Hornsea Project Three
Offshore Wind Farm

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Offshore Wind Farm

Preliminary Environmental Information Report:
Annex 8.1 – Aviation, Military and Communication Technical Report

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 5

Annex 8.1 – Aviation, Military and Communication Technical Report

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Front cover picture: Kite surfer near one of DONG Energy's UK offshore wind farms © DONG Energy Hornsea Project Three (UK) Ltd., 2016.

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Glossary

Term	Definition
0° Isotherm	The altitude in which the temperature is at 0°C (the freezing point of water) in a free atmosphere.
Flight Level	A standard nominal altitude of an aircraft, in hundreds of feet, based upon a standardised air pressure at sea-level.
Helicopter Main Route (HMR)	Routes which are established to facilitate safe helicopter flights in Instrument Flight Rules (IFR) conditions (i.e. when flight cannot be completed in visual conditions).
Instrument Approach	A procedure used by helicopters for low-visibility offshore approaches to offshore platforms which relies upon an aircraft's on-board weather radar for guidance and as a means of detecting obstacles in the approach path.
Instrument Flight Rules (IFR)	The rules governing procedures for flights conducted on instruments.
Instrument Meteorological Conditions (IMC)	Weather conditions which would preclude flight by the Visual Flight Rules (VFR) (i.e. conditions where the aircraft is in or close to cloud or flying in visibility less than a specified minimum).
Minimum Safe Altitude (MSA)	Under aviation flight rules, the altitude below which it is unsafe to fly in IMC owing to presence of terrain or obstacles within a specified area.
Missed Approach Procedure (MAP)	The actions for the crew of an aircraft to take when an instrument approach procedure is not successful (e.g. the crew are unable to see the runway, approach lights or helideck).
Precision Approach Radar (PAR)	A military instrument approach system which provides both horizontal and vertical guidance for landing from 10 or 20 nautical miles (nm) from the airfield.
Radar shadow	A region shielded from radar illumination by an intervening object (e.g. a turbine).
Radar shield	A region shadowed from radar illumination by an intervening objects shadow (e.g. a turbine shadow).
Uncontrolled airspace	Airspace in which Air Traffic Control (ATC) does not exercise any executive authority, but may provide basic information services to aircraft in radio contact. In the UK, Class G airspace is uncontrolled.
Visual Flight Rules (VFR)	The rules governing flight conducted visually (i.e. with the crew maintaining separation from obstacles and other aircraft visually).

Acronyms

Acronym	Description
ADR	Air Defence Radar
AGL	Above Ground Level
AMSL	Above Mean Sea Level
AIS	Aeronautical Information Service
ANSP	Air Navigation Service Provider
ASAC	Airspace Surveillance and Control Systems
ATA	Aerial Tactics Area
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATS	Air Traffic Services
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
CAS	Controlled Airspace
CNS	Communication, Navigation and Surveillance
DfT	Department for Transport
DIO	Defence Infrastructure Organisation
DSC	Digital Selective Calling
FIR	Flight Information Region
FL	Flight Level
GPS	Global Positioning System
HMR	Helicopter Main Route
IAIP	Integrated Aeronautical Information Package
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LFA	Low Flying Area
LOS	Line of Sight
MAP	Missed Approach Procedure
MCA	Maritime and Coastguard Agency
MDA	Managed Danger Area
MERRA	MoDern Era-Retrospective Analysis for Research and Applications
MET	Meteorological
MGN	Maritime Guidance Notice
Mil AIP	Military Aeronautical Information Package
MOD	Ministry of Defence
MSA	Minimum Safe Altitude
MTI	Moving Target Indicator
NAIZ	Non Automatic Initiation Zone
NATO	North Atlantic Treaty Organisation
NATS	NATS Ltd. (formerly National Air Traffic Services Ltd.)
PAR	Precision Approach Radar
PEXA	Practice and Exercise Area
PSR	Primary Surveillance Radar
RAP	Recognised Air Picture
RCS	Radar Cross Section
SARG	Safety and Airspace Regulation Group
SSR	Secondary Surveillance Radar
TV	Television
UHF	Ultra-High Frequency
UK	United Kingdom
UKLFS	UK Low Flying System
VFR	Visual Flight Rules
VHF	Very High Frequency

Units

Unit	Description
ft	Feet
km	kilometre
GW	Gigawatt
m	metre
m/s	metre per second
MW	Megawatt
nm	Nautical Mile

1. Introduction

1.1 Overview

1.1.1.1 DONG Energy Power (UK) Ltd. (hereafter referred to as DONG Energy), on behalf of DONG Energy Hornsea Project Three (UK) Ltd., is promoting the development of the Hornsea Project Three Offshore Wind Farm (hereafter referred to as Hornsea Three). Hornsea Three is a proposed offshore wind farm located in the southern North Sea, with a total generating capacity of up to 2,400 MW. Hornsea Three is located within the former Hornsea Zone in the southern North Sea. The Hornsea Three array area is 696 km^2, at a distance of 121 km from the UK coastline (at Trimingham, Norfolk) and 10.1 km from the median line between UK and Dutch territorial waters, at its closest point (Figure 1.1).

1.2 Purpose

1.2.1.1 The purpose of the Aviation, Military and Communication Technical Report is to analyse the potential for Hornsea Three to present an impact on aviation, military and communication interests within the southern North Sea aviation, military and communication study area (see Figure 1.1 for spatial extent of study area, which is delineated by a solid black line).

1.2.1.2 This Aviation, Military and Communication Technical Report specifically provides the technical information and modelling results relating to the Hornsea Three aviation, military and communication Environmental Impact Assessment (EIA) to support the assessments on MOD infrastructure and operations, NATS infrastructure and operations, communication systems, and helicopter operations regarding use of HMRs and ability to access offshore installations. The work presented has been carried out in accordance with guidance in the Civil Aviation Authority (CAA) Publication (CAP) 764 (CAA, 2016c). The EIA associated with all aviation, military and communication receptors is presented in volume 2, chapter 8: Aviation, Military and Communication.

1.3 Background

1.3.1.1 The effects of wind turbines on aviation interests have been widely publicised but the primary concern is one of safety. There are various subtleties in the effects but there are two dominant issues:

- Physical obstruction – turbines under construction or decommissioning (and associated cranes) and operational turbines can present a physical obstruction at or close to aircraft airspace routings (e.g. HMRs or an aerodrome/helicopter offshore platform); and
- Radar/Air Traffic Services (ATS) – in the use of Primary Surveillance Radar (PSR) and Precision Approach Radar (PAR), the rotation of wind turbine blades is detected and forms "clutter" on the radar display screen. This can affect the safe provision of air navigation services as it can mask unidentified aircraft from the controller and prevent them from accurately identifying aircraft under their control. This could result in miscommunication and confusion causing an increase in workload for the controller and unsafe service provision; and in some cases, radar reflections from the turbines can affect the performance of the radar system itself.

1.4 Document structure

1.4.1.1 This document utilises the following structure:

- Section 1 (this section) gives an introduction and purpose to the Aviation, Military and Communication Technical Report;
- Section 2 identifies the aviation, military and communication study area;
- Section 3 outlines the existing aviation baseline environment;
- Section 4 provides the assessment methodology;
- Section 5 analyses the impact on NATS operations;
- Section 6 considers the impact on MOD Airspace Surveillance and Control Systems (ASACS) operations;
- Section 7 studies the operational impact on helicopter support operations to the offshore oil and gas industries;
- Section 8 outlines the potential impact on offshore communication systems;
- Section 9 presents the assessment conclusions; and
- Section 10 lists the references used throughout the assessment.

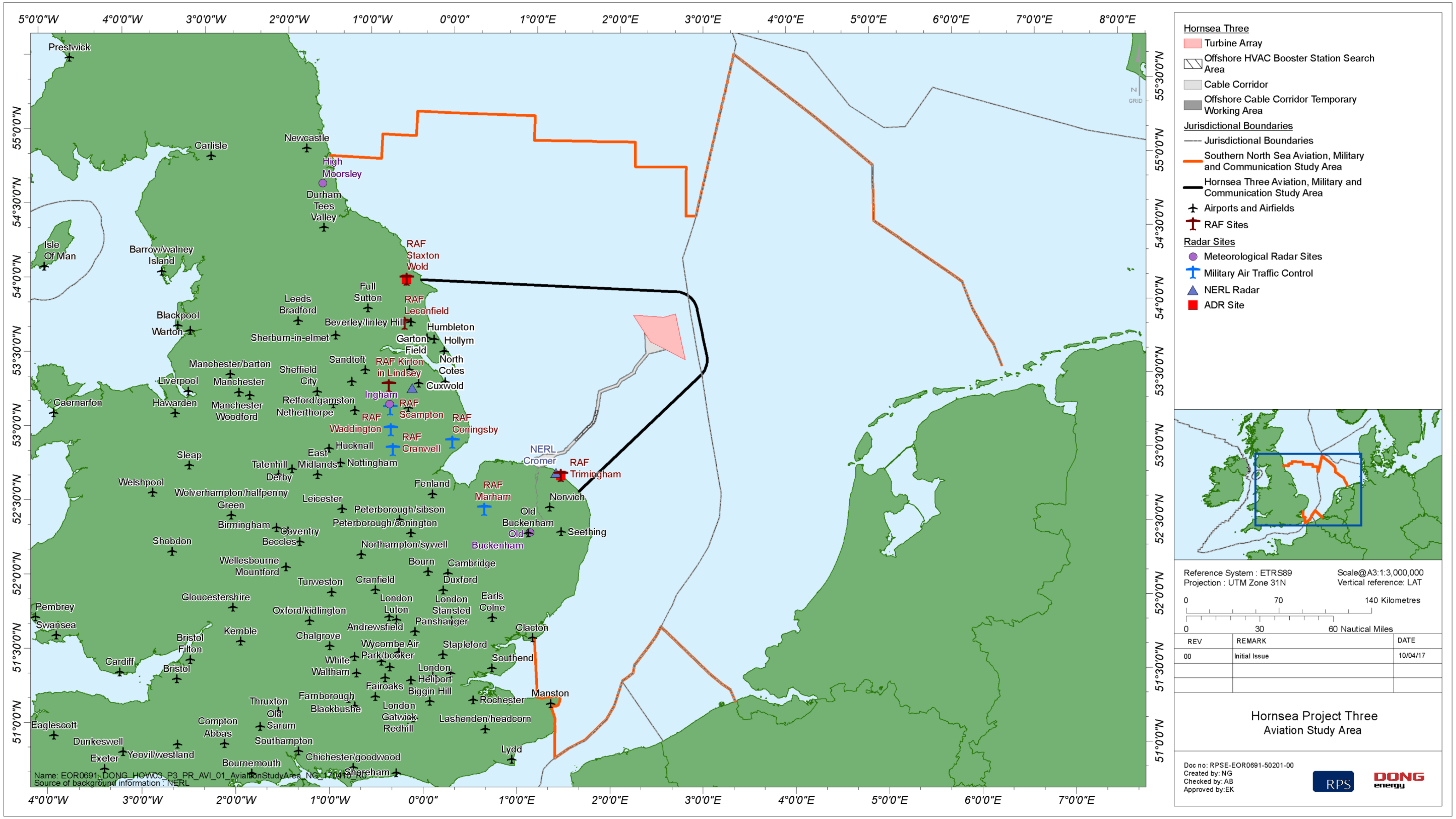

Figure 1.1: Aviation, military and communication study area.

2. Study Area

2.1.1.1 The Hornsea Three aviation, military and communication study area encapsulates the Hornsea Three array area and offshore cable corridor, as well as the airspace between the Hornsea Three array area and the UK mainland from Norwich airport to the south and RAF Staxton Wold to the north (see Figure 1.1).

2.1.1.2 Specifically, the Hornsea Three aviation, military and communication study area covers:

- The airspace most likely to be used by helicopters servicing Hornsea Three. It is not yet known which helicopter provider would be used for Hornsea Three or from which airport the helicopter operator would be based, however flights are likely to originate from the east coast of the UK or to come from an offshore base or vessel with helicopter personnel transfer;
- Radars on the east coast of England that could potentially detect 325 m high (blade tip) wind turbines within the Hornsea Three array area boundary (see Figure 1.1);
- Helicopter Main Routes (HMR) operating within the proximity of the Hornsea Three array area (see Figure 7.1);
- Offshore platforms that have 9 nm consultation zones that overlap with the Hornsea Three array area (see Figure 7.1);
- Low flying areas and military practice areas that intersect or are adjacent to the Hornsea Three array area and offshore cable corridor (see Figure 3.1);
- Microwave links within 30 km from the centre of the Hornsea Three array area (see Figure 8.1); and
- Very high frequency (VHF)/ultra-high frequency (UHF) communications.

2.1.1.3 The aviation, military and communication study area includes Hornsea Project One which was granted development consent by the Secretary of State for Energy and Climate Change in December 2014 and Hornsea Project Two which was granted development consent by the Secretary of State for Energy and Climate Change in August 2016 (see Figure 7.3). The study area for undertaking the assessment of cumulative effects for radar encapsulates the southern North Sea and adjacent Dutch territorial waters (see Figure 1.1) which also includes other offshore wind farms in the southern North Sea and in Dutch territorial waters that could have potential effects on identified radar receptors.

3. Aviation Baseline Environment

3.1 Airspace designations in the vicinity of Hornsea Three

3.1.1.1 The Hornsea Three array area and offshore cable corridor are situated in an area of Class G uncontrolled airspace, which is established from the surface up to Flight Level (FL) 195 (approximately 19,500 ft.) and Class C controlled airspace, which is established above FL 195. Under these classifications of airspace the following applies:

- Class G uncontrolled airspace: any aircraft can operate in this area of uncontrolled airspace without any mandatory requirement to be in communication with an ATC unit. Pilots of aircraft operating VFR (Visual Flight Rules) in Class G airspace are ultimately responsible for seeing and avoiding other aircraft and obstructions; and
- Class C controlled airspace: all aircraft operating in this airspace must be in receipt of an air traffic service (ATS).

3.1.1.2 In the Hornsea Three array area the Class G uncontrolled airspace below FL 195 is subdivided into areas with the following aviation stakeholder responsibility:

- Anglia Radar: based at Aberdeen Airport and employing NATS PSRs, has its area of responsibility established for the provision of ATC services to commercial helicopter operations that support the offshore oil and gas industry, from the surface up to FL 65 (approximately 6,500 ft.); and
- MOD ASACS: uses its Air Defence Radar (ADR) resources in support of operational flights within UK airspace and for training exercises. Two Managed Danger Areas (MDAs) are established over the North Sea (Central and Southern MDA). Within the lateral and vertical confines of the MDAs, air combat training, high energy manoeuvres and supersonic flight can be expected. The Southern MDA (EG D323) is located above the Hornsea Three array area and is divided into six distinct areas (A, B, C, D, E and F). EG D323D (in area D) is located directly above the Hornsea Three array area and, when active, operates from FL 50 up to FL 660.
  Note: When the Southern MDA is activated, Anglia Radar will restrict offshore helicopter operations to FL 40 and below.

3.1.1.3 The Hornsea Three offshore cable corridor, including the offshore HVAC reactive booster station search area, passes through the Wash Aerial Tactics Area (ATA) North, the Wash ATA South, an Offshore Safety Area and an air to air refuelling area. The ATAs are airspace of defined dimensions designated for air combat training within which high energy manoeuvres are regularly practiced by aircraft formations. Autonomous operations are only permitted within ATAs above FL 195 when the overlying Temporary Reserved Airspace (TRA) is active (NATS, 2017b).

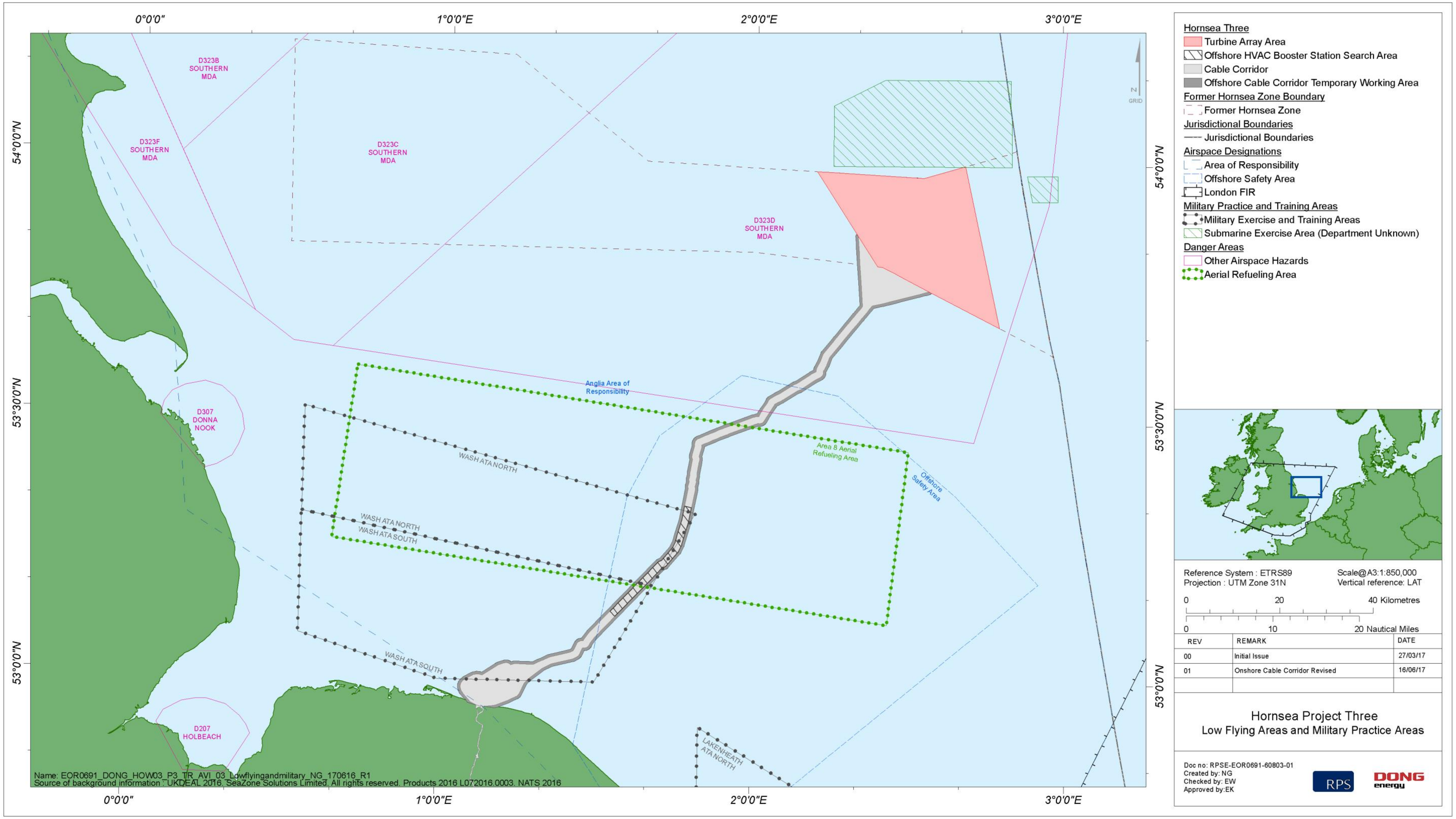

Figure 3.1: Overview of low flying and military practice areas.

3.1.1.4 Air combat training by military aircraft practicing high energy manoeuvres regularly takes place in the areas listed here. The ATA Wash North operates between FL 50 to FL 245. The ATA Wash South operates between FL 50 and FL 175. Both areas experience intense military activity and helicopter pilots are strongly advised to avoid the area; if this is not possible, they should request a service from London Radar, via London Flight Information (NATS, 2017b).

3.1.1.5 Offshore Safety Areas are promulgated on aeronautical charts to 'signpost' areas of intense offshore helicopter activity and to enhance the situational awareness through the mandatory use of radiotelephony contact and secondary surveillance radar by aircraft that are operating within the boundary of them (NATS 2017b). The air to air refuelling area is permanently available and allows refuelling for aircraft during flight (NATS 2017c).

3.1.2 Military low flying operations

3.1.2.1 The UK Low Flying System (UKLFS) covers the open airspace of the whole UK land mass and surrounding sea areas generally out to 2 nm from the coastline, from the surface to 2,000 ft. Above Ground Level (AGL) or Above Mean Sea Level (AMSL). The Hornsea Three array area, at 121 km (65.3 nm) from the UK coast (at Trimingham, Norfolk) will not affect routine Military Low Flying activity.

3.2 Air regulation

3.2.1.1 The CAA's Safety and Airspace Regulation Group (SARG) is responsible for the regulation of Air Traffic Services (ATS) in the UK; the planning and regulation of all UK airspace, including the communications, navigation and surveillance (CNS) infrastructure; and also has the lead responsibility within the CAA for all wind turbine related issues. At all times, responsibility for the provision of safe services lies with the ATS provider or Air Navigation Service Provider (ANSP) CAA, 2016c).

4. Assessment Methodology

4.1 Overview

4.1.1.1 This section presents:

- The Hornsea Three project information used in the aviation, military and communication assessments, including the maximum design scenario, the specific notification and lighting requirements and the helicopter operational requirements;
- The radar LOS analysis used for the NATS impact assessment and the MOD ASACS impact assessment; and
- The operational assessment methodology used to augment the LOS analysis and used for the helicopter operations assessment, which includes the potential effect on HMRs and access to offshore installations.

4.2 Maximum design scenario

4.2.1.1 The indicative turbine rating and dimensions for Hornsea Three are shown in Table 4.1. In summary, Hornsea Three could have a maximum of 342 turbines located within the Hornsea Three array area. The maximum turbine blade tip height could be up to 325 m above Lowest Astronomical Tide (LAT), although this would only apply to 160 or fewer turbines (on the basis that the individual turbines of this size would be expected to have a larger capacity).

4.2.1.2 The Hornsea Three aviation, military and communication EIA considers the potential turbine scenario with the maximum blade tip height (i.e. up to 160 turbines at a maximum blade tip height of 325 m), as the greatest height has the potential to result in the greatest possibility of turbine detection by radar and the increased possibility of turbines producing a physical obstruction to aircraft operations.

Table 4.1: Hornsea Three turbine dimensions and parameters.

Maximum number of turbines	Maximum blade tip height above LAT (m)	Maximum rotor diameter (m)	Minimum turbine Spacing (m)
342	240	185	1,000
160	325	265	1,000

4.2.2 Notification and lighting requirements

4.2.2.1 The Hornsea Three turbines will be lit in accordance with the mandated requirement for the lighting of wind turbine generators in UK territorial waters as set out at CAP 393: The Air Navigation Order 2016 and Regulations, Part 8, Chapter 2 (CAA, 2016a) and, CAP 764: CAA Policy and Guidelines on Wind Turbines, Sixth Edition (CAA, 2016c). The lighting shall meet the current CAA requirements and also be consulted on with Ministry of Defence (MOD) and Maritime Coastguard Authority (MCA) for any additional requirements.

4.2.2.2 The specifications include that each wind turbine shall be fitted with at least one medium intensity steady red light positioned as close as reasonably practicable to the top of the fixed structure and the lights must be so fitted as to show when displayed in all directions without interruption. For a group of wind turbines (such as Hornsea Three), consultation with CAA may advise that only those on the periphery of the group need be fitted with such a light. In addition, two medium intensity (2,000 candela) red aviation warning lights (flashing Morse W) are likely to be installed on each wind turbine on top of the heli-hoist platform on the turbines on the periphery line.

4.2.2.3 In addition, lighting requirements associated with helicopter hoist operations will be implemented as set out in CAP 437 Standards for offshore helicopter landing areas (CAA, 2016b). The specifications include that the wind turbine structure should be clearly identifiable from the air using a simple designator (typically a two-digit or three-digit number with block identification), painted in 1.5 m (minimum) characters in a contrasting colour, preferably black. The turbine designator should be painted on the nacelle top cover ideally utilising an area adjacent to the turbine rotor blades. A helihoist light should be located on the nacelle of the wind turbine within the pilot's field of view. This should be a green light capable of displaying in both steady and flashing signal mode. A steady green light is displayed to indicate to the pilot that the turbine blades and nacelle are secure and it is safe to operate. A flashing green light is displayed to indicate that the turbine is in a state of preparation to accept hoist operations or, when displayed during hoist operations, that parameters are moving out of limits. When the light is extinguished this indicates to the operator that it is not safe to conduct helicopter hoist operations.

4.2.2.4 Appropriate information about the site construction and any associated lighting (where applicable), for example the height and temporary location of construction cranes, should be provided to the UK Aeronautical Information Service (NATS AIS) via the Defence Geographic Centre (DGC) as per CAP 764 para 4.9 (1a) for promulgation in applicable aviation publications including the UK Integrated Aeronautical Information Package (UK IAIP) (NATS, 2017).

4.2.2.5 Search and Rescue (SAR) requirements, as provided in MGN 543 (MCA, 2016) shall be discussed with the MCA. SAR requirements are discussed in volume 2, chapter 7: Shipping and Navigation.

4.2.3 Helicopter operations specific to turbines

4.2.3.1 Helicopter hoisting platforms may be installed on each of the nacelles to enable crews to access the nacelle for maintenance. Any helicopter access would be designed in accordance with relevant CAA guidance and standards contained in CAP 764 Policy and Guidelines on Wind Turbines (CAA, 2016c) and CAP 437 Standards for Offshore Helicopter Landing (CAA, 2016b). The precise design details of a helicopter hoisting platform will be determined during the detailed design phase.

4.3 Radar Line of Sight (LOS) analysis

4.3.1.1 The LOS assessment methodology utilised the ATDI ICS LT (Version 3.9.92) tool to model the terrain elevation profile between the identified radar systems and the Hornsea Three array area. This is otherwise known as a point-to-point Line of Sight (LOS) analysis. The result is a graphical representation of the intervening terrain and the direct signal LOS (taking into account earth curvature and radar signal properties). This approach is a limited and theoretical desk based study; in reality there are unpredictable levels of signal diffraction and attenuation within a given radar environment (ambient air pressure, density and humidity) that can influence the probability of a turbine being detected.

4.3.1.2 The analysis undertaken is designed to give an indication of the likelihood of the turbine being detected such that the operational significance of the turbine relative to nearby aviation radar assets can be assessed.

4.3.1.3 The qualitative definitions used in the assessment are defined in Table 4.2 below.

Table 4.2: Qualitative definitions of LOS results.

Result	Definition
Yes	The turbine is highly likely to be detected by the radar: Direct LOS exists between the radar and the turbine.
Likely	The turbine is likely to be detected by the radar at least intermittently.
Unlikely	The turbine is unlikely to be detected by the radar but cannot rule out occasional detection.
No	The turbine is unlikely to be detected by the radar as significant intervening terrain exists.

4.3.2 Notes on radar operation

4.3.2.1 In simple terms, radar operates by alternately transmitting a stream of high power radio frequency pulses and 'listening' to echoes received back from targets within its LOS. Generally air surveillance radars employ a rotating antenna that provides 360° coverage in azimuth; the typical scan rate is 15 rotations per minute (rpm) thus illuminating a given target every four seconds.

4.3.2.2 Primary Surveillance Radar (PSR) operates in two dimensions: the target range is measured based on the time for the transmitted signal to arrive back at the receiver, and the direction of the beam provides the position of the target in azimuth. A PSR such as the type in use at aerodromes across the UK has no height finding capability and as such the Air Traffic Control Officer (ATCO) relies on Secondary Surveillance Radar (SSR) for this purpose: SSR is a collaborative radar system which means that the radar will 'interrogate' a transponder on the aircraft (if fitted) for useful information such as altitude and heading, which is then passed to the ATC display console. All military aircraft carry Identification Friend or Foe (IFF) transponders which respond to secondary radar interrogation.

4.3.2.3 PSR can distinguish between moving and static targets; for targets that are moving towards or away from the radar, the frequency of the reflected signal from a moving target changes between each pulse (transmit and receive) known as the Doppler shift.

4.3.2.4 More complicated mathematical signal processing techniques such as 'Moving Target Indicator' (MTI) processing are employed by the radar processor to determine targets moving tangential to the radar beam.

4.3.3 Notes on turbine effects on radar

4.3.3.1 Wind turbines can cause significant PSR false plots, or clutter, as the rotating blades can trigger the Doppler threshold (e.g. minimum shift in signal frequency) of the Radar Data Processor (RDP) and therefore may be interpreted as aircraft movements. Significant effects have been observed on radar sensitivity caused by the substantial Radar Cross Section (RCS) of the turbine structural components (blades, tower and nacelle) which can exceed that of a large aircraft; the effect 'blinds' the radar (or the operator) to wanted targets in the immediate vicinity of the wind turbine.

4.3.3.2 False plots and reduced radar sensitivity may reduce the effectiveness of radar to an unacceptable level and compromise the provision of a safe radar service to participating aircraft.

4.3.3.3 It is mainly for the above reasons that airport operators and other air navigation service providers object to wind farm developments that are within LOS to their radar. However, it is worth noting that detectability of turbines does not automatically constitute a valid reason for objection. There are several relevant examples where the impact of offshore sites is managed on an operational basis without the need for technical mitigation.

4.3.4 Operational assessment methodology

4.3.4.1 The operational assessment has been undertaken as outlined below.

- Stakeholder Identification: A list of potential aviation stakeholders, in accordance with CAP 764 (CAA, 2016c), were considered including those within the airspace used en route to Hornsea Three and the radar systems within the operational range of Hornsea Three. The identification stage also considers, for example, military areas of operation, tactical training and danger areas;
- Stakeholder Impact: for each identified stakeholder, the radar impact and subsequently the operational impact of the turbines being detectable by that radar were considered as follows:
  - The operational impact pays heed to, but is not limited to, consideration of: the orientation of approach and departure flight paths, physical safeguarding of flight, types of aircraft flying into the aerodrome, airspace characteristics and flight procedures as published in the UK IAIP (for civilian aviation activities) and the Military Aeronautical Information Publication (Mil AIP);
  - Consideration of mitigation where applicable; and
  - Recommendations for next steps.

5. NATS Impact Assessment

5.1 Overview

5.1.1.1 NATS provide air traffic services at some airports in the UK and provide air traffic services to traffic en-route (overflying or flying between airports) in UK airspace. NATS operate several long range PSRs and SSRs positioned to provide maximum coverage of UK airspace. Additionally, NATS has a licence obligation to provide radar data to other aviation stakeholders, to a high quality and performance standard for the benefit of UK aviation. Any effect that the Hornsea Three array area might have on NATS radars must be considered both in terms of effect on the civilian en-route services and in the context of its remote users.

5.1.1.2 In addition, Military ATC Units are based in NATS control centres to facilitate the control of aircraft that require ATS outside Controlled Airspace (CAS). NATS have a contracted responsibility to provide appropriate PSR coverage to support this task.

5.1.1.3 Anglia Radar, based at Aberdeen Airport also employs NATS radar to support their provision of services to helicopters travelling to/from oil and gas platforms within the lateral confines of their area of responsibility over the southern North Sea from sea level up to FL 65 (6,500 ft. approximately). However, should the military Southern MDA be active, Anglia Radar will restrict offshore helicopter operations to FL 40 and below.

5.1.1.4 The CAA, through CAP 764 (CAA, 2016c), advises that effects on SSR installations can be significant when turbines are very close to an SSR facility (i.e. within 10 km). The Hornsea Three array area is well in excess of 10 km from any SSR facility and therefore no impact is assessed on SSR.

5.2 Radar Line of Sight (LOS) analysis

5.2.1.1 NATS use PSRs based in North Lincolnshire (Claxby) and Norfolk (Cromer) to support their provision of ATS to aircraft operating between the UK and mainland Europe, and to those overflying the UK Flight Information Region (FIR) in the vicinity of the Hornsea Three array area. In facilitating this task, a number of established airways cross the area and are active from FL 195 and above. The Hornsea Three array area is located within operational range of the NATS Claxby PSR.

5.2.2 NATS Claxby PSR

5.2.2.1 The NATS Claxby PSR has an operational range of 200 nm. Figure 5.1 represents the results of the LOS analysis profiles between the NATS Claxby PSR and the Hornsea Three array area with a turbine tip height of 325 m.

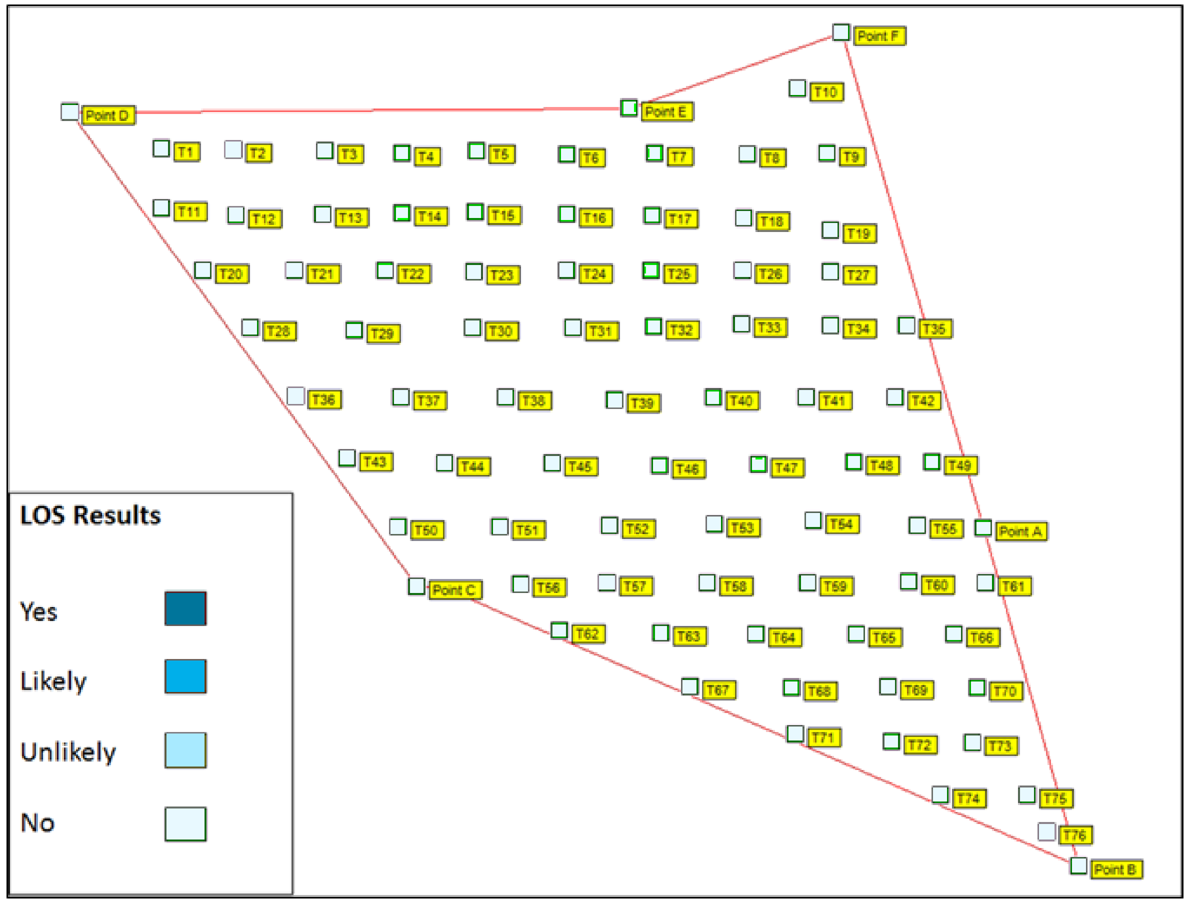

Figure 5.1: LOS Results from NATS Claxby PSR at a turbine tip height of 325 m.

Note: The points assessed in this diagram represent a grid across the development area to assess for the potential that the anticipated turbine parameters might be detectable by aviation radar systems. They do not represent specific turbine locations.

5.2.2.2 The LOS results predict that turbines within the Hornsea Three array area, which have a maximum tip height of 325 m (see Table 4.2), are not detectable by the Claxby PSR system. Therefore, this system has not been considered further in the aviation radar analysis assessment.

5.2.3 Cumulative impacts

5.2.3.1 As the LOS results predict that turbines within the Hornsea Three array area are not detectable by the Claxby PSR system; no cumulative impacts are expected to occur.

5.3 NATS consultation

5.3.1.1 As part of the pre-application consultation process, Hornsea Three has requested NATS to provide an assessment of the potential for Hornsea Three to affect any of the radar or communications systems operated or controlled by NATS. NATS responded by email dated 1 August 2016 that they had no objection to Hornsea Three and responded by email dated 9 March 2017 that they anticipate no impact on their own infrastructure and operations.

6. MOD ASACS Assessment

6.1 Overview

6.1.1.1 The MOD through the ASACS Force is responsible for compiling a Recognised Air Picture (RAP) to monitor the airspace in and around the UK in order to launch a response to any potential airborne threat. This is achieved through the utilisation of a network of long-range Air Defence Radar (ADR), some of which are located along the east coast of the UK. Any identified effect of turbines on the ASACS radars that serve the airspace above the Hornsea Three array area would potentially reduce the capability of the ASACS force.

6.1.1.2 ASACS radar resources are also used in support of training and exercises on an almost daily basis. Two MDAs are established over the North Sea (Central and Southern MDA). Within the lateral and vertical confines of the MDAs, air combat training, high energy manoeuvres and supersonic flight can be expected. The Southern MDA (specifically area EG D323D, see section 3) is located above the Hornsea Three array area, and when active, operates from FL 50 up to FL 660 (FL being a standard nominal altitude of an aircraft, in hundreds of feet, based upon a standardised air pressure at sea-level).

6.1.1.3 Note: When the MDAs are not required for specific military training or exercise use, the airspace is then available for use for Civil and Military En-route operations.

6.2 Radar Line of Sight (LOS) analysis

6.2.1 Staxton Wold ADR

6.2.1.1 The Staxton Wold ADR has an operational range of 400 km (215 nm). Figure 6.1 below represents the results of the LOS analysis profiles between the MOD Staxton Wold ADR and the Hornsea Three array area with a turbine tip height of 325 m.

6.2.1.2 The LOS analysis predicts turbines within the Hornsea Three array area, which have a maximum tip height of 325 m (see Table 4.2), are not detectable by the Staxton Wold ADR. Therefore, this system has not been considered further in the aviation radar analysis assessment.

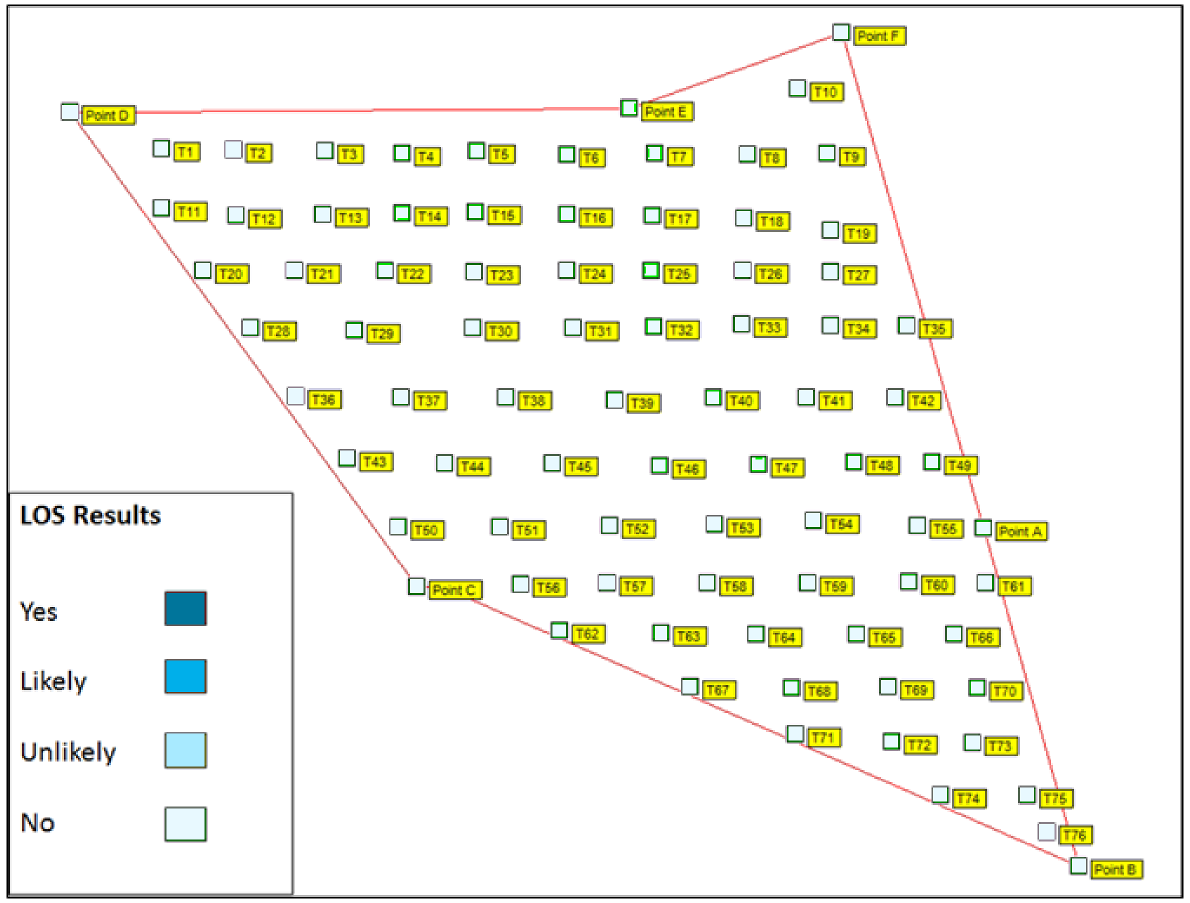

Figure 6.1: LOS results from MOD Staxton Wold ADR at a turbine tip height of 325 m.

Note: The points assessed in this diagram represent a grid across the development area to assess for the potential that the anticipated turbine parameters might be detectable by aviation radar systems. They do not represent specific turbine locations.

6.2.2 Trimingham ADR

6.2.2.1 The MOD Trimingham ADR has an operational range of 400 km (215 nm). Figure 6.2 represents the results of the LOS analysis profiles between the MOD Trimingham ADR and the Hornsea Three array area with a turbine tip height of 325 m.

6.2.2.2 Turbines within a small area of the Hornsea Three array area along the southwestern boundary would be considered theoretically intermittently detectable by the Trimingham ADR. Other turbines in the southwestern section of the Hornsea Three array area are unlikely to be routinely detectable, and turbines in the northeastern section are not predicted to be detectable by the Trimingham ADR.

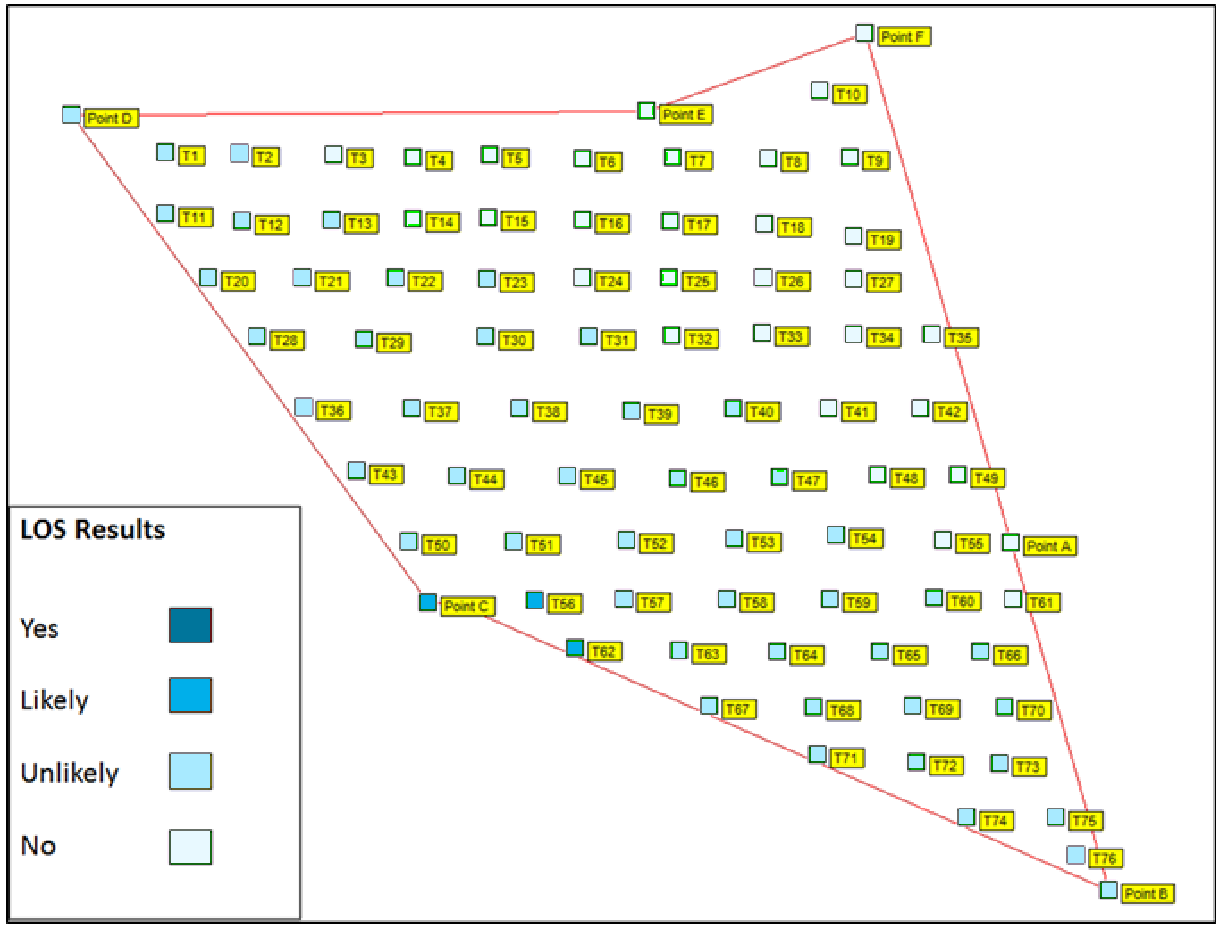

Figure 6.2: LOS results from MOD Trimingham ADR at a turbine tip height of 325 m.

Note: The points assessed in this diagram represent a grid across the development area to assess for the potential that the anticipated turbine parameters might be detectable by aviation radar systems. They do not represent specific turbine locations.

6.2.3 ASACS operational impact

6.2.3.1 Turbines in coverage areas of ASACS ADRs could potentially shield the radar from genuine aircraft targets and/or hide genuine aircraft targets, in display clutter, from the ASACS controller. Furthermore, a degree of 'shadowing' could be created behind detectable turbines. Any of these potential effects could impact on the controller's ability to provide a safe service to aircraft and successfully utilise the radar data to monitor the UK RAP. Consequently, any identified effect of turbines on the ASACS ADRs that serve the airspace above the Hornsea Three array area would potentially reduce the capability of the ASACS force. An assessment of the implications of this, in EIA terms, is presented in volume 2, chapter 8: Aviation, Military and Communication.

6.2.4 Cumulative impacts

6.2.4.1 The theoretical intermittent detection of wind turbines at a tip height of 325 m, in a small area of the Hornsea Three array area may contribute to a cumulative effect with other developments on the Trimingham ADR system, adding to the cumulative radar clutter and possibly an increase in the signal processing demands of the Trimingham ADR. The proximity of the other Round 3 projects (including other projects within the Hornsea Zone and, East Anglia Zone), together with Round 2 and Round 1 offshore wind farms (see Figure 7.3), and onshore developments, indicates there is the potential for a cumulative impact.

6.2.4.2 Specifically the other offshore wind farms that are considered likely to be detected by the Trimingham ADR include Hornsea Project One, Hornsea Project Two, the East Anglia offshore wind farms (East Anglia One, East Anglia One North, East Anglia Two, East Anglia Three and East Anglia Four (Norfolk Vanguard), Westermost Rough, Sheringham Shoal, Race Bank, Triton Knoll, Dudgeon, Humber Gateway, Lincs, Lynn and Inner Dowsing.

6.2.4.3 The Lockheed Martin TPS-77 ADR is the only current system that has inherent hardware and software mitigations for the effects of wind turbines on radar and infrastructure accepted by the MOD. The mitigation principle uses the concept of Non Automatic Initiation Zones (NAIZ). A NAIZ prevents the radar from automatically creating tracks from any returns that originate within the NAIZ. In creating a NAIZ around a wind farm, none of the turbine generated returns will be processed, thereby significantly reducing the possibility of false tracks. Tracks which have been formed from returns originating outside the NAIZ, such as an aircraft transiting through the NAIZ, will still be tracked.

6.2.4.4 A TPS-77 ADR is in operation at the Trimingham site to resolve the cumulative impact of other wind farms in the Greater Wash area, which demonstrates mitigation options are available were they to be required.

6.3 MOD consultation

6.3.1.1 As part of the pre-application consultation process for Hornsea Three, Hornsea Three has requested the Defence Infrastructure Organisation (DIO) to undertake an assessment of the potential for the Hornsea Three array area to affect any of the radar or communications systems operated or controlled by the MOD, and the potential for the Hornsea Three array area to affect any of the military exercise areas, military practice areas or military danger areas in the southern North Sea. The DIO has advised that the Scoping Report submitted by Hornsea Three (DONG Energy, 2016) recognises the principal defence issues that will be of relevance to the progression of the development and does not need to include further information to take account of national defence interests. The MOD confirmed that it is unlikely that there will be any detectability from any MOD ADR radars to the Hornsea Three array area due to the distance of the Hornsea Three array area offshore.. This informs the assessment in the EIA (volume 2, chapter 8 Aviation, military and communication) using the modelling results presented in this section, that any detection is sufficiently low to be not significant to the MOD.

6.3.1.2 The MOD also confirmed that it is unlikely that there will be any detectability from any MOD ATC radars to the Hornsea Three array area due to the distance of the Hornsea Three array area offshore. This consultation provides the confirmation requested by PINS in their Scoping Opinion toto justify scoping out effects on military ATC radar (PINS, 2016).

7. Offshore Helicopter Operations Assessment

7.1 Overview

7.1.1.1 A network of HMRs is established to support the transport of personnel and material to offshore oil and gas installations. One of these HMRs (HMR2) crosses through the Hornsea Three array area (see Figure 8.1).

7.1.1.2 In addition, a 9 nm radius consultation zone around offshore installations is referenced in CAP 764 to allow for the safe operation of helicopter instrument approaches to platforms in poor weather conditions. The consultation zones of nine platforms extend across the Hornsea Three array area.

7.1.1.3 Figure 7.1 shows the established HMR structure in the southern North Sea and in relation to the Hornsea Three array area, and the 9 nm consultation zones surrounding platforms which intersect with the Hornsea Three array area.

7.2 HMR operational impacts

7.2.1.1 HMR2 crosses through the Hornsea Three array area. The area of HMR2 over and beyond the Hornsea Three array area is used predominantly for transit from Norwich International Airport to the oil and gas platforms to the east of the Hornsea Three array area.

7.2.1.2 CAP 764 (CAA, 2016c) states that whilst HMRs have no defined lateral dimensions, they provide a network of offshore routes utilised by civilian helicopters. There should be no obstacles within 2 nm either side of HMRs but where planned these should be consulted upon with the helicopter operators and ANSP. It may be considered that some turbine development within 2 nm of the route centreline could be manageable. However, a large number of turbines beneath an HMR could result in significant difficulties by forcing the aircraft to fly higher in order to maintain a safe vertical separation from wind turbines.

7.2.1.3 When operating within Instrument Flight Rules (IFR), helicopters require a Minimum Safe Altitude (MSA) of 1,000 ft. height clearance from obstacles within 5 nm of the aircraft. This implies that whilst operating above the physical obstruction of the Hornsea Three turbines, offshore helicopters would be required to fly at 2,100 ft. AMSL (325 m blade tip height = 1,066ft., rounded up to nearest 100 ft., plus 1,000 ft.). When operating in Visual Flight Rules (VFR) conditions, helicopters will route direct to their destination point and require a minimum of 500 ft. separation from obstacles and would therefore be required to fly at 1,600 ft. AMSL (325 m blade tip height = 1,066ft., rounded up to nearest 100 ft., plus 500 ft.). However, whilst following an HMR the helicopters operate IFR under Anglia Radar service provision and so must fly at the former height (2,100 ft.).

7.2.1.4 Helicopters utilising HMR's are height-banded, so that those outbound to North Sea installations fly at 2,000 ft. and 3,000 ft., whilst those inbound fly at 1,500 ft. and 2,500 ft. This allows for 500 ft. vertical separation between helicopters travelling in opposite directions. A large number of turbines beneath an HMR would result in helicopters flying higher in order to maintain a safe vertical separation from turbines. The physical presence of the Hornsea Three turbines would mean that outbound flights must be flown at an MSA of 3,000 ft. and inbound flights at an MSA of 2,500 ft. However, this option is not available on days of low cloud base when the icing level is below 3,000 ft. or 2,500 ft. due to the risk of ice aggregation on the aircraft. In these conditions, utilising the portion of HMR2 that is located above the Hornsea Three array area would not be an available option and certain flights could therefore be restricted within the HMR. All flights bisecting the Hornsea Three array area using HMR2 will be directly impacted by the turbines and in certain weather conditions the use of HMR2 will be restricted.

7.2.2 HMR impact mitigation strategy

7.2.2.1 Following consultation with the aviation stakeholders including the helicopter operators undertaken by Hornsea Project One (see Table 8.3 in volume 2, chapter 8 Aviation, Military and Communication), it is understood that an HMR crossing a wind farm would not require revision because in most cases, helicopters will continue to fly their preferred routes in VFR directly over the wind turbines at the specified MSA. In Instrument Meteorological Conditions (IMC) and when the isotherm level is at an altitude that requires the helicopter to fly at less than 3,000 ft. or 2,500 ft. (depending on required direction of travel). an obstacle free route is required and in the case of Hornsea Three this is available as a deviation around the Hornsea Three array area, an example of which is shown in Figure 7.2.

7.3 HMR cumulative effects

7.3.1.1 There are no other offshore wind farms located below HMR2 and therefore there is no cumulative effect on HMR2.

7.3.1.2 Considering the Hornsea Project One and Hornsea Project Two wind farms at a distance of 3.9 nm from the western edge of the Hornsea Three array area, there is potential for a cumulative effect on HMR3. The physical presence of Hornsea Project One and Hornsea Project Two would restrict the use of HMR3 in certain weather conditions. An obstacle free route for HMR3 would need to take into account Hornsea Project One, Hornsea Project Two, and Hornsea Three (see Figure 7.3). A potential alternative route for HMR3 is therefore affected by the presence of Hornsea Three.

7.3.1 HMR cumulative impact mitigation strategy

7.3.1.1 Following consultation with the aviation stakeholders including the consultation with helicopter operators undertaken by Hornsea Project One (see Table 8.3 in volume 2, chapter 8 Aviation, Military and Communication), it is understood that HMRs would not require revision because in most cases, helicopters will continue to fly their preferred routes in VFR directly over the wind turbines at the specified MSA. In Instrument Meteorological Conditions (IMC) and when the isotherm level is at an altitude that requires the helicopter to fly at less than 3,000 ft. or 2,500 ft. (dependant on direction of travel, and being the required height for Hornsea Project One, Hornsea Project Two and Hornsea Three), an obstacle free route is required. There are other available route deviation options, including around Hornsea Project One and Hornsea Project Two to the west of the two projects, or to the east of Hornsea Project Three, or potentially between Hornsea Project One and Hornsea Project Two, and Hornsea Three. This route is a corridor of 3.9 nm in width between Hornsea Three and Hornsea Project One and Hornsea Project Two as shown in Figure 7.3.

7.4 Offshore installations operational impact

7.4.1.1 In order to help achieve a safe operating environment, a consultation zone of 9 nm radius around offshore helicopter installations is referenced in CAP 764. This consultation zone is not considered a prohibition on wind turbine development within a 9 nm radius of offshore operations, but rather a trigger for consultation between wind farm developers, offshore helicopter operators, the operators of existing platforms, and/or exploration and production licence holders, that will help to ensure safe offshore helicopter operations.

7.4.1.2 The basic requirement of the 9 nm consultation zone is to promote consultation that will help to ensure safe instrument approaches in poor weather conditions where a low visibility approach profile is needed. In addition, the consultation helps to ensure that helicopter pilots are able to safely carry out a Missed Approach Procedure (MAP). Such profiles must allow for an acceptable pilot workload, a controlled rate of descent, one engine inoperative performance and obstacle clearance (CAA, 2016c).

7.4.1.3 There are nine platforms with 9 nm of the Hornsea Three array area as shown in Table 7.1. The Cutter platform has no helideck and so no further assessment has been undertaken.

7.4.1.4 Wind turbines are considered as physical obstructions and infringe the minimum obstacle clearance criteria of 1,000 ft. Furthermore, during the approach to an installation, all radar contacts (including radar contacts that are turbines) must be avoided laterally by at least 1 nm. These combined effects within a 9 nm consultation zone of an offshore installation may impair the safety of air operations to that installation and affect the installation operators' regulatory requirements with regard to safety of operation.

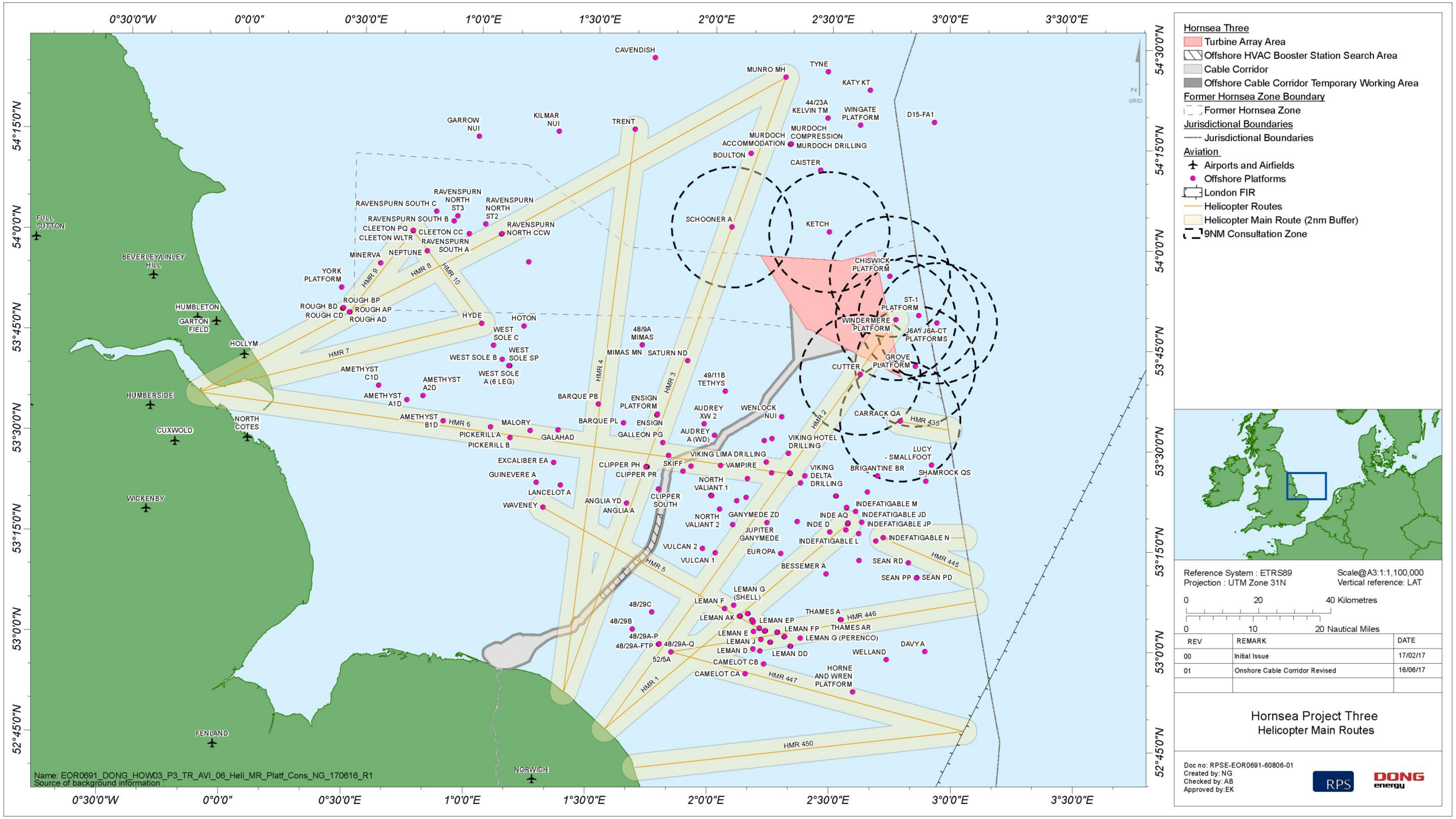

Figure 7.1: The HMR structure and 9 nm consultation zones which intersect with the Hornsea Three array area.

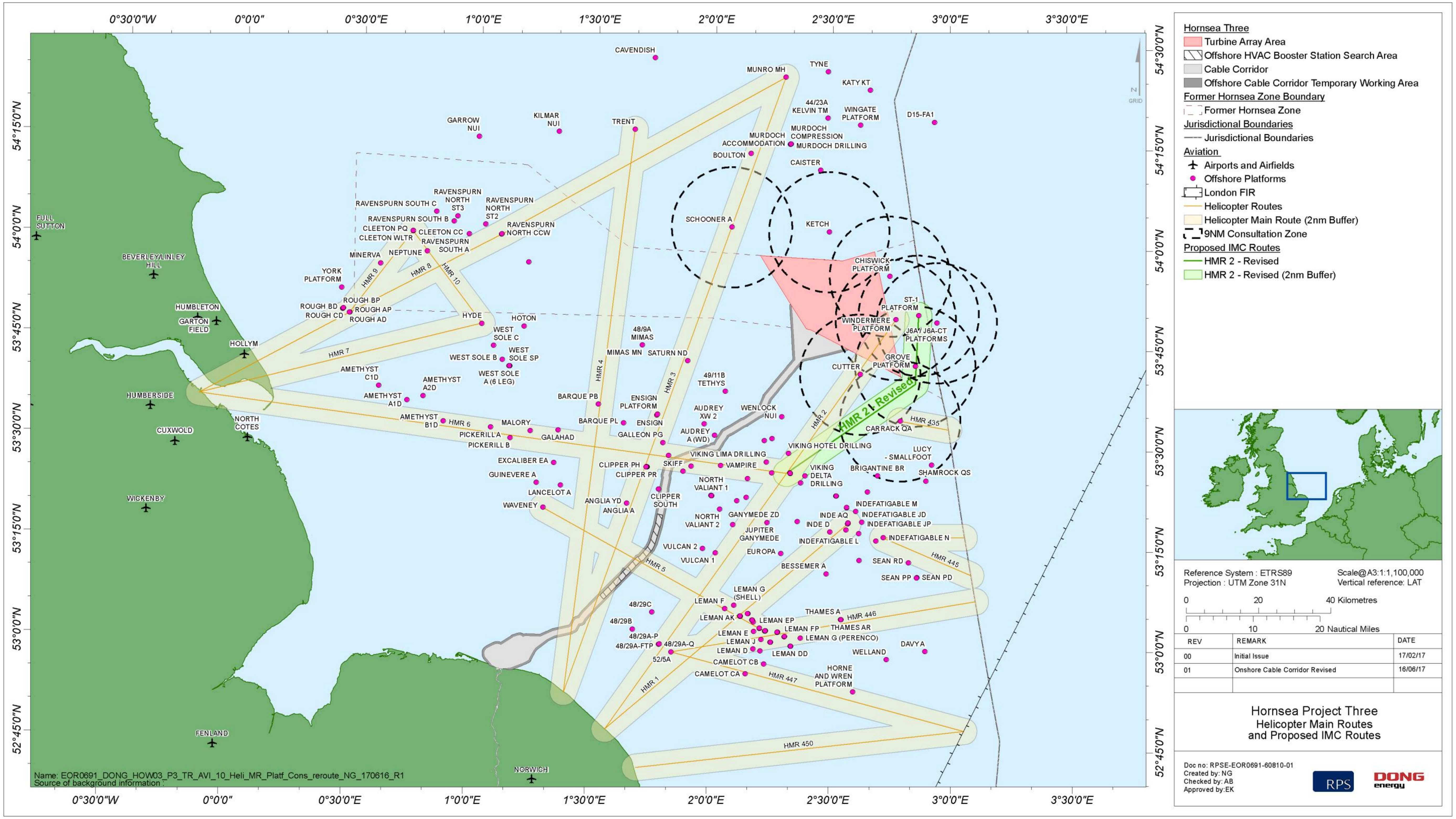

Figure 7.2: Potential re-route of HMR2 around the Hornsea Three array area.

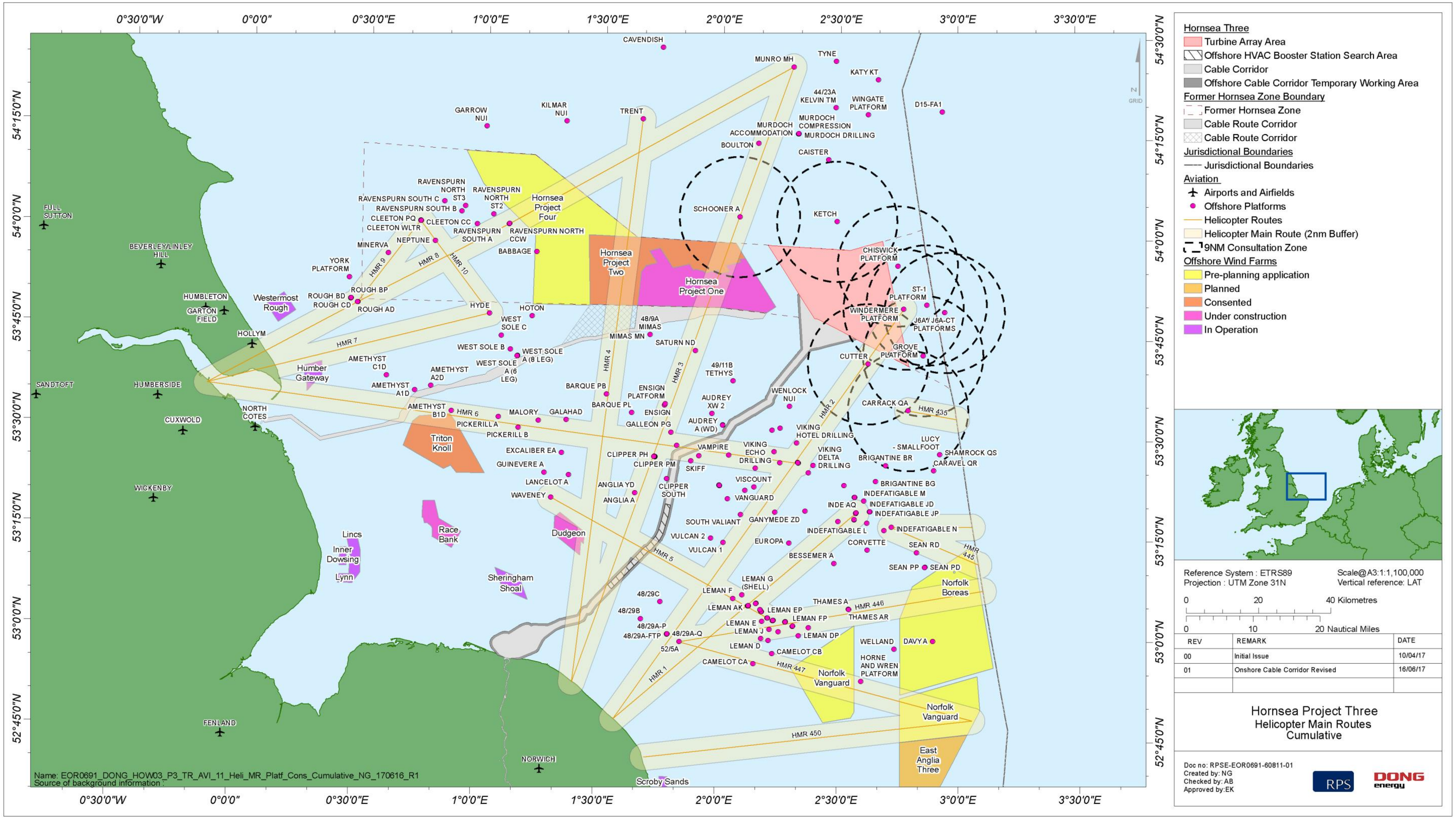

Figure 7.3: Cumulative impact on HMRs in relation to Hornsea Three, Hornsea Project Two and Hornsea Project One.

Table 7.1: Offshore platforms with 9 nm consultation zone overlap with Hornsea Three array area.

Platform	Operator	Helideck	Latitude (N)	Longitude (E)	Status	Distance to Hornsea Three array area boundary	
						nm	km
Schooner A	Faroe Petroleum	Yes	54°3' 32.520" N	2°4' 34.980" E	Active. Potential to be decommissioned by 2023.	5.98	11.07
Ketch	Faroe Petroleum	Yes	54°2' 57.900" N	2°29' 18.060" E	Active. Potential to be decommissioned by 2023.	4.14	7.67
Chiswick	Centrica	Yes	53°56' 21.160" N	2°44' 44.732" E	Active	1.45	2.69
ST-1	Centrica	Yes	53°50' 31.978" N	2°52' 3.819" E	Production ceased. Due to be decommissioned by 2021. Decommissioning plans submitted but not yet approved.	4.48	8.29
J6A/J6A-CT	Centrica	Yes	53°49' 24.160" N	2°56' 37.987" E	Active	6.90	12.77
Grove	Centrica	Yes	53°42' 57.000" N	2°51' 13.200" E	Active	2.43	4.50
Windermere	INEOS	Yes	53°49'53.283"N	2°46'15.958"E	Production ceased. To be decommissioned by 2023. Plans not yet submitted or approved.	0.98	1.82
Cutter	Shell	No helideck	53°41'41.446"N	2°37'20.645"E	Active	2.52	4.67
Carrack QA	Shell	Yes	53°34' 43.672" N	2°47' 27.239" E	Active	6.65	12.31

7.4.2 Helicopter instrument approach procedures

7.4.2.1 Instrument approach procedures are used as a low-visibility approach procedure to the platforms, and rely upon an on-board weather radar for obstacle detection and navigation. Helicopters which operate to and from offshore platforms are fitted with airborne weather radar which can be used to conduct an instrument approach in poor visibility. The radar is designed to display weather phenomena, such as rain, as well as obstacles such as oil or gas platforms, or wind turbines. In IMC and in certain wind conditions, which dictate the area of approach to the platform, a standard instrument approach procedure might not be possible due to the proximity of wind turbine structures to the flight approach path.

7.4.2.2 Current operational procedures indicate that the optimum descent angle for helicopters on approach to offshore platforms is a descent rate of 300 ft. per nm to 400 ft. per nm (3° to 4° glide path) (CAA, 2016c) which is shown illustratively in Figure 7.4.

7.4.2.3 When the helicopter is operating below the MSA and conducting an instrument approach it must also maintain a horizontal separation of 1 nm from all radar contacts seen by the pilots, using the helicopter's on-board radar. If it is assumed that an acceptable rate of descent is a 3.5° glide path, then this means that the minimum distance that a 325 m high turbine can be constructed from the centre of a helicopter consultation zone is 8 nm before instrument approach procedures may become restricted. An example approach profile for a 325 m turbine is shown in Figure 7.5. The helicopter descends from the MSA at 8.4 nm avoiding all radar contacts by 1 nm but flying in any wind direction, to the Fixed Approach Point at 7nm (the procedural value set by the helicopter operator and ranging typically from 5 to 7 nm). The helicopter then flies a straight line approach (up to 30 degrees out of wind in either direction) to a minimum descent height of 200 to 300 ft typically at 2 nm (CAA, 2016c). The helicopter then flies to the Missed Approach Point at 0.75 nm where a decision is made either to land or to fly past and conduct a Missed Approach Procedure.

7.4.3 Missed Approach Procedure (MAP)

7.4.3.1 In the event a helicopter may not be able to land at its destination platform, it would be required to execute a MAP. Should the airspace that is required to fly a MAP not be available due to the presence of turbines, then this would restrict helicopter operations. Upon initiating a MAP, the helicopter turns away from the destination structure by up to 45° laterally and climbs to the MSA; the anticipated rate of climb during the missed approach phase is based upon the one engine inoperative performance criteria and could be quite shallow. For obvious safety reasons, a MAP involving a climb from the minimum descent height needs to be conducted in an area free of obstructions.

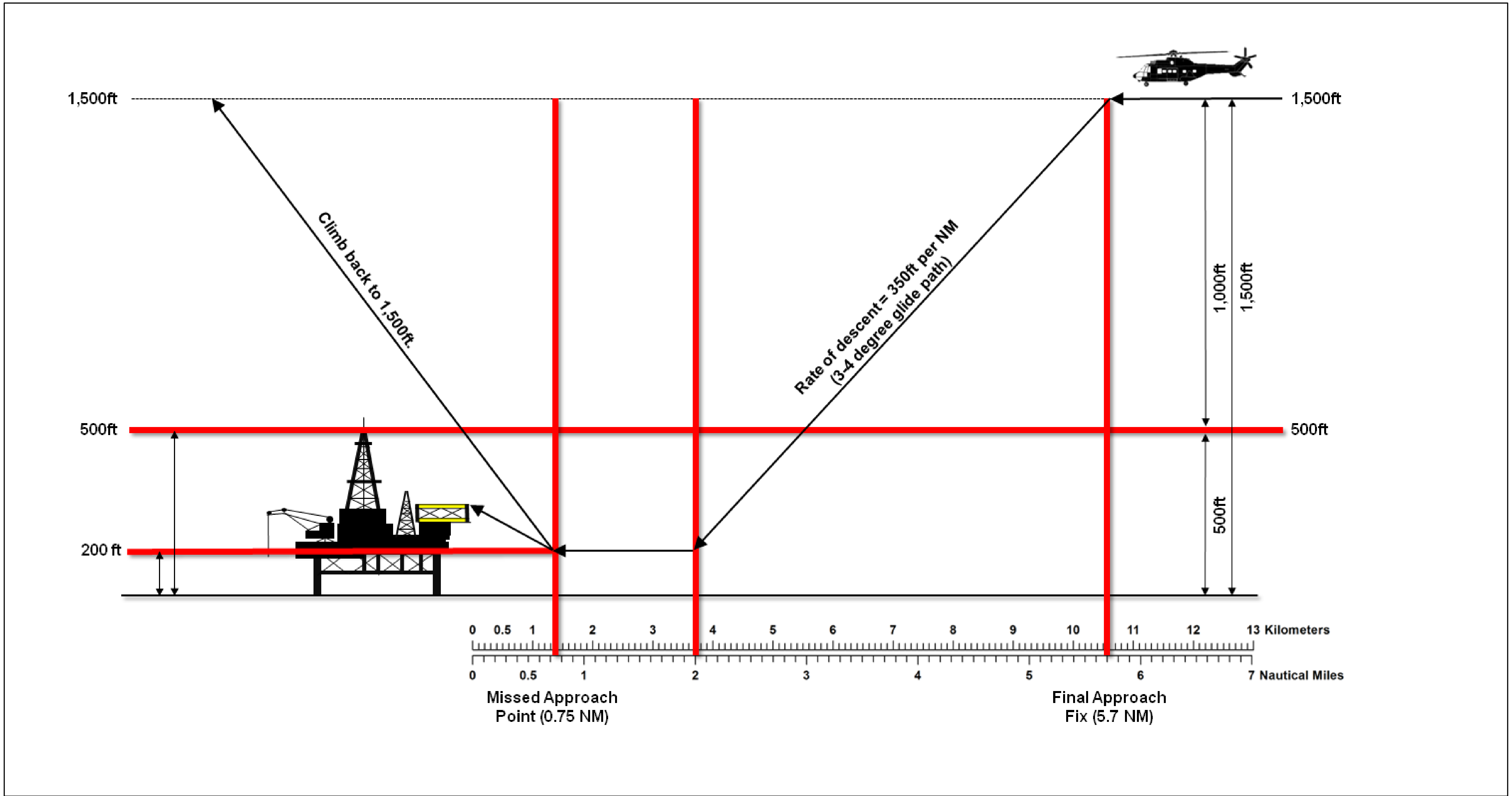

Figure 7.4: Indicative instrument approach procedure without turbines present.

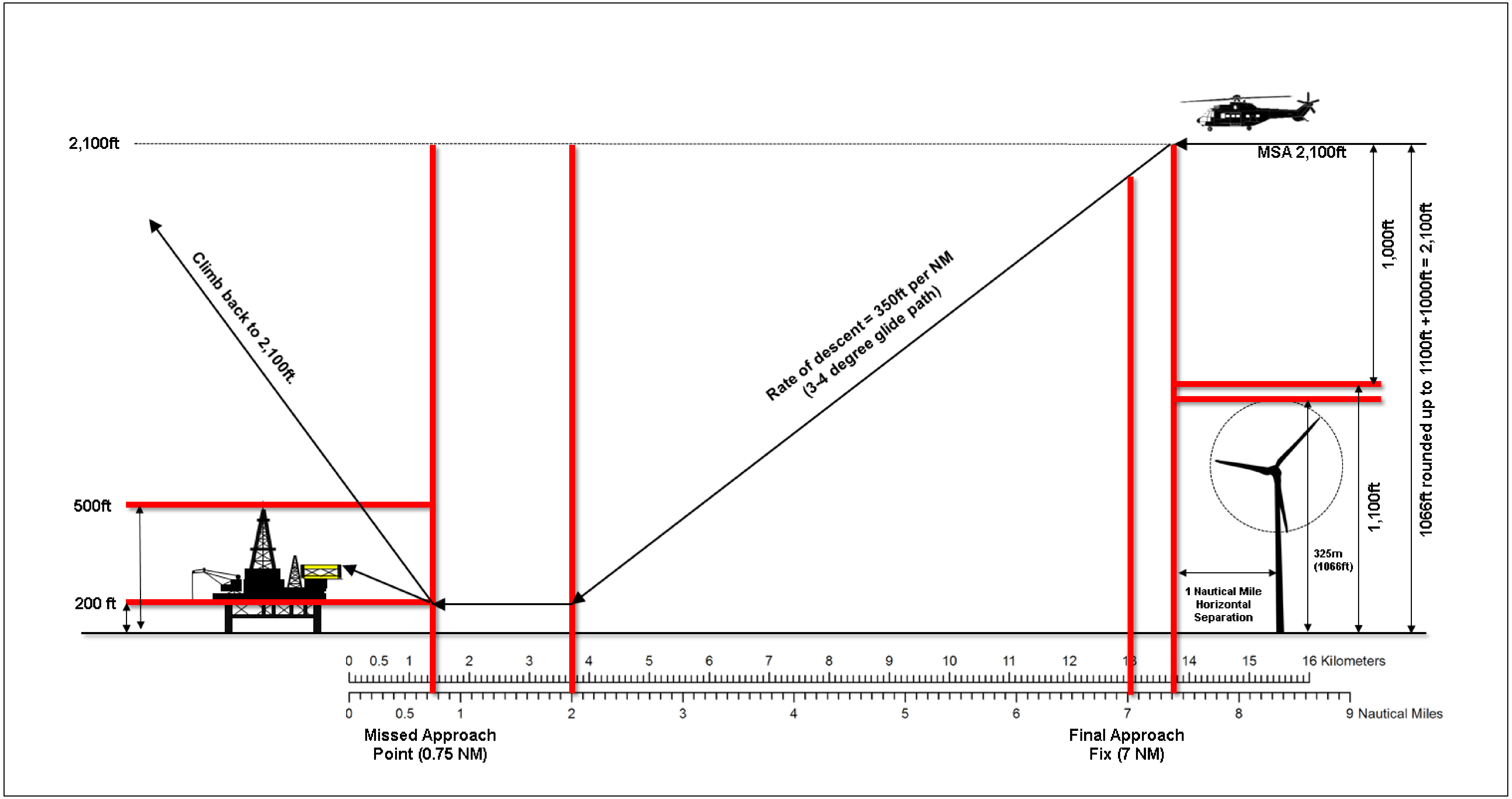

Figure 7.5: Indicative instrument approach procedure with turbines present.

7.4.4 Wind data analysis

7.4.4.1 Wind speed and direction data has been processed to determine the frequency of wind speed and direction. The wind data supplied was recorded at the Schooner A Platform at an altitude of 101 m AMSL using data from 2002 to 2012. For the purposes of this assessment it is assumed that this wind data is applicable to the remaining subject platforms given the consistency in weather patterns in the area.

7.4.4.2 Two sets of wind data were provided; the first represents a 13 month data set commencing February 2011. It is understood that this distribution represents a seasonal unbiased 13 months. The second represented a long term distribution between 2002 and 2012. In order to assess long term data on a directional basis, the 13 months of modelled data was adjusted to a long term (12 years) modelled Reanalysis dataset (MoDern Era-Retrospective Analysis for Research and Applications – MERRA). This is assumed to be an accurate method in predicting the long term distribution of wind speed and direction at the measured location. For this assessment, the longer term data file was used as it provides the most accurate and stable distribution.

7.4.4.3 The wind speed and direction data has been processed into the wind rose in Figure 7.6 illustrating the frequency of wind speed and direction over the 2002 to 2012 periods.

7.4.4.4 For the purposes of this assessment it has been assumed that with slack wind conditions (wind speed below 2.5 m/s) helicopters will be able to fly an instrument approach from any direction. It is considered that helicopters have the capability to approach a platform 30° offset from the surface wind (EASA, 2015) direction; therefore, it is possible in some wind conditions that instrument approach procedures would be required to take place over the Hornsea Three array.. As outlined in paragraph 7.4.1.4 this may not be acceptable due to the distance required to descend and the requirement to avoid any radar contacts.

7.4.4.5 Table 7.2 lists the estimated airspace that is available for instrument approach procedures and MAP and the corresponding wind direction which gives rise to the constrained instrument approach sectors for each platform. The constrained instrument approach sectors are illustrated in Figure 7.7 (in pink).

7.4.4.6 The constrained areas for each platform have been calculated based on the following assumptions:

- Straight in approach from 7nm;
- Helicopters must avoid the wind farm boundary by 1 nm laterally.

7.4.4.7 A 1 nm buffer, providing the 1 nm required separation distance from wind turbines, was used around the Hornsea Three array area to establish the restricted instrument approach areas.

7.4.4.8 For the assessment it has been assumed that flying to the platforms is conducted throughout the year (365 days). Consultation has advised that low cloud and poor visibility may occur 15 % of the time (informed through pre-application consultation with helicopter operators for Hornsea Project One; see Table 8.3 in volume 2, chapter 8 Aviation, Military and Communication). An additional assumption has been made, drawing on the operational experience of DONG Energy's helicopter specialist, that during this 15 % duration, there are two methods of approach. For 10% of the time, a circling approach can be made, which would not be affected by the wind turbines. For the remaining 5 % of the time, a direct instrument approach is required. This analysis has assumed inflight wind and visibility conditions are independent from each other. It is therefore concluded that an instrument approach procedure is conducted, due to low cloud or poor visibility in the platform's vicinity, approximately 5% of the time. The above assumptions will be further discussed and agreed with relevant stakeholders prior to the submission of the Environmental Statement.

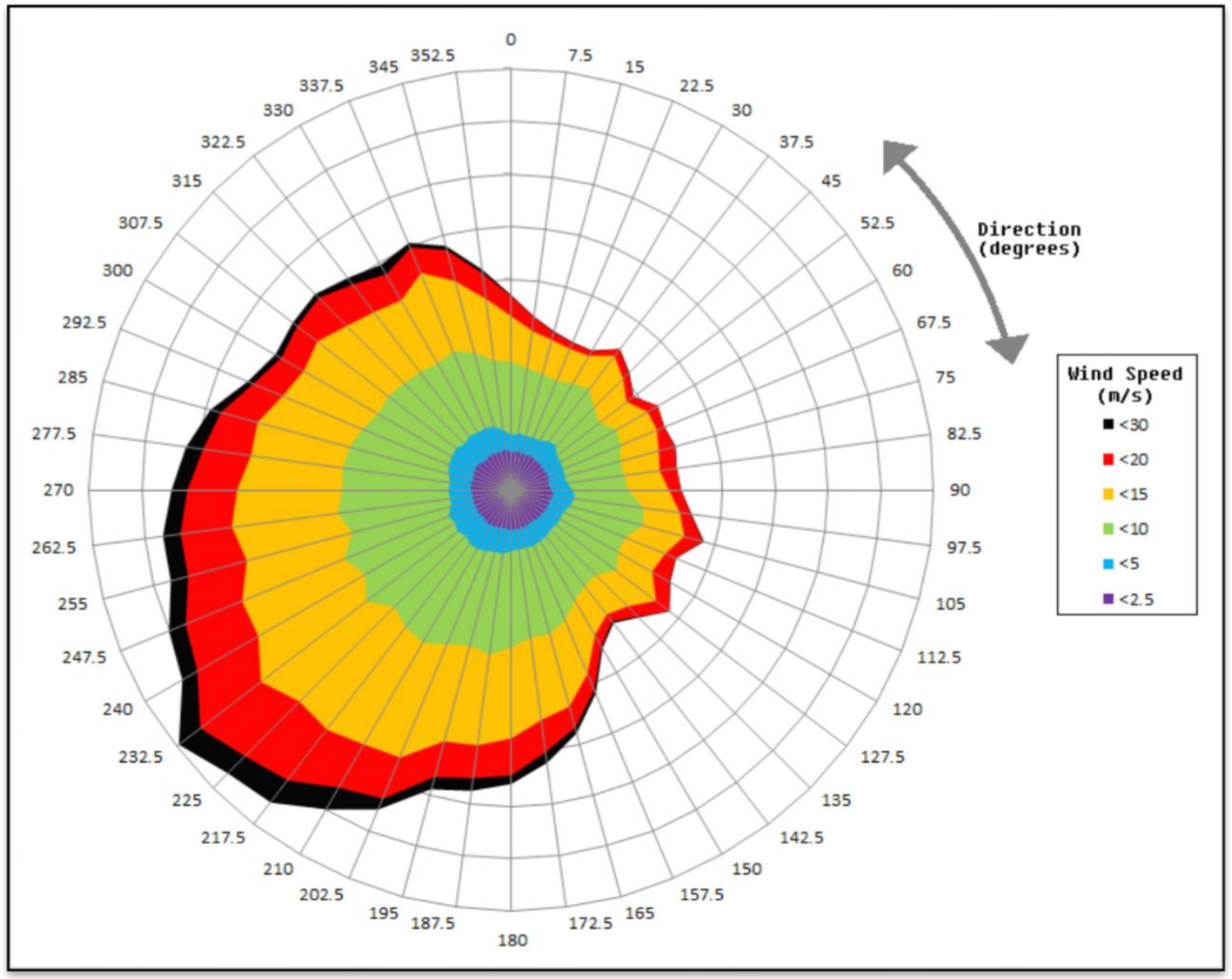

Figure 7.6: Wind speed and direction frequency distribution for 2002 to 2012.

Table 7.2: The available airspace and constrained approach sectors for each platform.

	Schooner A	Ketch	Chiswick	ST-1
Available airspace (°)	333.3	212.5	190	239.6
Constrained Approach Sector (°) ** 7nm from Platform, 1nm from wind farm*	115.9-142.6	102.5-250.0	171.8-341.8	197.9-318.3
Constrained Approach Sector (°) ** Considering 30° Offset*	N/A	132.5-220.0	201.8-311.8	227.9-288.3
Prevailing Wind Direction Constraint(°)	N/A	312.5-040.0	021.8-131.8	047.9-108.3
Compartmentalized Wind Direction (°) ** Assigned to 7.5 Degree Bins*	N/A	311.25-041.25	018.75-131.25	048.75-108.75
	J6A/J6A-CT	**Grove**	**Windermere**	**Carrack QA**
Available airspace (°)	294.1	234.9	180	333.6
Constrained Approach Sector (°) ** 7nm from Platform, 1nm from WF*	225.2-291.1	211.3-336.4	168.0-348.0	341.5-007.9
Constrained Approach Sector (°) ** Considering 30° Offset*	255.2-261.1	241.3-306.4	198.0-318.0	N/A
Prevailing Wind Direction Constraint(°)	075.2-081.1	061.3-126.4	018.0-138.0	N/A
Compartmentalized Wind Direction (°) ** Assigned to 7.5 Degree Bins*	071.25-086.25	063.75-131.25	018.75-138.75	N/A

7.4.4.9 During other periods, it is assumed that helicopter approaches will be conducted under VFR which dictates a helicopter flying at a speed which, having regard to visibility, is reasonable: clear of cloud, with the surface in sight, in a flight visibility of 1,500 m (CAA, 2016c). As the subject platforms are greater than this distance from the Hornsea Three array area boundary, no VFR operations will be impacted by turbines within the Hornsea Three array area.

7.4.4.10 The wind speed data (Appendix A) were analysed to determine the percentage of time at which wind direction/speed would affect helicopters approaching in the constrained sectors, discounting wind speeds below 2.5 m/s. Analysis of the annual averaged data, shows the potential number of instrument approach procedures to the respective platforms that are likely be affected by the Hornsea Three array area.

7.4.4.11 The results shown in Table 7.3 indicate that the impact of the Hornsea Three array area would be to prevent instrument approach procedures for the following calculated number of days per year to each of the platforms:

- Schooner A platform: Not affected;
- Ketch platform: 3.66 days per year;
- Chiswick platform: 3.49 days per year;
- ST-1platform: 1.84 days per year;
- J6/J6A-CT platform: 0.45 days per year;
- Grove platform: 2.18 days per year;
- Windermere platform: 3.73 days per year; and
- Carrack QA platform: Not affected.

7.4.4.12 Analysis of the month averaged data (Table 7.3 through to Table 7.9) shows the seasonal variation in the potential number of instrument approach procedures to the respective platforms that are likely to be affected by the Hornsea Three array area. The variation in number of instrument approach procedures that is seen is due to the variation in wind direction over the year.

Table 7.3: Resulting instrument approach procedures precluded by the Hornsea Three array area.

Description of calculation		Schooner A	Ketch	Chiswick	ST-1
Number of days per year that the wind direction would require flight into wind to be over the constrained sector.	A	NA	73.19	69.78	36.71
Assumed percentage of time that instrument approaches are conducted.	B	NA	5.00%	5.00%	5.00%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	NA	3.66	3.49	1.84
Corresponding percentage of days in a year that flights may be restricted by the wind farm (C/365 X 100).	D	NA	1.00%	0.96%	0.50%
Description of calculation		**J6A/J6A-CT**	**Grove**	**Windermere**	**Carrack QA**
Number of days per year that the wind direction would require flight into wind to be over the constrained sector.	A	9.01	43.52	74.70	NA
Assumed percentage of time that instrument approaches are conducted.	B	5%	5%	5%	NA
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	0.45	2.18	3.73	NA
Corresponding percentage of days in a year that flights may be restricted by the wind farm (C/365 X 100).	D	0.12%	0.60%	1.02%	NA

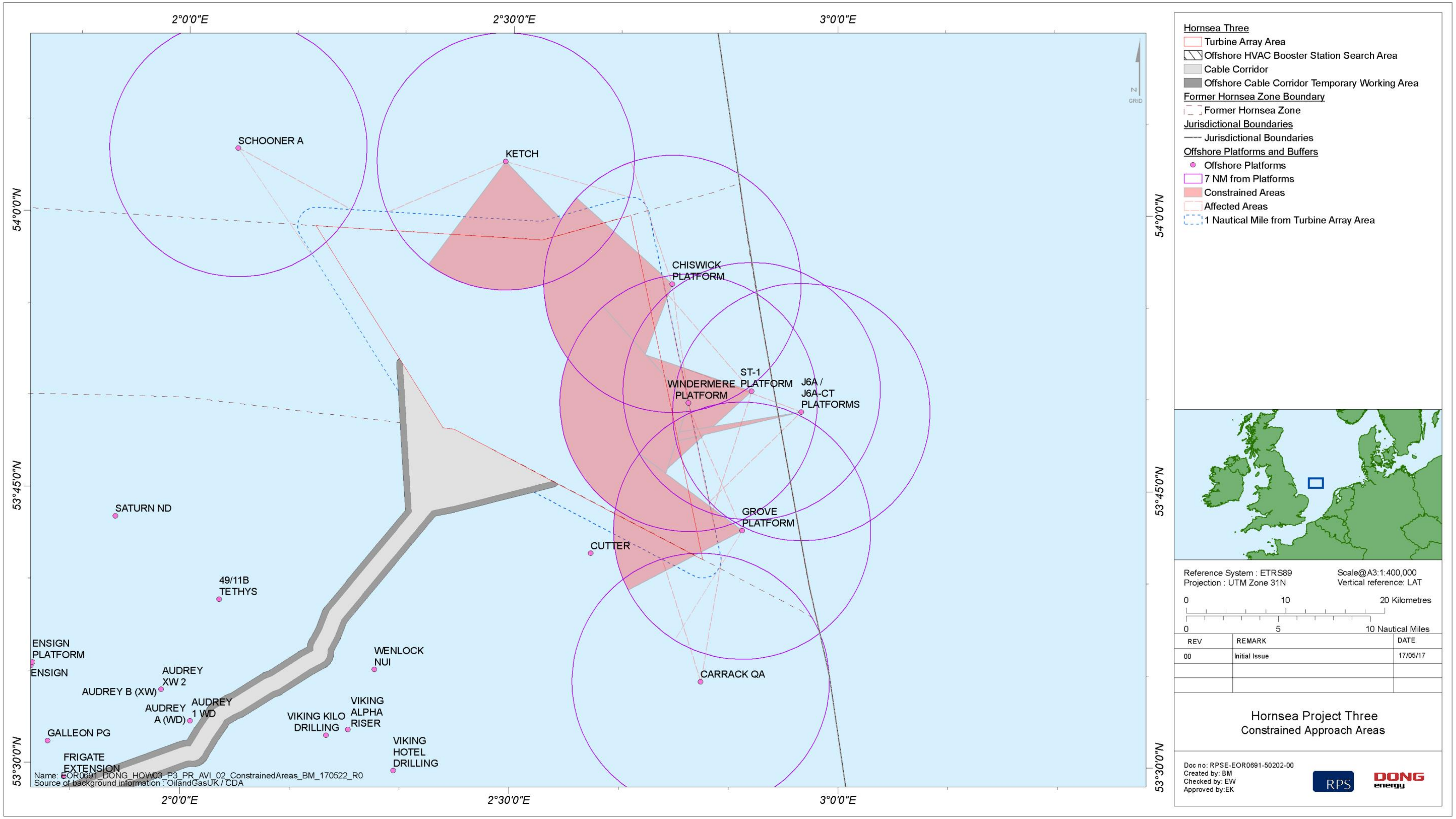

Figure 7.7: Constrained approach areas from Hornsea Three array area.

Table 7.4: Resultant instrument approach procedures to Ketch Platform that would be affected by Hornsea Three array area.

Description of calculation for Ketch Platform		January	February	March	April	May	June	July	August	September	October	November	December
Number of days per year that the wind direction would require flight into wind to be over the constrained sector	A	5.38	6.18	6.59	5.89	7.23	6.83	5.27	6.84	5.34	5.10	6.30	6.04
Assumed percentage of time that instrument approaches are conducted.	B	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	0.27	0.31	0.33	0.29	0.36	0.34	0.26	0.34	0.27	0.26	0.32	0.30
Corresponding percentage of flights in a month that may be restricted by the wind farm (C/number of days in month x 100).	D	0.87%	1.10%	1.06%	0.98%	1.17%	1.14%	0.85%	1.10%	0.89%	0.82%	1.05%	0.97%

Table 7.5: Resultant instrument approach procedures to Chiswick Platform that would be affected by Hornsea Three array area.

Description of calculation for Chiswick Platform		January	February	March	April	May	June	July	August	September	October	November	December
Number of days per year that the wind direction would require flight into wind to be over the constrained sector	A	5.27	6.20	6.47	8.09	7.73	5.94	4.74	3.49	4.67	5.90	4.32	6.14
Assumed percentage of time that instrument approaches are conducted.	B	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	0.26	0.31	0.32	0.40	0.39	0.30	0.24	0.17	0.23	0.30	0.22	0.31
Corresponding percentage of flights in a month that may be restricted by the wind farm (C/number of days in month x 100).	D	0.85%	1.11%	1.04%	1.35%	1.25%	0.99%	0.77%	0.56%	0.78%	0.95%	0.72%	0.99%

Table 7.6: Resultant instrument approach procedures to ST-1 Platform that would be affected by Hornsea Three array area.

Description of calculation for ST-1 Platform		January	February	March	April	May	June	July	August	September	October	November	December
Number of days per year that the wind direction would require flight into wind to be over the constrained sector	A	2.73	3.10	3.31	4.46	4.18	3.03	2.39	1.43	1.94	2.92	2.03	3.43
Assumed percentage of time that instrument approaches are conducted.	B	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	0.14	0.15	0.17	0.22	0.21	0.15	0.12	0.07	0.10	0.15	0.10	0.17
Corresponding percentage of flights in a month that may be restricted by the wind farm (C/number of days in month x 100).	D	0.44%	0.55%	0.53%	0.74%	0.67%	0.50%	0.39%	0.23%	0.32%	0.47%	0.34%	0.55%

Table 7.7: Resultant instrument approach procedures to J6/J6A-CT Platform that would be affected by Hornsea Three array area.

Description of calculation for J6/J6A-CT Platform		January	February	March	April	May	June	July	August	September	October	November	December
Number of days per year that the wind direction would require flight into wind to be over the constrained sector	A	0.48	0.69	0.75	1.27	0.88	0.65	0.51	0.29	0.42	0.63	0.48	0.81
Assumed percentage of time that instrument approaches are conducted.	B	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	0.02	0.03	0.04	0.06	0.04	0.03	0.03	0.01	0.02	0.03	0.02	0.04
Corresponding percentage of flights in a month that may be restricted by the wind farm (C/number of days in month x 100).	D	0.08%	0.12%	0.12%	0.21%	0.14%	0.11%	0.08%	0.05%	0.07%	0.10%	0.08%	0.13%

Table 7.8: Resultant instrument approach procedures to Grove Platform that would be affected by Hornsea Three array area.

Description of calculation for Grove Platform		January	February	March	April	May	June	July	August	September	October	November	December
Number of days per year that the wind direction would require flight into wind to be over the constrained sector	A	2.96	3.96	4.11	4.97	4.11	3.48	3.39	2.42	2.75	4.28	2.41	3.92
Assumed percentage of time that instrument approaches are conducted.	B	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	0.15	0.20	0.21	0.25	0.21	0.17	0.17	0.12	0.14	0.21	0.12	0.20
Corresponding percentage of flights in a month that may be restricted by the wind farm (C/number of days in month x 100).	D	0.48%	0.71%	0.66%	0.83%	0.66%	0.58%	0.55%	0.39%	0.46%	0.69%	0.40%	0.63%

Table 7.9: Resultant instrument approach procedures to Windermere Platform that would be affected by Hornsea Three array area.

Description of calculation for Windermere Platform		January	February	March	April	May	June	July	August	September	October	November	December
Number of days per year that the wind direction would require flight into wind to be over the constrained sector	A	5.45	6.54	6.81	8.57	8.08	6.31	5.11	3.87	5.01	6.55	4.67	6.35
Assumed percentage of time that instrument approaches are conducted.	B	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	0.27	0.33	0.34	0.43	0.40	0.32	0.26	0.19	0.25	0.33	0.23	0.32
Corresponding percentage of flights in a month that may be restricted by the wind farm (C/number of days in month x 100).	D	0.88%	1.17%	1.10%	1.43%	1.30%	1.05%	0.82%	0.62%	0.83%	1.06%	0.78%	1.02%

Ketch platform

7.4.4.13 The results shown in Table 7.4 indicate that the impact of the Hornsea Three array area would be to prevent instrument approaches to the Ketch Platform on approximately 0.27 to 0.36 days per month (up to 3.66 days per year). The greatest impact is seen in the month of May when 1.17% of flights may be precluded. The least impact is seen in October when 0.82% of flights may be precluded.

Chiswick platform

7.4.4.14 The results shown in Table 7.5 indicate that the impact of the Hornsea Three array area would be to prevent instrument approaches to the Chiswick Platform on approximately 0.17 to 0.4 days per month (up to 3.49 days per year). The greatest impact is seen in the month of April when 1.35% of flights may be precluded. The least impact is seen in August when 0.56% of flights may be precluded.

ST-1 platform

7.4.4.15 The results shown in Table 7.6 indicate that the impact of the Hornsea Three array area would be to prevent instrument approaches to the ST-1 Platform on approximately 0.07 to 0.22 days per month (up to 1.84 days per year). The greatest impact is seen in the month of April when 0.74% of flights may be precluded. The least impact is seen in August when 0.23% of flights may be precluded.

J6/J6a-CT platform

7.4.4.16 The results shown in Table 7.7 indicate that the impact of the Hornsea Three array area would be to prevent instrument approaches to the J6/J6a-CT Platform on approximately 0.01 to 0.06 days per month (up to 0.45 days per year). The greatest impact is seen in the month of April when 0.21% of flights may be precluded. The least impact is seen in August when 0.05% of flights may be precluded.

Grove platform

7.4.4.17 The results shown in Table 7.8 indicate that the impact of the Hornsea Three array area would be to prevent instrument approaches to the Grove Platform on approximately 0.12 to 0.25 days per month (up to 2.18 days per year). The greatest impact is seen in the month of April when 0.83% of flights may be precluded. The least impact is seen in August when 0.39% of flights may be precluded.

Windermere platform

7.4.4.18 The results shown in Table 7.9 indicate that the impact of the Hornsea Three array area would be to prevent instrument approaches to the Windermere Platform on approximately 0.19 to 0.43 days per month (up to 3.73 days per year). The greatest impact is seen in the month of April when 1.43% of flights may be precluded. The least impact is seen in August when 0.62% of flights may be precluded.

7.4.4.19 A summary of the conclusions reached in the platform wind data analysis is contained in the graph at Figure 7.8. It should be noted that the monthly cumulative average of flights that would be affected by the Hornsea Three array area, together with Hornsea Project One and Hornsea Project Two (which is only applicable to the Schooner A platform), is also shown in Figure 7.8 and is relevant to the analysis in section 7.4.5

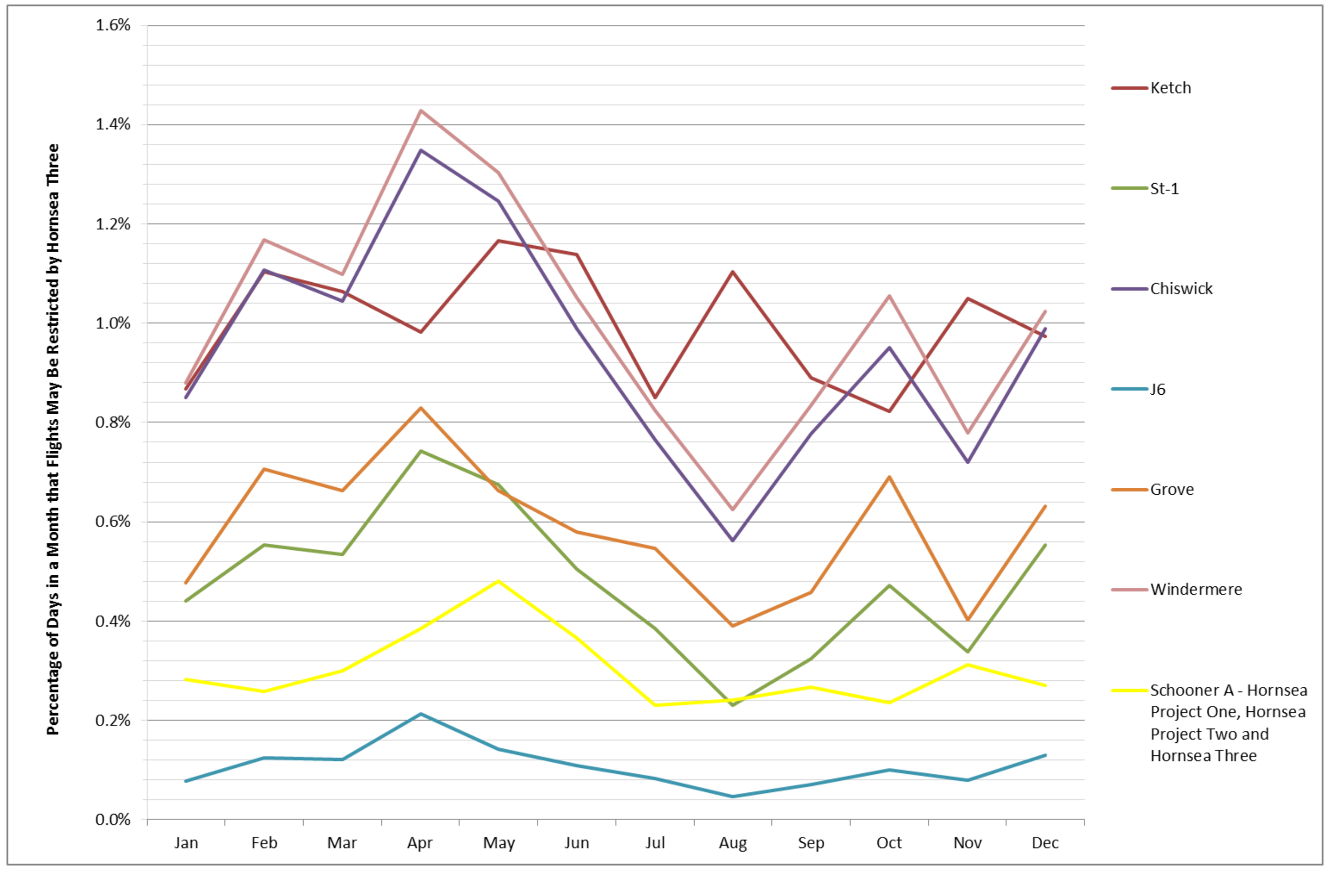

Figure 7.8: Monthly average of flights that may be restricted to each platform by Hornsea Three (alone) and by Hornsea Project One, Hornsea Project Two and Hornsea Three (cumulatively).

7.4.5 Cumulative effects

7.4.5.1 The potential for cumulative effects of Hornsea Three in conjunction with Hornsea Project One and Hornsea Project Two on the platforms assessed has been accounted for within the analysis. A 1 nm buffer, providing the 1 nm required separation distance from wind turbines, was used around the Hornsea Three array area and Hornsea Project One and Hornsea Project Two to establish the restricted instrument approach areas. Table 7.10 shows the cumulative constrained areas for the Schooner A platform, the only platform for which a cumulative effect applies. The Hornsea Project One and Hornsea Project Two array areas are not within 9 nm of the remaining platforms; therefore, the Hornsea Three development will not present any direct cumulative impact on flight operations to these platforms and these platforms are not considered further in this cumulative assessment.

Table 7.10: Cumulative constrained approach sector for Schooner A platform.

	Schooner A
Available airspace (°)	241.4
Constrained approach sector (°)	115.9-142.6 and 158.0-249.9
Corresponding wind direction (°)	N/A and 008.0-039.9

7.4.5.2 Due to the installation of wind turbines within the Hornsea Three array area, alongside Hornsea Project One and Hornsea Project Two, a volume of airspace would be considered unavailable for instrument approach procedures to the Schooner A Platform based on a fixed approach point at 7 nm from the platform and a 1 nm separation distance around each array (Hornsea Project One, Hornsea Project Two and Hornsea Three).

7.4.5.3 It is estimated that 241.4° of airspace surrounding the Schooner A Platform would remain available for instrument approach procedures and any MAP. Figure 7.9 shows the cumulative constrained approach sectors that would be restricted for instrument approach procedures by Hornsea Three, Hornsea Project One and Hornsea Project Two.

7.4.5.4 Table 7.11 presents the potential number of instrument approach procedures to the Schooner A platform that will likely be affected by Hornsea Project One, Hornsea Project Two and Hornsea Three based on analysis of the wind speed data.

7.4.5.5 The assessment indicates that the impact of Hornsea Three, together with Hornsea Project One and Hornsea Project Two, would be to prevent instrument approach procedures to the Schooner A Platform on approximately 1.12 days per year.

Table 7.11: Resulting instrument approach procedures precluded by Hornsea Three, Hornsea Project One and Hornsea Project Two.

Description of calculation		Schooner A
Number of days per year that the wind direction would require flight into wind to be over the constrained sector	A	22.39
Assumed percentage of time that instrument approaches are conducted.	B	5%
Number of days per year that both the wind direction requires flight into wind to be over constrained sector and an instrument approach is required (A x B).	C	1.12
Corresponding percentage of days in a year that flights may be restricted by the wind farm (C/365 x 100).	D	0.31%

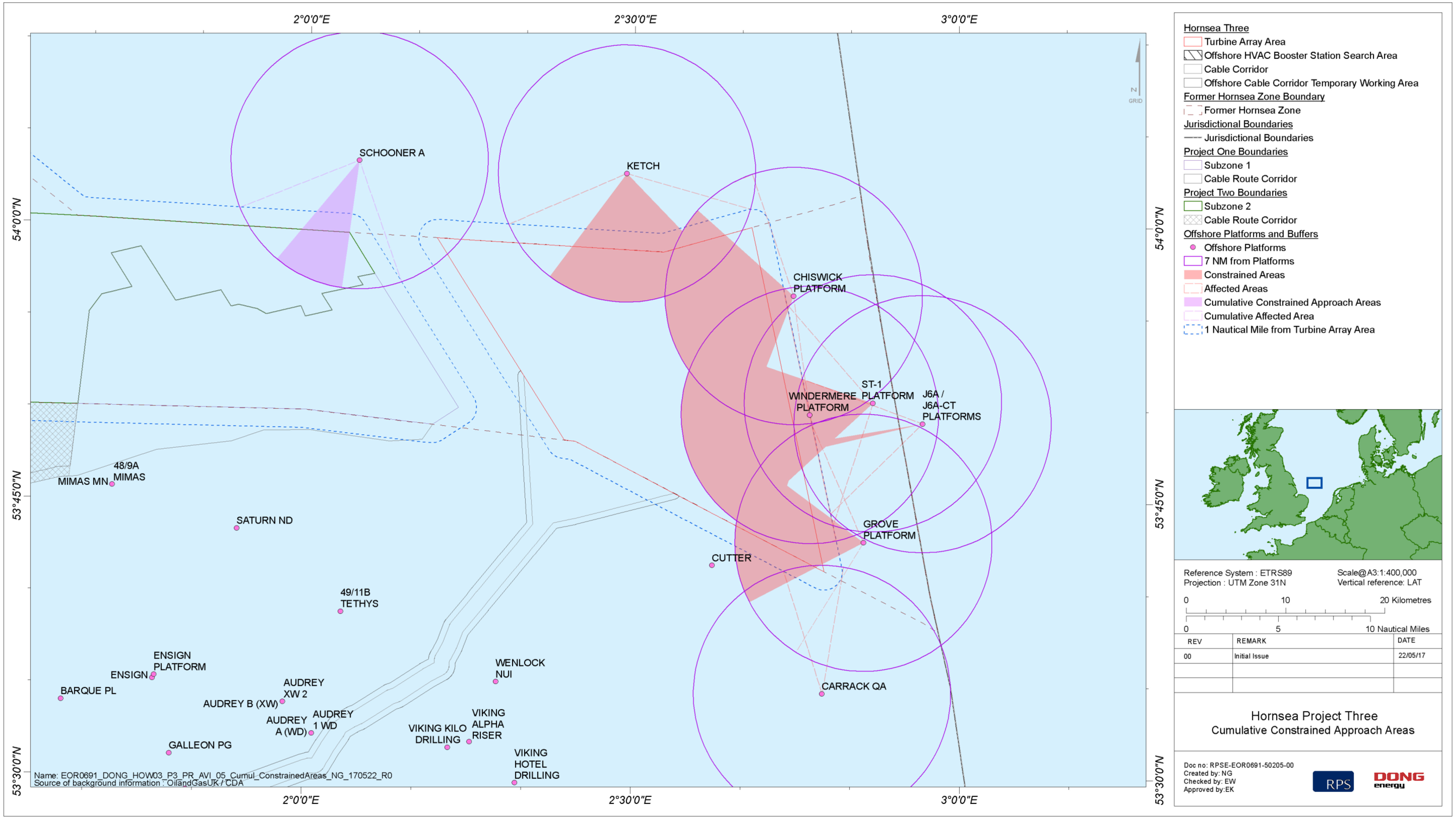

Figure 7.9: Cumulative constrained approach areas from Hornsea Three and Hornsea Project One and Hornsea Project Two.

8. Communication Systems

8.1 Aviation communications

8.1.1.1 Military and civil aviation rely on Communication, Navigation and Surveillance (CNS) infrastructure to support airspace and air traffic management. Military CNS has a crucial role in providing air defence surveillance and control for UK and the North Atlantic Treaty Organization (NATO). The CAA has been made aware of research that indicates the possibility of wind turbines adversely affecting the quality of radio communication between ATC and aircraft under their control (CAA, 2016c). The CAA are working in conjunction with NATS and others to test a variety of civil VHF aircraft radios and a smaller number of military UHF airborne radios against a simulated wind farm signature waveform. Until further information is available, reference should be made to the guidance contained in Section GEN-01 of CAP 670 (CAA, 2014) which provides a safeguarding distance of 610 m. The Hornsea Three array area is situated 121 km from the coast and so this is outside the range of any ATSP.

8.2 Maritime communications

8.2.1.1 Maritime communications devices considered within the Hornsea Three EIA include satellite communications, VHF radio, television and offshore microwave fixed links.

8.2.1.2 Satellite communications users include surface vessels or rigs/platforms. The Ofcom Tall Structures guidance document indicates that the principal impact of new structures, such as wind turbines, on Satellite TV is potential blocking between the receiver and the satellite in the sky (Ofcom, 2009). Satellite signals are generally received from a high elevation; this means that disruption to satellite reception is usually limited only to cases where a receiver is very close to a tall structure (e.g. a ship passing a wind turbine).

8.2.1.3 Trials undertaken for North Hoyle Wind Farm tested Global Positioning System (GPS) performance in the vicinity of the North Hoyle wind turbines, and found there to be no significant impact (DfT, 2004).

8.2.1.4 VHF radio is used by large commercial container ships, offshore service vessels, fishing boats and pleasure craft in the marine band (approximately 156 to 174 MHz) for ship-ship, ship-platform and ship-shore voice communication for the purposes of communication and navigation. The North Hoyle trials also indicated that wind turbines had no noticeable effects on any voice communications system, vessel to vessel or vessel to shore station. These included shipborne, shore based and hand held VHF transceivers and mobile telephones. Digital selective calling (DSC) was also satisfactorily tested. The VHF Direction Finding equipment carried in the lifeboats did not function correctly when very close to wind turbines (within about 50 m).

8.3 Offshore microwave Links

8.3.1.1 The offshore microwave links in the vicinity of the Hornsea Three array area have been identified through consultation with oil and gas companies and using Ofcom data. No microwave links pass through the Hornsea Three array area. Figure 8.1 shows the location of fixed microwave links within a 30 km search area from a central point in the Hornsea Three array area as provided by Ofcom. The microwave link from the Chiswick Platform to the J6A Platform is the nearest to the Hornsea Three array area at a distance of 2.8 km. There is one microwave link which crosses the Hornsea Three offshore cable corridor. Microwave links are LOS instruments and there will therefore be no impact associated with Hornsea Three.

8.3.2 Stakeholder consultation

8.3.2.1 A request was made to Ofcom for known microwave links within a 26.5 km radius of a central point within the Hornsea Three array area boundary. Ofcom provided microwave fixed links in band range 1.4 to 55 GHz and frequency range 1,350 to 57,000 MHz. One link was identified which is operated by Centrica Production Nederland BV between the Chiswick platform and J6A platform and two links operated by ConocoPhillips (UK) Limited between the Ketch platform and the Murdoch platform and the Ketch platform and the Caister platform, as shown in Figure 8.1.

8.3.2.2 A request was made to Atkins Windfarm support in relation to UHF Radio Scanning Telemetry communications, who responded that no such communication links would be affected by Hornsea Three.

8.3.2.3 A request was made to JRC in regard to interference with radio systems operated by utility companies in support of their regulatory operational requirements. A 26 km radius was assessed by JRC and the result confirmed was that no links would be affected by Hornsea Three.

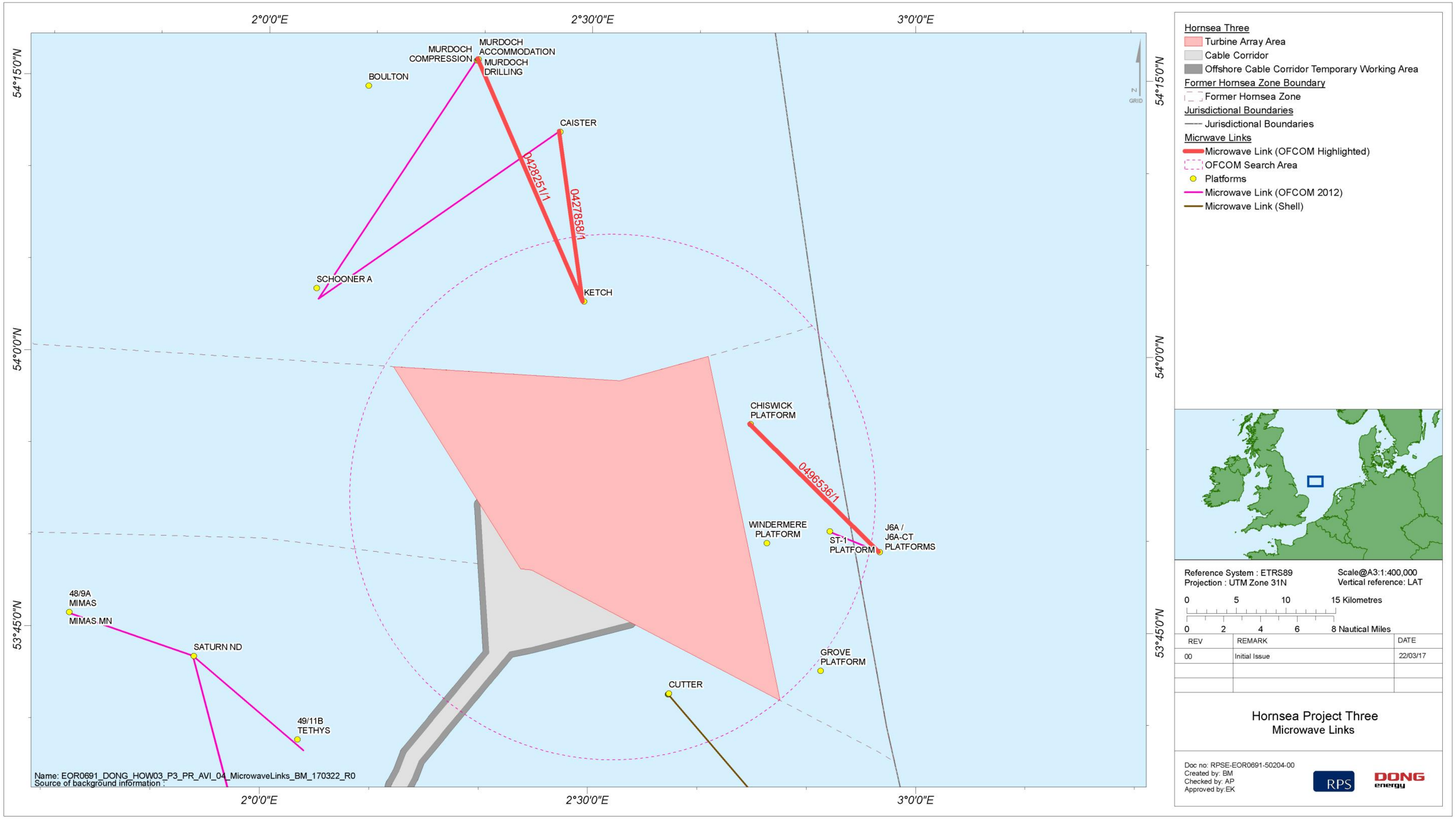

Figure 8.1: Microwave fixed links within 26.5 km of the centre of the Hornsea Three array area.

9. Conclusions

9.1 NATS impact assessment

9.1.1.1 NATS use PSRs to support their provision of ATC services to aircraft operating between the UK and mainland Europe, and to those overflying the UK FIR in the region of the Hornsea Three array area. In addition, Anglia Radar based at Aberdeen Airport employs NATS radar to support their provision of services to aircraft servicing the oil and gas industries within the lateral confines of their area of responsibility over the southern North Sea.

9.1.1.2 The NATS Claxby PSR has an operational range of 200 nm. From the LOS assessment the turbines within the Hornsea Three array area are theoretically not detectable by the Claxby PSR system. As turbines within the Hornsea Three array area are considered not theoretically detectable by the Claxby PSR system, no cumulative impacts are expected to occur with other projects in the Hornsea Zone (namely Hornsea Project One and Hornsea Project Two).

9.1.1.3 As part of the pre-application consultation process, Hornsea Three enquired with asked to provide an assessment of the potential for Hornsea Three to affect any of the radar or communications systems operated or controlled by NATS. NATS responded that they had no objection to Hornsea Three and that they anticipate no impact on their own infrastructure and operations.

9.2 MOD ASACS impact assessment

9.2.1.1 The MOD, through the ASACS Force, is responsible for compiling a RAP to monitor the airspace in and around the UK in order to launch a response to a potential airborne threat. This is achieved through the utilisation of a network of long-range ADR. Any identified effect of turbines on the ASACS radars that serve the airspace above the Hornsea Three array area will reduce the capability of the ASACS force. In addition, ASACS radar resources are also used in support of training and exercises above the Hornsea Three array area on an almost daily basis.

9.2.1.2 The Staxton Wold ADR has an operational range of 400 km (215 nm). From the LOS assessment the turbines at 325 m height within the Hornsea Three array area are not detectable by the Staxton Wold ADR.

9.2.1.3 The MOD Trimingham ADR has an operational range of 400 km (215 nm). From the LOS assessment, a small number of turbines along the southwestern boundary within the Hornsea Three array area (which have a maximum height of up to 325 m) would be considered theoretically intermittently detectably by the Trimingham ADR. Other turbines in the southwestern section of the Hornsea Three array area are unlikely to be routinely detectable, and turbines in the northeastern section are not predicted to be detectable by the Trimingham ADR.

9.2.1.4 Any identified effect of turbines on the ASACS ADRs that serve the airspace above the Hornsea Three array area would potentially reduce the capability of the ASACS force. If unmitigated, other offshore and onshore wind farms will have the potential to add to cumulative radar clutter and possibly an increase in the signal processing demands of the Trimingham ADR.

9.2.1.5 A TPS-77 ADR is in operation at the Trimingham site to resolve the cumulative impact of other wind farms in the Greater Wash area.

9.2.1.6 As part of the pre-application consultation process for Hornsea Three, Hornsea Three has contacted the DIO to undertake an assessment of the potential for Hornsea Three to affect any of the radar or communications systems operated or controlled by the MOD. The MOD confirmed that, due to the distance of the Hornsea Three array area offshore it is unlikely that there will be any detectability of Hornsea Three from any MOD ADR or ATC radars.

9.3 Offshore helicopter operations impact assessment

9.3.1.1 A network of HMRs is established to support the transport of personnel and material to offshore oil and gas installations. In addition, a 9 nm radius consultation zone around offshore installations is established to allow for the safe operation of helicopter instrument approaches to platforms in poor weather conditions.

9.3.1.2 HMR2 crosses through the Hornsea Three array area and is used predominantly for transit from Norwich International Airport to the oil and gas platforms to the east of the Hornsea Three array are. In certain weather conditions, the use of HMR2 will be restricted. An obstacle free route is available as a deviation to the east of the Hornsea Three array area.

9.3.1.3 There is no cumulative effect on HMR2 with other offshore wind farm developments. However there is potential for a cumulative effect on HMR3 when considering Hornsea Project One, Hornsea Project Two and Hornsea Three, as a potential alternative route for HMR3 is affected by the presence of Hornsea Three. There is an available deviation around Hornsea Project One and Hornsea Project Two to the west of the projects or potentially to the east which is a corridor of 3.9 nm in width between Hornsea Project One and Hornsea Project Two, and Hornsea Three.

9.3.1.4 There are nine platforms with 9 nm consultation zones overlapping the Hornsea Three array area, namely Schooner A, Ketch, Chiswick, ST-1, J6A/J6A-CT, Grove, Windermere, Cutter and Carrack QA. As the Cutter platform has no helideck it was considered further within the assessment. In IMC and in certain wind conditions, which dictate the area of approach to the platform, a standard instrument approach procedure might not be possible due to the proximity of wind turbine structures to the flight approach path. In addition, should the airspace that is required to fly a MAP not be available due to the presence of turbines, then this would restrict helicopter operations.

9.3.1.5 The results indicate that the impact of the Hornsea Three array area would be to prevent instrument approach procedures for the following calculated number of days per year to each of the platforms:

- Schooner A platform: Not affected;
- Ketch platform: 3.66 days per year;
- Chiswick platform: 3.49 days per year;
- ST-1platform: 1.84 days per year;
- J6/J6A-CT platform: 0.45 days per year;
- Grove platform: 2.18 days per year;
- Windermere platform: 3.73 days per year; and
- Carrack QA platform: Not affected.

9.3.1.6 The Schooner A platform is the only platform for which the 9 nm consultation zone intersects with Hornsea Project One and Hornsea Project Two, as well as Hornsea Three. The assessment indicates that the impact of Hornsea Three, together with Hornsea Project One and Hornsea Project Two would be to prevent instrument approach procedures to the Schooner A Platform on approximately 1.12 days per year.

9.4 Communication systems

9.4.1.1 The CAA are working in conjunction with NATS and others to test a variety of civil VHF aircraft radios and a smaller number of military UHF airborne radios against a simulated wind farm signature waveform. Reference should be made to the guidance contained in Section GEN-01 of CAP 670 which advises relatively small safeguarding parameters for VHF radios. However the Hornsea Three array area is at a distance of 121 km from the UK coast (at Trimingham, Norfolk) and is therefore not considered to have an effect on VHF radios.

9.4.1.2 Satellite reception is usually limited only to cases where a receiver is very close to a tall structure (e.g. a ship passing a wind turbine). The North Hoyle trials (DfT, 2004) indicated that wind turbines had no noticeable effects on any voice communications system, vessel to vessel or vessel to shore station. These included shipborne, shore based and hand held VHF transceivers and mobile telephones. Digital selective calling (DSC) was also satisfactorily tested. The VHF Direction Finding equipment carried in the lifeboats did not function correctly when very close to wind turbines (within about 50 m).

9.4.1.3 No microwave links pass through the Hornsea Three array area, although one microwave link crosses the Hornsea Three offshore cable corridor. Microwave links are LOS and therefore, there will be no impact associated with Hornsea Three. A request was made to Atkins Windfarm support in relation to UHF Radio Scanning Telemetry communications, who responded that no such communication links would be affected by Hornsea Three. A request was made to JRC in regard to interference with radio systems operated by utility companies in support of their regulatory operational requirements, who advised no links would be affected by Hornsea Three.

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Appendix A Wind Data Analysis for Aviation Assessment

2002 to 2012 Schooner platform wind data – adjusted to Modern Era Retrospective Analysis for Research and Application (MERRA) model.

48 direction sectors (7.5 degree bins) with centre of true north.

60 velocity classes (0.5 m/s bins).

Total of data = 100,010.00

Total <2.5 m/s = 3,540 (3.54%)

Speed Bin (m/s)	Sector Bin (degrees)																					
	356.25 to 3.75	3.75 to 11.25	11.25 to 18.75	18.75 to 26.25	26.25 to 33.75	33.75 to 41.25	41.25 to 48.75	48.75 to 56.25	56.25 to 63.75	63.75 to 71.25	71.25 to 78.75	78.75 to 86.25	86.25 to 93.75	93.75 to 101.25	101.25 to 108.75	108.75 to 116.25	116.25 to 123.75	123.75 to 131.25	131.25 to 138.75	138.75 to 146.25	146.25 to 153.75	153.75 to 161.25
0 to 0.5	5.6	5.7	3.4	2.3	0.0	3.4	1.1	1.1	2.3	2.2	1.1	2.3	6.9	3.4	3.4	2.2	2.3	1.1	5.7	1.1	0.0	0.0
0.5 to 1	7.9	11.3	13.6	6.8	10.1	10.2	9.1	6.8	11.2	8.0	10.1	7.9	12.5	10.2	9.1	14.7	10.1	1.1	2.2	6.8	4.5	11.4
1 to 1.5	11.3	14.7	10.2	13.5	19.5	12.6	14.7	10.1	6.8	18.0	21.6	9.1	15.7	28.2	11.4	14.7	21.3	14.7	14.7	14.6	4.5	11.4
1.5 to 2	10.1	13.5	15.9	10.2	19.4	15.8	20.3	26.2	23.7	26.0	14.9	15.8	27.3	31.6	23.6	12.5	18.1	25.0	21.3	19.3	22.7	23.6
2 to 2.5	13.6	21.5	21.5	22.7	28.3	18.1	23.7	18.1	17.8	20.3	20.5	18.2	23.6	27.2	27.3	33.8	21.3	23.8	18.2	18.1	23.7	23.9
2.5 to 3	20.4	30.5	28.4	27.1	23.8	38.5	36.2	23.7	25.0	19.2	28.1	23.7	23.6	28.4	32.9	26.0	28.1	28.3	16.9	21.3	26.0	23.9
3 to 3.5	26.2	27.3	26.1	40.8	34.0	48.9	40.9	39.8	30.4	24.7	32.9	37.3	44.3	42.0	32.7	29.8	38.5	43.1	29.2	31.5	35.1	33.7
3.5 to 4	36.2	33.9	42.9	39.6	18.3	32.7	45.5	29.2	38.5	38.4	28.5	34.0	38.2	29.4	39.4	31.8	24.9	33.9	36.4	32.6	36.9	34.9
4 to 4.5	47.7	42.8	32.9	40.9	39.6	34.1	51.8	41.8	42.8	31.6	30.1	37.3	40.8	46.1	42.9	29.5	34.9	27.1	26.0	44.5	42.9	56.3
4.5 to 5	44.2	41.9	38.4	32.8	48.5	69.2	53.1	44.1	40.8	40.7	35.9	44.9	49.9	57.8	52.1	41.9	34.8	43.1	54.3	59.4	57.6	49.6
5 to 5.5	67.4	48.5	54.6	45.3	45.1	64.3	60.6	40.7	38.3	45.4	47.7	60.1	43.7	60.0	45.2	47.8	51.9	62.5	53.2	53.0	44.8	65.6
5.5 to 6	61.2	55.3	52.1	73.7	46.4	55.2	56.1	50.5	57.4	37.4	35.3	40.9	49.9	46.3	47.3	31.8	57.5	81.5	62.4	57.7	69.4	52.2
6 to 6.5	87.8	62.3	54.3	60.0	45.3	60.8	42.8	46.5	72.2	76.9	45.7	43.4	44.4	68.8	67.9	70.0	47.2	72.3	55.5	65.4	79.7	83.0
6.5 to 7	59.8	64.4	62.0	49.4	55.8	64.2	51.5	58.7	71.9	51.8	49.1	45.6	46.4	74.0	72.2	69.7	59.2	52.9	63.5	61.0	81.9	75.8
7 to 7.5	59.1	68.9	50.9	57.3	81.8	58.8	46.1	40.5	75.1	59.7	48.6	53.1	60.1	47.0	58.6	79.1	70.3	58.5	68.3	63.9	76.4	89.1
7.5 to 8	63.3	53.8	59.0	57.5	71.9	47.3	39.3	56.2	44.7	51.7	55.3	72.2	46.4	49.6	73.3	63.5	69.0	81.5	80.5	69.8	73.2	82.2
8 to 8.5	53.0	64.2	80.8	59.8	83.0	74.6	47.5	46.6	54.8	68.1	71.7	56.4	53.3	60.9	85.2	74.0	65.2	89.0	54.0	70.5	77.6	80.4
8.5 to 9	98.3	58.4	78.7	76.9	81.2	65.3	35.8	53.3	66.6	73.0	58.5	54.3	66.0	107.8	77.0	71.7	85.9	77.2	58.7	58.0	49.5	79.6
9 to 9.5	77.8	93.6	54.5	45.9	69.1	69.1	75.5	80.4	77.8	69.2	74.1	58.3	55.7	71.5	103.0	65.0	66.4	79.9	60.8	49.3	55.5	74.9
9.5 to 10	67.4	54.1	61.5	57.8	50.0	65.4	54.8	36.0	49.2	64.0	56.6	62.7	57.0	71.5	87.3	60.7	58.7	58.2	53.0	47.3	43.2	83.6
10 to 10.5	55.4	34.8	55.7	46.2	40.8	57.4	41.5	38.1	50.4	47.7	39.6	34.0	43.0	71.0	75.2	79.4	44.8	57.5	55.4	47.2	46.4	69.1
10.5 to 11	56.0	40.6	48.7	53.0	42.6	61.1	60.4	41.4	36.7	60.2	48.3	43.2	40.4	67.7	53.6	58.8	36.4	49.6	59.2	42.5	41.9	82.1
11 to 11.5	48.5	33.8	43.0	36.2	34.0	63.2	43.1	51.9	43.9	51.6	59.2	44.1	44.8	40.6	47.6	43.7	26.9	57.4	48.6	42.3	39.3	61.4
11.5 to 12	39.7	38.3	27.2	33.7	36.2	75.3	57.8	59.8	58.4	44.7	48.4	48.8	48.3	47.1	53.1	55.2	40.4	39.5	41.8	30.4	39.7	62.4
12 to 12.5	38.2	35.6	31.7	30.5	39.9	52.7	43.9	37.0	30.1	36.7	55.7	37.1	52.5	38.0	34.8	29.4	45.1	41.6	50.2	44.1	44.1	47.5

Speed Bin (m/s)	Sector Bin (degrees)																					
	356.25 to 3.75	3.75 to 11.25	11.25 to 18.75	18.75 to 26.25	26.25 to 33.75	33.75 to 41.25	41.25 to 48.75	48.75 to 56.25	56.25 to 63.75	63.75 to 71.25	71.25 to 78.75	78.75 to 86.25	86.25 to 93.75	93.75 to 101.25	101.25 to 108.75	108.75 to 116.25	116.25 to 123.75	123.75 to 131.25	131.25 to 138.75	138.75 to 146.25	146.25 to 153.75	153.75 to 161.25
12.5 to 13	38.6	25.7	31.6	31.7	40.1	31.0	39.0	31.1	37.4	42.3	27.1	23.5	33.5	29.9	22.8	44.4	40.9	63.3	42.5	28.2	33.7	55.3
13 to 13.5	42.9	34.7	18.0	25.6	19.1	21.1	26.8	30.0	28.8	24.8	26.1	41.3	29.9	17.6	40.5	28.4	42.8	45.1	47.2	29.2	39.6	54.7
13.5 to 14	48.5	38.3	26.1	34.9	25.9	13.5	28.6	17.9	15.1	22.6	26.3	24.8	31.0	8.7	18.9	19.4	41.7	42.9	23.4	27.9	25.9	34.0
14 to 14.5	34.8	34.1	30.5	17.6	12.3	11.4	31.5	11.2	19.1	15.7	30.4	25.0	35.0	11.2	24.8	21.7	34.8	41.2	27.0	20.3	36.4	37.3
14.5 to 15	28.4	40.7	22.4	21.2	9.1	9.0	16.8	7.8	21.1	19.8	18.2	18.1	28.4	14.7	33.0	27.3	21.4	33.7	31.6	28.2	35.3	46.0
15 to 15.5	24.8	34.6	20.2	11.3	9.1	14.8	23.2	17.7	22.9	25.6	23.7	28.1	14.7	14.7	30.6	20.5	46.1	41.9	24.9	9.1	18.2	30.6
15.5 to 16	31.7	15.8	14.8	6.8	9.1	4.6	14.5	8.9	13.2	10.0	26.9	22.5	14.8	14.7	26.0	23.9	28.8	36.3	14.8	13.6	13.5	35.0
16 to 16.5	27.0	16.7	8.9	19.4	6.9	17.1	9.1	9.0	15.5	11.4	32.8	37.6	10.3	18.2	15.9	12.3	35.2	20.4	20.6	7.9	13.5	24.9
16.5 to 17	20.5	11.3	4.6	10.1	8.0	20.6	4.6	4.6	8.9	3.4	28.5	23.9	20.0	11.4	26.1	14.5	25.6	13.6	13.7	22.7	16.0	15.9
17 to 17.5	29.6	15.8	8.0	1.1	3.3	18.3	3.4	16.4	8.7	3.4	10.3	15.8	28.1	20.5	18.1	11.4	14.7	15.7	8.0	6.8	19.3	11.4
17.5 to 18	13.4	10.2	1.1	2.3	5.7	5.6	6.8	8.8	18.7	5.7	9.2	13.5	14.3	10.0	10.0	10.2	14.7	3.4	14.6	6.8	11.4	10.3
18 to 18.5	10.2	8.9	3.4	3.4	4.5	1.1	6.8	7.6	12.3	3.4	9.2	7.9	6.5	5.7	19.9	2.2	13.6	12.6	11.4	1.1	6.8	12.5
18.5 to 19	14.5	6.8	6.9	3.4	3.4	0.0	4.2	2.2	6.8	8.0	8.0	9.0	5.6	9.0	16.4	5.5	6.7	3.4	14.8	4.5	6.8	4.6
19 to 19.5	6.7	5.7	4.6	3.4	2.2	0.0	1.1	1.1	4.5	2.3	5.7	4.6	0.0	0.0	16.8	3.4	3.4	6.9	8.0	6.8	6.8	9.1
19.5 to 20	9.9	5.6	1.1	1.1	1.1	0.0	0.0	1.1	0.0	1.1	3.4	0.0	1.1	0.0	3.2	2.3	1.1	4.6	4.6	2.3	9.1	12.6
20 to 20.5	0.0	5.6	5.7	0.0	1.1	0.0	0.0	1.1	0.0	0.0	5.7	0.0	1.1	0.0	1.1	3.4	2.3	3.4	9.1	6.8	5.6	10.3
20.5 to 21	2.2	0.0	1.1	2.2	0.0	0.0	1.1	0.0	0.0	3.4	1.1	0.0	0.0	0.0	1.1	1.1	4.6	1.1	0.0	4.5	1.1	3.4
21 to 21.5	5.6	0.0	0.0	0.0	1.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	1.1	0.0	2.1	1.1	2.3	0.0	1.1	9.1	3.3	1.1
21.5 to 22	1.1	0.0	2.1	1.1	1.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.1	4.3	0.0	0.0	0.0	0.0	2.3	1.1	6.9
22 to 22.5	1.1	0.0	0.0	1.1	1.1	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	6.4	2.1	0.0	0.0	0.0	2.3	0.0	3.4	2.3
22.5 to 23	1.1	0.0	0.0	1.1	1.1	0.0	3.4	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	3.4
23 to 23.5	0.0	0.0	1.1	1.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	4.5
23.5 to 24	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
24 to 24.5	1.1	0.0	0.0	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.5 to 25	0.0	0.0	0.0	0.0	0.0	2.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 to 25.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
25.5 to 26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
26 to 26.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
26.5 to 27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
27 to 27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1
27.5 to 28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1
28 to 28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.5 to 29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 to 29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.5 to 30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Speed Bin (m/s)	Sector Bin (degrees)																									
	161.25 to 168.75	168.75 to 176.25	176.25 to 183.75	183.75 to 191.25	191.25 to 198.75	198.75 to 206.25	206.25 to 213.75	213.75 to 221.25	221.25 to 228.75	228.75 to 236.25	236.25 to 243.75	243.75 to 251.25	251.25 to 258.75	258.75 to 266.25	266.25 to 273.75	273.75 to 281.25	281.25 to 288.75	288.75 to 296.25	296.25 to 303.75	303.75 to 311.25	311.25 to 318.75	318.75 to 326.25	326.25 to 333.75	333.75 to 341.25	341.25 to 348.75	348.75 to 356.25
0 to 0.5	3.4	1.1	0.0	2.3	3.4	2.3	1.1	0.0	1.1	3.4	2.2	6.8	3.4	3.4	3.4	4.6	1.1	2.3	4.5	3.4	0.0	3.4	6.8	3.4	3.4	2.3
0.5 to 1	6.8	4.5	9.1	13.5	9.0	11.2	5.7	12.6	8.0	6.8	13.5	7.9	13.4	10.0	11.2	5.7	11.4	9.1	10.1	12.4	5.7	18.2	15.8	9.0	7.9	11.3
1 to 1.5	13.5	11.4	9.0	9.0	11.3	13.6	14.8	17.0	12.4	21.2	16.9	10.2	10.2	15.9	21.5	17.0	9.1	16.9	19.3	20.4	13.5	7.9	20.2	21.4	11.3	28.2
1.5 to 2	16.9	28.4	28.1	15.9	15.6	28.4	22.6	26.1	17.0	21.3	20.3	23.7	18.0	7.9	19.3	21.5	27.0	18.2	27.0	22.6	27.0	20.2	20.4	20.2	26.7	24.8
2 to 2.5	29.6	31.7	28.5	29.4	30.4	23.9	35.3	38.4	25.7	26.2	23.8	24.8	30.3	29.2	27.1	37.6	30.4	38.3	33.9	43.8	24.7	24.8	24.7	21.6	21.4	26.3
2.5 to 3	27.3	31.7	25.9	26.0	26.0	32.8	36.3	22.8	43.9	35.1	29.5	32.6	26.9	45.1	44.7	28.3	40.7	45.9	45.0	39.8	30.5	34.9		43.0	36.0	21.6
3 to 3.5	43.1	28.2	33.7	36.1	42.8	44.8	48.4	36.2	47.4	53.1	35.0	49.5	34.9	29.2	42.9	30.2	27.1	43.7	39.3	50.8	48.6	54.3	43.0	40.9	48.8	32.9
3.5 to 4	24.8	33.8	37.3	50.2	36.1	44.9	52.2	47.2	39.6	58.8	49.3	57.6	53.0	32.8	40.6	27.0	56.4	45.9	34.6	52.8	54.3	46.6	62.5	48.7	64.8	45.5
4 to 4.5	46.5	38.6	46.1	65.9	54.2	57.4	55.4	62.4	66.9	51.2	67.9	51.9	49.7	58.4	44.0	44.1	46.3	60.9	59.6	53.1	40.5	56.6	46.6	65.8	51.0	45.2
4.5 to 5	52.0	56.3	60.6	63.5	74.5	66.7	73.5	81.5	48.8	68.3	56.5	83.3	48.2	53.0	43.9	68.9	64.3	59.6	72.9	55.3	76.2	81.7	64.2	63.2	52.9	36.1
5 to 5.5	68.9	64.2	55.2	75.8	76.4	80.6	75.9	77.2	56.7	72.4	85.7	73.1	63.4	76.9	76.2	70.4	66.5	72.4	62.8	66.5	66.0	89.2	69.2	61.4	47.3	56.2
5.5 to 6	65.3	68.9	82.4	76.6	58.9	105.0	88.2	79.4	79.4	96.5	73.1	71.0	59.6	87.1	64.5	88.3	75.9	69.9	66.5	61.2	70.3	95.1	68.3	59.0	63.0	72.4
6 to 6.5	82.7	68.4	93.7	80.2	95.0	92.5	71.1	95.4	73.4	95.0	75.7	84.3	58.7	105.6	98.1	83.8	89.0	67.5	67.6	79.3	70.2	89.1	69.4	82.5	49.2	78.1
6.5 to 7	73.7	91.6	89.9	85.1	83.7	95.8	120.1	80.8	92.6	98.3	74.7	85.5	89.2	106.1	103.6	108.0	92.3	91.8	78.5	85.5	66.5	71.2	92.8	97.2	57.5	73.2
7 to 7.5	100.2	81.1	101.6	103.7	88.1	100.7	96.4	92.1	77.2	96.3	99.0	113.7	89.2	118.2	116.1	110.6	96.0	96.2	90.0	75.1	74.2	84.5	77.3	101.9	97.2	63.8
7.5 to 8	88.4	108.6	99.9	126.0	97.0	91.2	104.6	104.6	97.7	113.8	77.0	113.0	130.0	131.4	98.1	90.4	93.7	95.5	88.5	85.3	76.8	54.4	55.6	71.3	89.3	53.0
8 to 8.5	85.6	100.5	100.4	108.5	106.3	110.8	117.0	111.0	100.6	105.5	134.5	123.4	112.6	122.5	98.4	101.2	68.1	82.4	82.6	84.3	110.1	65.4	61.9	74.8	93.8	68.9
8.5 to 9	99.4	103.3	90.4	109.4	94.6	96.0	105.1	118.0	126.1	123.1	120.8	119.9	130.8	115.6	113.9	115.3	96.1	86.7	91.0	96.9	113.4	59.2	78.0	88.4	75.0	62.9
9 to 9.5	103.0	78.4	113.8	101.1	103.8	82.8	128.1	114.9	137.2	152.2	128.8	142.1	133.1	111.5	111.5	138.2	137.9	111.8	90.2	79.1	85.9	68.4	89.9	88.6	83.9	61.0
9.5 to 10	82.6	82.4	88.0	98.4	117.7	106.5	121.4	126.6	118.7	134.7	117.7	138.7	108.4	102.5	121.3	122.4	153.0	109.9	89.8	98.3	81.8	91.0	96.3	68.0	70.3	77.0
10 to 10.5	108.0	101.7	92.4	106.8	114.6	114.9	133.9	122.9	129.1	133.3	148.7	126.5	122.0	110.0	137.0	120.1	138.3	104.1	96.8	98.0	93.8	102.7	86.8	113.3	74.8	57.5
10.5 to 11	106.4	87.0	105.9	111.0	118.3	164.8	125.2	117.8	154.7	141.2	115.3	109.5	110.8	109.6	110.1	109.7	124.9	106.7	93.7	85.9	96.1	76.5	91.5	72.6	97.2	60.0
11 to 11.5	82.5	97.3	93.4	104.5	117.8	139.1	148.5	124.0	142.9	157.3	133.6	113.5	99.0	118.6	117.9	109.9	112.6	96.5	102.1	95.0	69.8	80.6	100.8	92.8	75.7	65.8
11.5 to 12	69.6	95.1	106.1	102.5	110.4	125.5	123.3	147.2	145.3	109.2	128.2	84.8	98.4	103.9	99.4	97.1	76.3	106.8	95.0	88.3	83.6	64.1	85.0	93.7	75.6	69.2
12 to 12.5	57.9	69.9	78.9	82.6	97.9	133.5	129.9	138.3	116.6	121.6	120.1	106.2	103.5	108.6	121.1	87.1	95.5	83.6	91.6	98.8	72.1	69.1	69.8	91.3	64.3	57.7
12.5 to 13	61.3	63.2	90.5	80.3	110.6	127.4	95.0	135.2	115.4	128.3	114.4	106.1	115.2	99.5	96.9	96.0	94.4	70.6	97.1	92.5	85.6	84.8	60.5	72.2	69.6	54.5
13 to 13.5	80.7	93.9	99.8	75.7	85.3	117.1	96.5	106.8	140.4	126.6	116.7	106.3	91.8	111.1	80.4	77.7	79.6	51.5	68.6	99.1	85.3	60.4	57.1	86.8	75.9	40.4
13.5 to 14	56.3	70.4	71.0	71.2	65.3	76.9	86.9	130.2	113.3	138.6	90.6	97.6	103.0	75.5	67.8	63.9	65.8	59.4	56.4	54.0	68.6	54.7	51.0	64.3	53.6	71.5
14 to 14.5	48.9	58.8	65.8	76.9	73.3	80.7	86.1	114.3	102.8	108.3	99.0	102.4	94.6	81.8	86.4	63.5	59.1	71.6	56.0	79.8	59.7	63.4	50.5	59.9	54.0	55.1
14.5 to 15	41.5	48.6	59.8	55.3	50.9	81.1	90.4	86.9	107.5	92.8	100.3	95.3	93.4	89.2	81.8	50.5	58.8	66.3	57.3	59.4	54.0	59.2	37.5	55.2	61.4	56.3
15 to 15.5	45.3	50.8	66.7	57.4	50.8	68.5	82.6	93.5	81.2	94.0	110.6	74.0	97.6	62.1	65.9	49.0	58.0	60.7	51.6	37.2	44.8	47.1	44.5	41.8	47.1	41.2
15.5 to 16	37.0	44.0	55.7	60.0	52.2	62.9	73.6	93.9	82.2	98.1	85.2	58.5	67.9	74.3	49.6	72.0	60.6	47.7	39.6	35.0	58.3	51.5	38.1	37.3	48.8	26.8
16 to 16.5	36.1	37.5	56.7	35.0	39.2	54.9	69.8	72.1	86.7	89.4	79.9	67.4	69.7	78.4	72.5	58.4	52.8	44.2	23.9	32.7	48.2	50.5	31.6	36.2	34.6	29.5
16.5 to 17	23.8	30.7	25.9	29.4	39.7	46.2	52.1	59.6	98.9	91.4	67.1	78.2	72.2	56.1	51.4	59.9	41.8	31.9	28.4	24.8	32.5	37.0	19.2	29.2	38.3	16.7
17 to 17.5	16.9	37.4	25.8	24.9	26.0	36.0	49.5	57.9	80.2	75.5	67.0	63.8	50.5	52.5	47.4	49.6	21.3	25.0	23.8	19.2	35.7	40.2	32.7	25.9	24.6	30.4
17.5 to 18	14.5	28.5	37.3	31.7	24.7	29.4	36.4	47.5	72.6	61.0	67.3	42.6	51.5	44.9	50.8	35.2	31.2	23.8	22.2	24.8	36.7	23.4	26.5	17.9	22.3	22.5
18 to 18.5	5.6	26.7	29.4	19.3	32.8	33.0	29.2	51.8	70.4	75.6	65.5	60.8	57.0	48.9	50.5	31.5	25.7	18.3	19.1	29.6	34.8	30.7	25.9	18.1	23.6	28.1

Speed Bin (m/s)	Sector Bin (degrees)																									
	161.25 to 168.75	168.75 to 176.25	176.25 to 183.75	183.75 to 191.25	191.25 to 198.75	198.75 to 206.25	206.25 to 213.75	213.75 to 221.25	221.25 to 228.75	228.75 to 236.25	236.25 to 243.75	243.75 to 251.25	251.25 to 258.75	258.75 to 266.25	266.25 to 273.75	273.75 to 281.25	281.25 to 288.75	288.75 to 296.25	296.25 to 303.75	303.75 to 311.25	311.25 to 318.75	318.75 to 326.25	326.25 to 333.75	333.75 to 341.25	341.25 to 348.75	348.75 to 356.25
18.5 to 19	12.5	14.7	17.0	20.3	20.4	38.5	31.7	46.2	63.6	51.6	44.9	45.8	41.5	30.1	43.7	40.4	30.4	15.9	14.6	19.0	28.9	23.3	33.8	20.1	31.4	20.0
19 to 19.5	6.9	17.1	19.2	21.5	36.0	30.1	24.4	35.2	43.6	47.2	46.4	37.6	32.5	19.9	20.4	35.2	22.4	13.5	15.8	12.3	28.6	16.6	18.9	21.1	18.9	12.0
19.5 to 20	8.0	20.1	18.2	14.5	28.2	21.0	23.6	48.6	53.8	40.3	33.7	49.1	35.1	24.4	19.0	27.0	17.0	20.1	7.7	5.6	25.7	11.2	12.3	12.4	14.7	16.5
20 to 20.5	4.6	14.7	10.1	21.7	27.2	18.1	22.2	48.6	47.1	43.4	30.4	32.3	39.2	28.1	19.2	38.5	20.2	16.8	15.8	8.8	14.5	7.7	24.8	9.0	15.9	14.6
20.5 to 21	4.6	12.3	13.4	14.8	14.8	11.3	47.7	41.0	38.1	45.6	16.7	20.2	19.0	32.3	22.4	26.0	19.9	11.3	6.8	11.3	3.4	7.8	20.2	12.4	4.5	6.7
21 to 21.5	11.2	18.0	9.1	13.3	12.4	12.5	38.5	42.1	29.8	34.9	26.4	30.1	23.7	23.9	22.2	24.8	17.9	4.6	13.6	7.8	4.6	4.6	14.3	13.4	4.5	4.5
21.5 to 22	6.9	10.1	6.8	8.9	18.0	11.4	23.9	30.4	21.2	21.4	20.3	20.0	14.4	12.1	14.3	28.1	11.1	11.0	6.8	9.9	5.7	11.3	13.6	2.1	3.4	2.3
22 to 22.5	4.6	5.6	7.9	15.7	10.3	11.2	18.1	24.8	21.3	27.0	22.3	21.9	16.8	11.2	22.7	15.6	6.6	5.7	7.8	3.4	12.4	11.2	6.9	4.3	5.7	4.5
22.5 to 23	5.7	5.6	6.7	10.1	7.9	10.0	12.6	26.9	21.9	18.1	12.4	12.1	7.8	6.7	13.1	10.0	10.0	2.2	2.2	0.0	6.9	5.4	9.0	4.3	5.6	2.1
23 to 23.5	5.5	10.2	5.6	9.1	7.8	8.0	20.1	15.9	16.3	21.5	10.7	11.3	11.1	6.6	10.9	2.2	5.5	0.0	2.3	0.0	2.3	6.8	5.7	0.0	2.3	1.1
23.5 to 24	1.1	10.0	5.6	5.7	6.8	6.8	12.5	12.6	10.1	17.0	5.5	4.5	6.8	9.7	6.7	5.4	4.6	0.0	2.2	3.2	0.0	8.0	3.4	2.3	0.0	0.0
24 to 24.5	5.7	7.8	5.5	5.6	3.3	5.5	7.6	9.1	11.3	6.7	3.4	1.1	4.5	8.6	3.2	4.3	0.0	1.1	3.3	2.1	1.1	2.2	1.1	0.0	0.0	0.0
24.5 to 25	3.4	5.7	2.3	0.0	3.4	0.0	7.5	5.7	3.4	5.7	5.6	5.4	6.6	8.9	2.2	0.0	1.1	2.3	0.0	2.1	0.0	5.7	1.1	0.0	0.0	0.0
25 to 25.5	3.4	1.1	1.1	8.8	1.1	5.5	9.8	0.0	2.2	1.1	2.2	0.0	3.3	6.7	2.1	4.6	0.0	0.0	2.2	0.0	0.0	4.5	2.3	0.0	1.1	1.1
25.5 to 26	0.0	1.1	1.1	3.4	0.0	4.6	11.9	4.4	3.3	4.6	0.0	0.0	1.1	4.5	3.3	1.1	2.3	1.1	0.0	1.1	0.0	0.0	1.1	0.0	0.0	0.0
26 to 26.5	0.0	0.0	0.0	2.2	3.4	2.3	1.1	2.2	1.1	5.5	2.2	0.0	2.1	5.5	3.4	0.0	1.1	0.0	1.1	0.0	0.0	1.1	1.1	0.0	0.0	1.1
26.5 to 27	0.0	1.1	2.3	1.1	2.1	0.0	0.0	1.1	0.0	0.0	1.1	1.1	6.7	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
27 to 27.5	0.0	0.0	0.0	0.0	2.3	1.1	0.0	1.1	0.0	1.1	2.2	7.7	3.4	0.0	0.0	1.1	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27.5 to 28	0.0	0.0	2.3	1.1	0.0	1.1	1.1	0.0	0.0	0.0	1.1	2.1	2.2	1.1	0.0	1.1	1.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0
28 to 28.5	0.0	0.0	1.1	1.1	0.0	1.1	1.1	0.0	0.0	0.0	0.0	1.1	1.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28.5 to 29	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 to 29.5	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0
29.5 to 30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0