illuminated when helicopters are operating within the confines of the wind farm at night or in poor visibility. It may be prudent for all low intensity red lights to be illuminated together.

It is proposed that all turbines not fitted with medium intensity red lights are fitted with low intensity red lights.

### Low Intensity Infrared Lights

The MoD has recently conducted research and trials into the use of low intensity infrared lights fitted to onshore wind turbines in the UK enabling visibility to aircrew equipped with night vision goggles (NVG) – particularly for low flying – without any wider visual impact.

It may be that modern LED red lights do not register on NVG (whereas older technology lights that emit significant amounts of infrared energy in addition to the visible red light do register on NVG). However, there are no instances known to AARDVaRC on offshore wind farms where infrared lighting has been requested.

It is not proposed that any turbines be fitted with infrared lights. However, if these are required in addition to other red lights, they should be fitted and unless otherwise directed, operate with the accompanying medium or low intensity red lights.

### Summary of Proposed Lights

The lighting scheme proposed for the Neart-na-Gaoithe wind farm are summarised in the following table (see also Appendices 2A and 2B for details of specific turbines selected for medium intensity red lighting to satisfy Article 220 of the Air Navigation Order 2009).

Type of Light	Brightness	Proposed Lighting Scheme
Red (Medium Intensity)	2,000 cd	On selected turbines (see appendices 2A and 2B): illuminated at night and poor visibility.
Green (Low Intensity)	16-60 cd	On all turbines: illuminated when turbine rotor is safely locked for helicopter winching/ SAR operations.
Red (Low Intensity)	50-200 cd	On turbines <u>not</u> fitted with medium intensity lights: illuminated during winching/ SAR operations within the wind farm.

The turbines selected for medium intensity lighting are shown in Appendices 2A and 2B, for layout options A and B respectively as described in the Rochdale Envelope.

Depending on the turbine size selected, the Rochdale Envelope allows for some turbine locations in either layout to be omitted: such omissions may include turbines selected for medium intensity lights. In this case, the lighting scheme for medium intensity lights will need to be reconsidered; even if the omitted turbines do not include those with such lights, it may be desirable to amend



the proposed scheme to suit the revised layout. Advanced planning for such contingencies is not worthwhile as the proposed schemes can be easily amended after the decision is made.

It should be noted that the CAA (and/ or MoD) may have comment on the proposed lighting scheme and may suggest changes.

## **Lighting in the Construction Phase**

It is understood that the wind farm is likely to be built in phases, with different 'sectors' of wind turbines becoming operational in each phase. The actual construction plan is not known at present, but a separate lighting plan should be approved by the CAA for this phase.

Depending on the timeframe for construction, the turbines on the periphery of each sector should be fitted with medium intensity lights (it is unlikely that lights will need to be fitted to the interior turbines in each sector). Ideally, these turbines would be those to be lit when the whole wind farm is operational: this may require some modification to the lighting schemes as proposed.

Furthermore, construction will necessitate the use of tall plant, perhaps taller than the turbines. A lighting plan for such plant – as well as for partially completed turbines – should also be agreed with the CAA as part of the construction plan. It is impossible to propose any scheme until the construction plan is developed.

## Conclusions

The MoD and CAA are the only significant aviation stakeholders representing interests in a lighting or marking scheme.

There is no requirement to mark the turbines for aviation conspicuity other than by using the proposed RAL7035 colour. Civil Aviation Publication (CAP) 437 – Chapter 10, Paragraph 2 and sub-paragraphs detail guidance for the marking scheme on the top of the nacelle to support helicopter winching operations.

The following are proposed for the wind farm's operational phase (see References section for detailed specifications, and details of selected turbines in Appendices 2A and 2B):

- Selected turbines should be fitted with 2 medium intensity red lights to the tops of the nacelles, spaced so as to minimise the likelihood of blades temporarily obscuring both lights simultaneously in any direction. There may be a requirement for these lights to flash 'W' Morse code simultaneously and repeatedly, however, at the time of writing, the requirement is for steady red lights.
- All turbines should be fitted with a low intensity green light to indicate when the turbine rotor is locked in a safe position for a helicopter to approach and commence winching operations.
- Turbines not fitted with medium intensity red lights should be fitted with low intensity red lights to support helicopter winching operations.

There is a separate proposal for each layout in the Rochdale Envelope. Where this allows for turbine locations to be omitted it may be necessary to revise the proposed lighting scheme to accommodate changes, even if only unlit turbines are omitted.

The construction phase will need its own lighting scheme to be developed. Ideally, this should be based on the scheme for the operational phase but can only be developed once the construction plan is known. It may be desirable to amend the proposed operational lighting scheme once the construction plan is known to simplify the transition from construction to operation.

Similarly, a lighting scheme for decommissioning will be required, although that is many years off.

Finally, the Civil Aviation authority should approve any lighting scheme before it is implemented.

## Appendix 1

### Article 220 of the Air Navigation Order 2009

#### Lighting of wind turbine generators in United Kingdom territorial waters

- 220** (1) Subject to paragraph (10), this article applies to any wind turbine generator:
- (a) the height of which is 60 metres or more above the level of the sea at the highest astronomical tide; and
  - (b) which is situated in waters within or adjacent to the United Kingdom up to the seaward limits of the territorial sea.
- (2) Subject to paragraph (3) the person in charge of a wind turbine generator must ensure that it is fitted with at least one medium intensity steady red light positioned as close as reasonably practicable to the top of the fixed structure.
- (3) If four or more wind turbine generators are located together in the same group, with the permission of the CAA only those on the periphery of the group need be fitted with a light in accordance with paragraph (2).
- (4) Subject to paragraph (5), the light or lights required by paragraph (2) must be so fitted as to show when displayed in all directions without interruption.
- (5) When displayed:
- (a) the angle of the plane of the beam of peak intensity emitted by the light must be elevated to between three and four degrees above the horizontal plane;
  - (b) not more than 45% or less than 20% of the minimum peak intensity specified for a light of this type is to be visible at the horizontal plane;
  - (c) not more than 10% of the minimum peak intensity specified for a light of this type is to be visible at a depression of 1.5 degrees or more below the horizontal plane.
- (6) Subject to paragraph (7), the person in charge of a wind turbine generator must ensure that by night, any light required to be fitted by this article is displayed.
- (7) In the event of the failure of any light which is required by this article to be displayed by night the person in charge of a wind turbine generator must repair or replace the light as soon as reasonably practicable.
- (8) If visibility in all directions from every wind turbine generator in a group is more than 5 km the light intensity for any light required by this article to be fitted to any generator in the group and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type.
- (9) In any particular case the CAA may direct that a wind turbine generator must be fitted with and display such additional lights in such positions and at such times as it may specify.
- (10) This article does not apply to any wind turbine generator for which the CAA has granted a permission to the person in charge permitting that person not to fit and display lights in accordance with this article.
- (11) A permission may be granted for the purposes of this article for a particular case or class of cases or generally.
- (12) In this article:
- (a) 'wind turbine generator' is a generating station which is wholly or mainly driven by wind;
  - (b) the height of a wind turbine generator is the height of the fixed structure or if greater the maximum vertical extent of any blade attached to that structure; and
  - (c) a wind turbine generator is in the same group as another wind turbine generator if the same person is in charge of both and:
    - (i) it is within 2 km of that other wind turbine generator; or
    - (ii) it is within 2 km of a wind turbine generator which is in the same group as that other wind turbine generator.

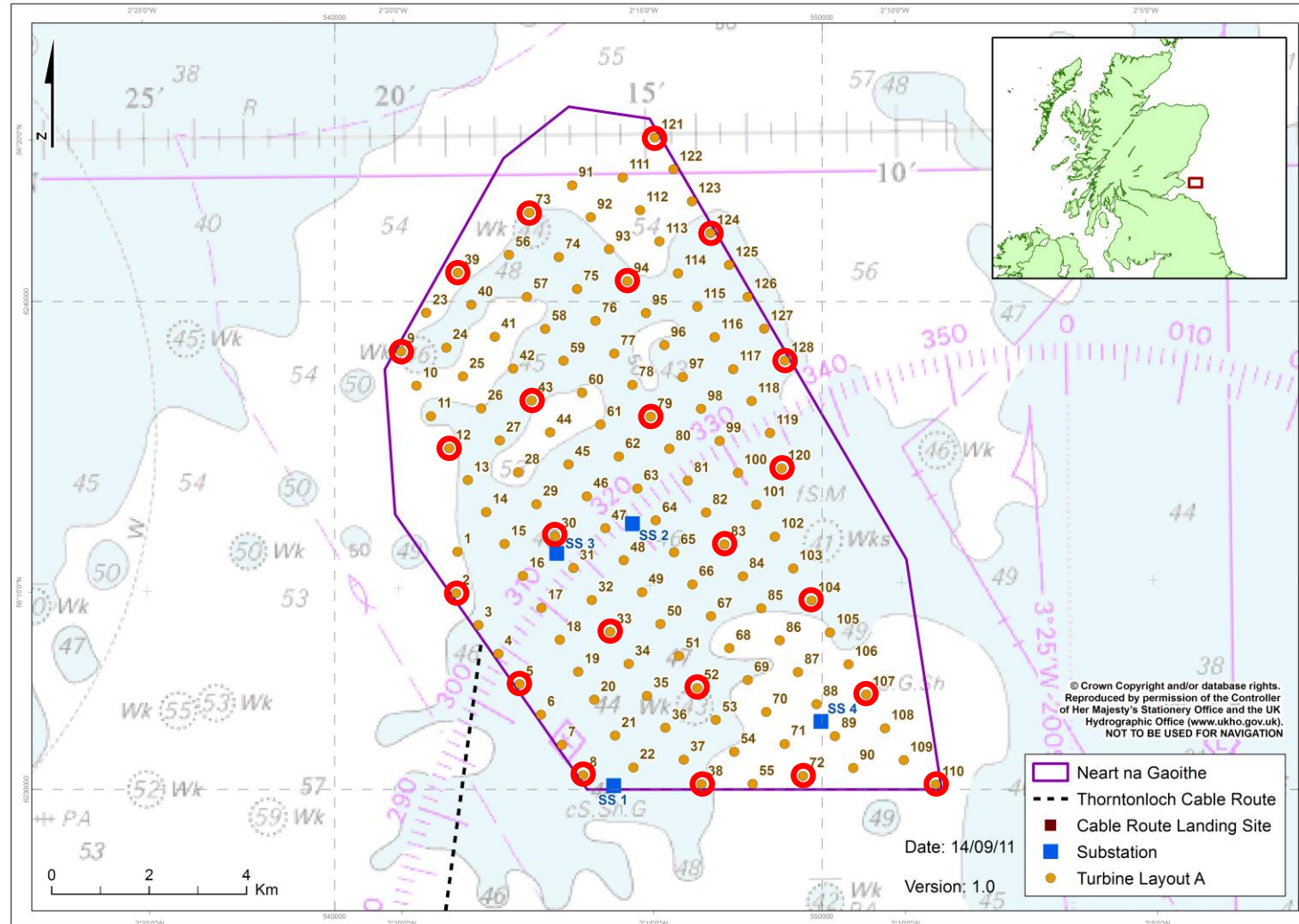
## Appendix 2A

### Layout A – Proposed Lighting Scheme

#### Schedule of Wind Turbines to be fitted with Medium Intensity Red Lights

Turbine	Lights
2	<p><b>Fitted to the nacelle top:</b></p> <p><u>Medium intensity red lights.</u></p> <ul style="list-style-type: none"> <li>• 2 lights may be required on the nacelle in order to minimise observed flickering due to passing blades.</li> <li>• All red lights in the wind farm may be required to flash 'W' in Morse code (· – –) simultaneously and repeatedly in the future.</li> </ul> <p>Note that low intensity infrared lights may be requested in addition by the MoD (if the medium intensity lights do not emit sufficient infrared energy).</p> <p><u>Low intensity green lights.</u></p> <p>The green light is only illuminated to indicate to helicopters conducting winching and search and rescue operations that a turbine is locked with the blades in a safe position.</p>
5	
8	
9	
12	
30	
33	
38	
39	
43	
52	
72	
73	
79	
83	
94	
104	
107	
110	
120	
121	
124	
128	
Remainder	<p><b>Fitted to the nacelle top:</b></p> <p><u>Low intensity red lights.</u></p> <p><u>Low intensity green lights.</u></p>

## Chart of Wind Turbines to be fitted with Medium Intensity Red Lights



## Appendix 2B

### Layout B – Proposed Lighting Scheme

#### Schedule of Wind Turbines to be fitted with Medium Intensity Red Lights

Turbine	Lights
1	<p><b>Fitted to the nacelle top:</b></p> <p><u>Medium intensity red lights.</u></p> <ul style="list-style-type: none"> <li>• 2 lights may be required on the nacelle in order to minimise observed flickering due to passing blades.</li> <li>• All red lights in the wind farm may be required to flash 'W' in Morse code (· – –) simultaneously and repeatedly in the future.</li> </ul> <p>Note that low intensity infrared lights may be requested in addition by the MoD (if the medium intensity lights do not emit sufficient infrared energy).</p> <p><u>Low intensity green lights.</u></p> <p>The green light is only illuminated to indicate to helicopters conducting winching and search and rescue operations that a turbine is locked with the blades in a safe position.</p>
2	
5	
7	
8	
10	
19	
26	
31	
35	
41	
45	
47	
52	
58	
61	
69	
71	
73	
74	
75	
78	
80	
Remainder	<p><b>Fitted to the nacelle top:</b></p> <p><u>Low intensity red lights.</u></p> <p><u>Low intensity green lights.</u></p>

## Chart of Wind Turbines to be fitted with Medium Intensity Red Light

