Aviation Impact Assessment

Harestanes South Windfarm Extension

09 December 2020

CL-5480-RPT-001 V1.1

www.cyrrus.co.uk

info@cyrrus.co.uk

Executive Summary

Cyrrus Limited has been engaged to provide guidance on aviation issues associated with the proposed Harestanes South Windfarm Extension (HSWE) development to the north of Dumfries in Dumfries and Galloway. The Proposed Development is anticipated to comprise up to 8 turbines with a maximum blade tip height of 200m.

Of the aviation stakeholders consulted at scoping, NATS (En Route) [NERL] and the Ministry of Defence (MOD) have indicated that they will object to the proposal due to turbines being visible to one of their Primary Surveillance Radars (PSRs). The MOD will also object due to the impact of the turbines on the Eskdalemuir Seismological Recording Station. Glasgow Prestwick Airport (GPA) has indicated that it will object to the proposal should any turbines be visible to its PSR.

Initial modelling of the NERL PSRs at Lowther Hill and Great Dun Fell shows that turbine T14[1] may be in marginal Radar Line of Sight (RLoS) of Lowther PSR. Probability of Detection analysis indicates that turbines T12 and T14 have a high probability of being detected by Lowther PSR. This confirms the findings of the NATS Technical and Operational Assessment.

Initial modelling of the S511 and Terma PSRs at GPA shows that none of the proposed turbines are in RLoS of these radars and are unlikely to be detected.

Initial modelling of the MOD Air Traffic Control (ATC) PSRs at Deadwater Fell and Berry Hill shows that all of the turbines are in RLoS of Deadwater Fell PSR and likely to be detected. Berry Hill PSR is unlikely to detect any of the HSWE turbines. Deadwater Fell PSR is used to control aircraft engaged in electronic warfare operations within the Spadeadam Range. The Range boundary is approximately 35km to the east of HSWE which suggests that the Proposed Development is not in an operationally significant area.

There are no significant areas for concern specifically in relation to airspace or airspace users. The HSWE development site lies below a volume of uncontrolled airspace predominantly used by General Aviation and military aircraft. This Class G airspace extends from the ground to Flight Level (FL) 85 (approximately 8,500ft Above Mean Sea Level (AMSL)) and falls outside the support provided by Lower Airspace Radar Service units. The site does fall within the Tactical Training Area within Low Flying Area 20T within which military aircraft perform low flying as low as 100ft Minimum Separation Distance. From FL85 upwards the airspace is Class A controlled airspace and aircraft are placed under a Radar Control Service provided by Scottish Control, located at Prestwick Centre. Within Class A airspace aircraft are required to be transponder equipped.

Where radar impacts result in an adverse impact on the Air Traffic Service provided, mitigation may be required. Mitigation options for NERL include applying small area blanking of turbines T12 and T14. This could be combined with infill coverage from another radar. Alternatively, Project RM mitigation could be employed to mitigate the impact of turbines on Lowther Hill PSR. This would result in a minimum detection altitude of approximately 4,300ft overhead the turbines.

[1] The turbine numbering convention used during consultation has since been updated for the final turbine layout. The modelling in this report was prepared using the original numbering convention.

Potential infill mitigation could be provided by various PSRs which provide 3,000ft of additional PSR coverage below the base of NERL controlled airspace in the vicinity of the Propose Development. This includes Cumbernauld PSR, which has a minimum coverage of 3,500ft AMSL over HSWE. Glasgow PSR and Kincardine PSR have the required minimum coverage of 5,500ft AMSL over HSWE. All these PSR are integrated into NERL's Multi-Radar Tracking (MRT) infrastructure.

The GPA Terma PSR has minimum coverage of 5,500ft AMSL over HSWE so has potential as an infill radar to mitigate the impact on Lowther PSR. However, it is at the edge of range and the GPA Terma has not been integrated into NERL's MRT infrastructure.

If MOD requires mitigation, options include the windfarm filter which forms part of the STAR-NG being deployed at Deadwater Fell by end 2021 or an infill from Berry Hill PSR.

Abbreviations

AGL	Above Ground Level
AIAA	Area of Intense Air Activity
AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
ATA	Aerial Tactics Area
ATC	Air Traffic Control
ATS	Air Traffic Service
CAD	Computer Aided Design
DTM	Digital Terrain Model
FL	Flight Level
FOI	Freedom of Information
GPA	Glasgow Prestwick Airport
HSWE	Harestanes South Windfarm Extension
MOD	Ministry of Defence
MRT	Multi-Radar Tracker
NERL	NATS (En Route)
NM	Nautical Miles
PD	Probability of Detection
PSR	Primary Surveillance Radar
RCS	Radar Cross Section
RLoS	Radar Line of Sight
SPR	ScottishPower Renewables
SSR	Secondary Surveillance Radar
TMA	Terminal Manoeuvring Area
TMZ	Transponder Mandatory Zone
TOPA	Technical and Operational Assessment

Contents

List of figures

List of tables

1. Introduction

1.1. Background

1.1.1. ScottishPower Renewables (SPR) is proposing to develop an extension to the operational Harestanes Windfarm on land immediately to the south. The development site is approximately 13km north of Dumfries, in Dumfries and Galloway. Harestanes South Windfarm Extension (HSWE), the Proposed Development, is anticipated to comprise up to 8 turbines with a maximum blade tip height of 200m Above Ground Level (AGL).

1.1.2. Cyrrus Limited has been engaged to provide guidance on aviation issues to support the Environmental Impact Assessment process for the Project.

1.2. Effects of Wind Turbines on Aviation

1.2.1. Wind turbines are an issue for aviation Primary Surveillance Radars (PSRs) as the characteristics of a moving wind turbine blade are similar to that of an aircraft. As a general rule, the PSR is unable to differentiate between wanted aircraft targets and clutter targets introduced by the presence of turbines.

1.2.2. The significance of any radar impact depends on airspace usage in the vicinity of the windfarm site and the nature of the Air Traffic Service (ATS) provided in that airspace.

1.3. Scoping Responses

1.3.1. Following a request for pre-application scoping advice, responses have been received from the following aviation stakeholders:

- NATS (En Route) [NERL] – 11 May 2020;
- Ministry of Defence (MOD) – 14 May 2020; and
- Glasgow Prestwick Airport (GPA) – 18 May 2020.

1.3.2. Based on their preliminary technical findings, NERL indicates in their response that they would object to the proposal. A NATS Technical and Operational Assessment (TOPA)[2] issued on 2 July 2020 anticipates that two of the turbines will have an unacceptable technical impact on Lowther Hill radar.

1.3.3. The MOD states that it may object to the proposal as the turbines will be detectable by the Deadwater Fell Air Traffic Control (ATC) PSR utilised by RAF Spadeadam. The MOD also states that it must object due to the unacceptable impact the turbines would have upon the Eskdalemuir Seismological Recording Station.

1.3.4. GPA noted that the Proposed Development lies within range of its primary radar and that they would require to object to the proposal should any turbines be visible to the radar.

[2] TOPA for Harestanes South Windfarm Extension, NATS ref: SG09361, Issue 3, July 2020

1.4. Aviation Modelling Tasks

1.4.1. The initial modelling tasks identified are:

- Determine the radar visibility of the Proposed Development to NERL's PSRs;
- Determine the radar visibility of the Proposed Development to GPA's PSRs;
- Determine the radar visibility of the Proposed Development to MOD PSRs; and
- Review the nature of the airspace in the vicinity of HSWE to determine any potential impact on aviation.

2. Data

2.1. Harestanes South Windfarm Extension

2.1.1. A final turbine layout for the Development, dated 21 August 2020, has been issued in the following file:

- Harestanes_Extension_Turbine_Locations_WC_210820.shp.

2.1.2. It should be noted that the turbine numbering convention used for the consultation and the NATS TOPA has since been updated for the final turbine layout.

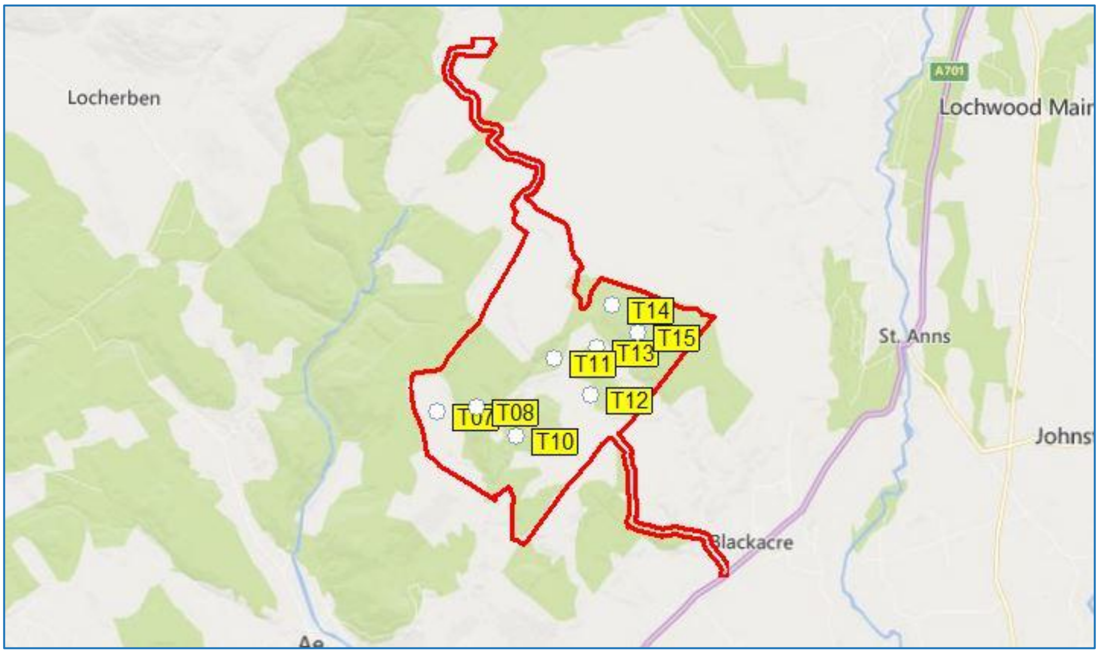
2.1.3. The Ordnance Survey National Grid coordinates for this final turbine layout, as used in the assessment, are listed in Table 1. The table also shows the original and new turbine numbering conventions. This modelling report was prepared using the original numbering convention.

Turbine (original)	Turbine (new)	Easting	Northing
T07	T01	300146.58	592473.35
T08	T02	300726.20	592539.13
T10	T03	301280.50	592103.97
T11	T04	301841.08	593216.93
T12	T05	302347.83	592684.62
T13	T06	302440.20	593352.31
T14	T07	302666.69	593966.57
T15	T08	303049.33	593566.69

Table 1: Turbine coordinates

2.1.4. The 8 turbines are planned to have a blade tip height of up to 200m AGL and maximum hub height of 125m AGL.

2.1.5. The proposed turbine layout used for the modelling is shown in Figure 1.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 1: Turbine layout

2.2. Radar Data

2.2.1. Radar parameters used in the assessment have been taken from data held on file by Cyrrus.

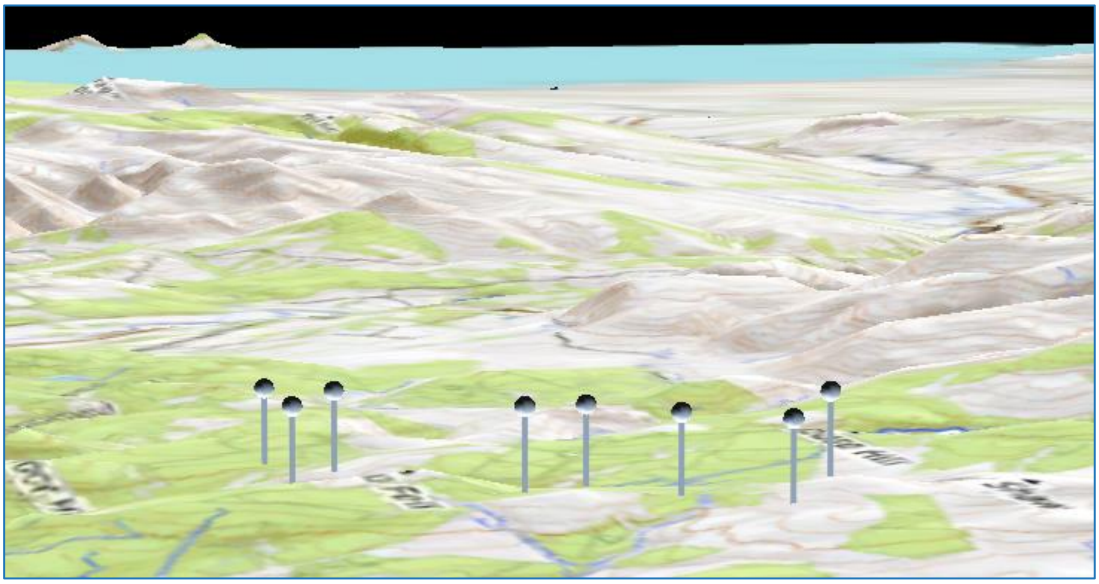
2.3. Analysis Tools

- ATDI ICS telecom EV v15.5.3 x64 radio network analysis tool;
- Global Mapper v21.1.1 Geographic Information System data processing utility;
- ZWCAD+ 2015 SP2 Pro v2015.05.26(27086) Computer Aided Design (CAD) software.

2.4. Terrain Data

- 30m Digital Terrain Model (DTM).

2.4.1. A 3D view of the turbines and the terrain model is shown in Figure 2.



© OpenStreetMap contributors

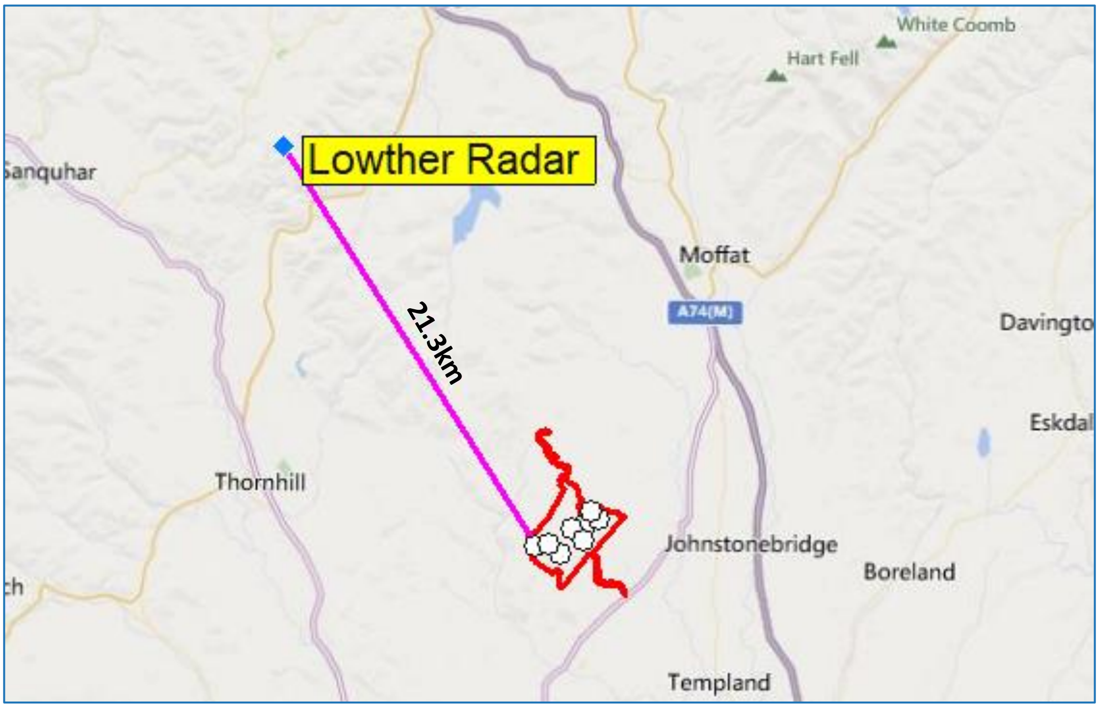
Figure 2: 3D view of turbines and terrain from east

3. NERL Modelling

3.1. Radar Locations

3.1.1. The closest NERL facilities to the Proposed Development that require assessment are the Lowther Hill and Great Dun Fell PSRs.

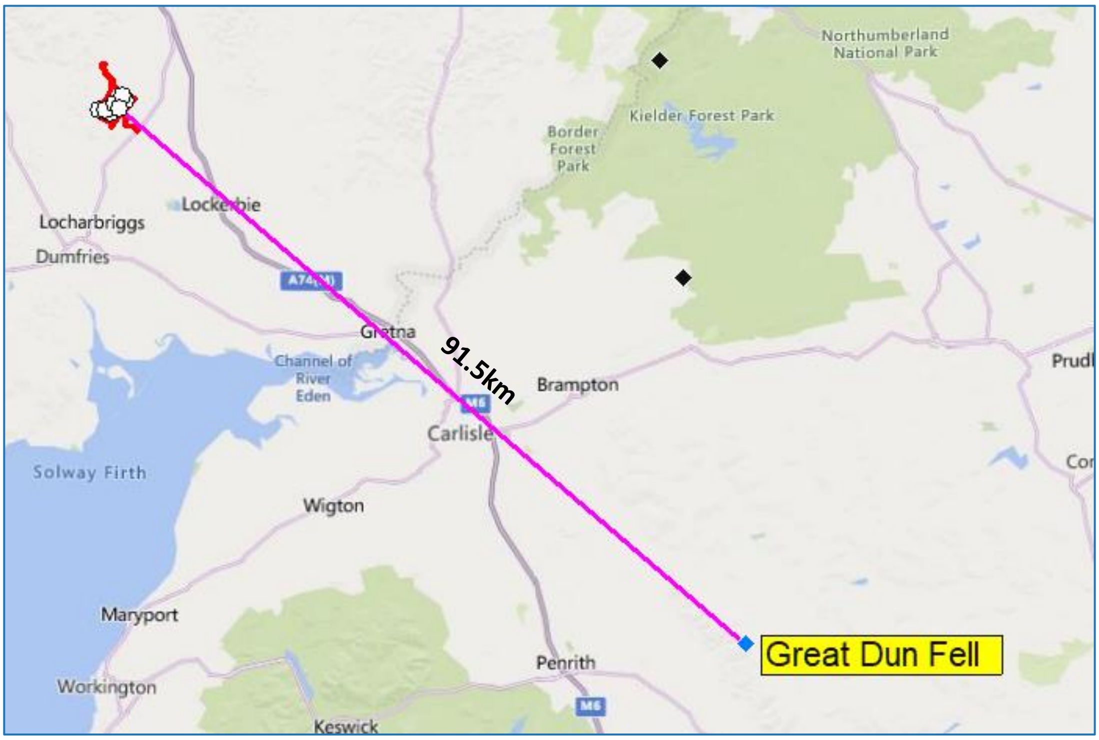
3.1.2. The closest turbine within the Proposed Development area is approximately 21.3km south-east of Lowther Hill PSR, as shown in Figure 3.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 3: Location of Lowther Hill PSR and Proposed Development

3.1.3. The closest turbine within the Proposed Development area is approximately 91.5km north-west of Great Dun Fell PSR, as shown in Figure 4.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 4: Location of Great Dun Fell PSR and Proposed Development

3.2. Radar Line of Sight

3.2.1. Radar Line of Sight (RLoS) is determined from a radar propagation model (ATDI ICS telecom EV) using 3D DTM data with 30m horizontal resolution. Radar data is entered into the model and RLoS to the turbines from the radar is calculated.

3.2.2. Note that by using a DTM no account is taken of possible further shielding of the turbines due to the presence of structures or vegetation that may lie between the radars and the turbines. Thus, the RLoS assessments are worst-case results.

3.2.3. For PSR, the principal sources of adverse windfarm effects are the turbine blades, so RLoS is calculated for the maximum tip height of the turbines, i.e. 200m AGL.

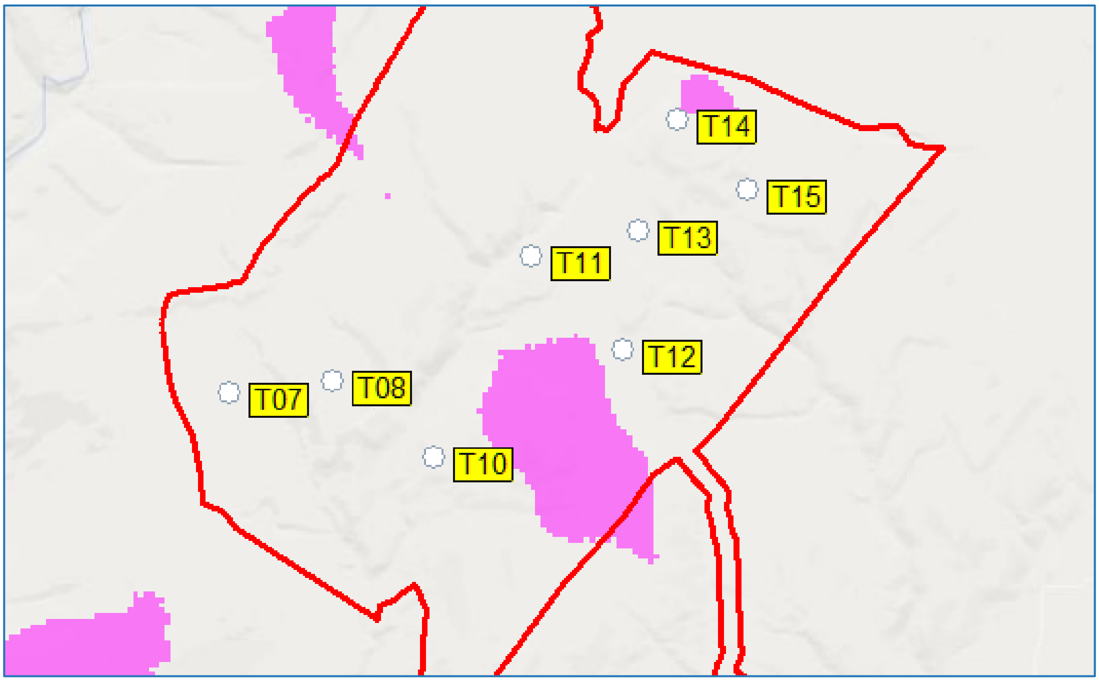
3.3. RLoS – Lowther Hill PSR

3.3.1. The magenta shading in Figure 5 illustrates the RLoS coverage from Lowther Hill PSR to turbines with a blade tip height of 200m AGL.

Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 5: Lowther Hill PSR RLoS to 200m AGL

3.3.2. The zoomed view of the Proposed Development in Figure 6 shows that marginal RLoS may exist between Lowther PSR and turbine T14.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

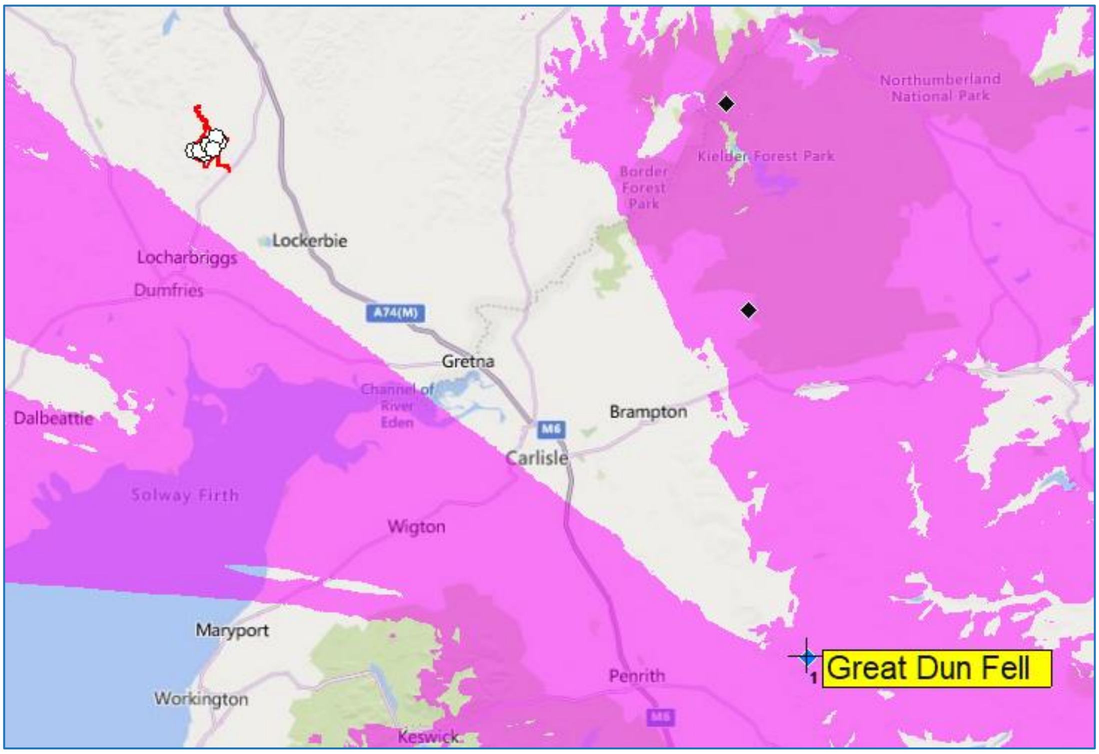
Figure 6: Lowther Hill PSR RLoS to 200m AGL – zoomed

3.3.3. The NATS TOPA states that "*the terrain screening available will not adequately attenuate the signal for turbines 12 and 14*". The close proximity of the Proposed Development to the radar site means that turbines that are not in RLoS may still be detected by the PSR. It can be seen in Figure 6 that turbines T12 and T14 are the closest turbines to the magenta shaded coverage areas.

3.3.4. The likelihood of turbines being detected can be determined by analysis of path profiles between the radar and each turbine and conducting Probability of Detection (PD) calculations.

3.4. RLoS – Great Dun Fell PSR

3.4.1. The magenta shading in Figure 7 illustrates the RLoS coverage from Great Dun Fell PSR to turbines with a blade tip height of 200m AGL.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 7: Great Dun Fell PSR RLoS to 200m AGL

3.4.2. Figure 7 shows that RLoS does not exist between Great Dun Fell PSR and any of the turbines.

3.4.3. Given that RLoS does not exist, it can be assumed that Great Dun Fell PSR is unlikely to detect any of the HSWE turbines.

3.5. Probability of Detection – Lowther Hill PSR

3.5.1. Using a radar propagation model, the actual path loss between Lowther PSR and various parts of each turbine can be determined.

3.5.2. Figure 8 illustrates the path loss profile between Lowther PSR and turbine T07.

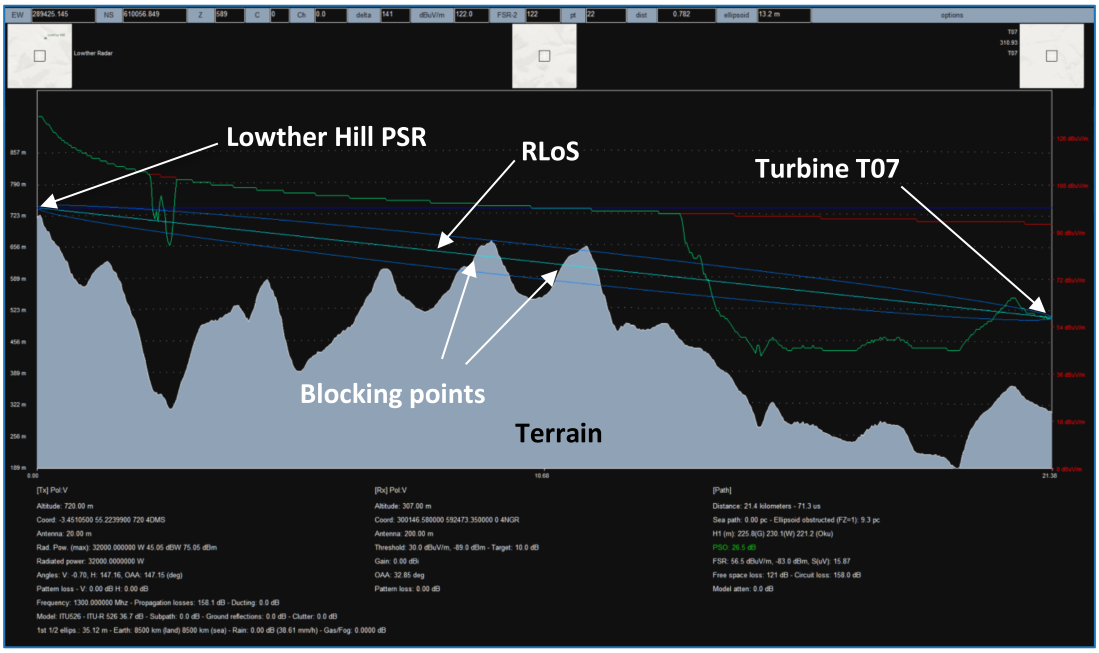


Figure 8: Path loss profile between Lowther PSR and tip of turbine T07

3.5.3. In Figure 8 the terrain, shaded grey, penetrates the path between the PSR and the turbine tip. The indicated blocking points prevent Lowther PSR from having RLoS to turbine T07.

3.5.4. Figure 9 illustrates the path loss profile between Lowther PSR and turbine T14.

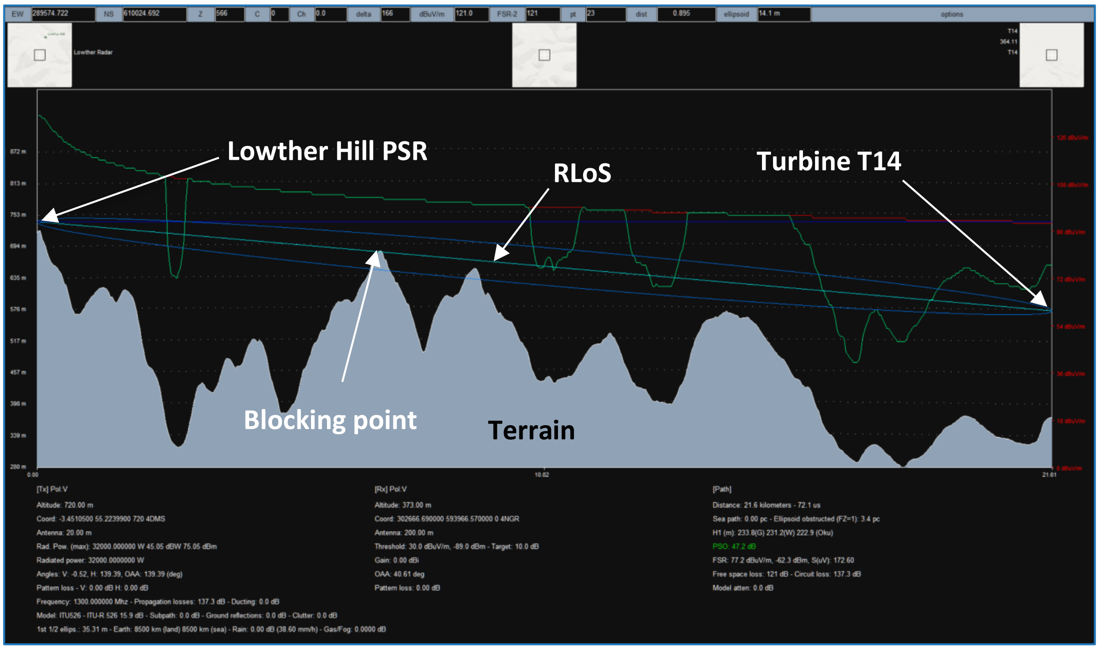


Figure 9: Path loss profile between Lowther PSR and tip of turbine T14

3.5.5. In this case a peak in the terrain marginally penetrates the path between the PSR and the turbine tip. The indicated blocking point may not fully prevent Lowther PSR from having RLoS to turbine T14.

3.5.6. All of the path profiles between Lowther PSR and the 8 HSWE turbines are shown in Annex A at the end of this report.

3.5.7. Even when intervening terrain blocks RLoS between the radar and a turbine, the probability that the turbine will be detected by the radar is still dependant on several factors including the radar's power, radar signal path loss, the angle of antenna tilt and distance to the object.

3.5.8. The radar propagation model can determine the actual path loss between the PSR and various parts of the turbine. By knowing the PSR transmitter power, antenna gain, 2-way path loss, receiver sensitivity and the turbine Radar Cross Section (RCS) gain, the probability of the radar detecting the target (PD) can be calculated.

3.5.9. The static parts of the turbine (tower structure) are ignored in the calculation as these will be rejected by the radar Moving Target filter. In this refined model, 3 parts of the turbine blade are considered: the hub, the blade tip, and a point midway along the turbine blade. Each part of the turbine blade is assigned an RCS of $60m^2$ based on a blade length of 75m (half of 150m rotor diameter). Path loss calculations are made to all turbines. The received signal at the radar from each component part of the turbine is then summed to determine the total signal level.

3.5.10. The path loss calculation carried out for each turbine component is as follows:

	Tx Power	dBm
+	Antenna Gain	dB
-	Path Loss	dB
+	RCS Gain	dB (60m^2 ~ +41.5dB)
-	Path Loss	dB
+	Antenna Gain	dB
=	Received Signal	dBm

3.5.11. The received signal is then compared with the radar receiver Minimum Detectable Signal level.

3.5.12. An example of the path loss calculation from Lowther PSR to turbine T07 is shown in Figure 10.

Radar 2-Way Path Loss Calculator

Data		
Tx Frequency	1300	MHz
Tx Power	50000	Watts
Antenna Gain	33	dBi
Rx Sensitivity	-125	dBm
Target		
RCS	60	m^2
Path Loss (1-way)	158.1	dB
Calculations		
Tx Wavelength	0.23	m
Tx power	76.9897	dBm
EIRP	109.9897	dBm
Power at Target	-48.1103	dBm
RCS Gain	41.52	dB
Power at Rx	-131.69	dBm
dB over Rx Threshold	-6.69	dB

Figure 10: Path loss calculation for turbine T07

3.5.13. The two-way path losses from the turbine components are tabulated and combined to give total radar received signals from each turbine. The results are colour-coded to indicate the likelihood of detection. Radar returns >3dB above the detection threshold are coloured green as these values show a high probability of detection. Those between +3dB and -3dB are coloured yellow and indicate a possibility of detection. Between -3dB and -6dB, results are coloured orange to show only a small possibility of detection. Signals >6dB below the threshold of detection are shaded red as these values show that detection is unlikely.

3.5.14. Using this representation provides a ready visual comparison of different scenarios. The final result is shown in the final column (TOTAL) of each colour-coded chart. The results of the PD calculations for each turbine are shown in Table 2.

	Turbine Nacelle	Blade mid-point	Blade Tip	TOTAL
Turbine ID	Path Loss dB	Path Loss dB	Path Loss dB	dB over RX threshold
T07	165.0	162.0	158.1	**-5.87**
T08	159.6	157.0	153.4	**3.67**
T10	161.6	158.7	154.9	**0.57**
T11	162.8	158.4	152.0	**5.76**
T12	155.7	150.3	141.9	**25.81**
T13	161.2	156.7	149.8	**10.11**
T14	149.7	143.6	137.3	**35.15**
T15	157.0	151.2	145.6	**18.65**

Table 2: Lowther Hill PSR PD results

3.5.15. From Table 2 it appears that there is a high probability that all the turbines except T07 and T10 will be detected by Lowther PSR. There is a small possibility that turbine T07 and a possibility that T10 will be detected.

3.5.16. The above calculations are based on the optimum performance of the radar, however the gain of a radar antenna in the vertical axis is not uniform with elevation angle. The beam is a complex shape to minimise ground returns by having low gain at elevations close to the horizonal but having high gain at elevations just a few degrees above the horizon.

3.5.17. The Lowther Hill PSR antenna is a twin beam SREM-5 system with one pencil beam and one Cosec^2 beam. The combined beam pattern provides extra gain at low elevations when compared with a standard Cosec^2 radar.

3.5.18. Cyrrus does not hold data for the Lowther antenna Vertical Polar Diagram, however it is likely that the turbine tip elevations from Lowther PSR (between -0.5° and -0.7°) are below the peak elevation of the beam where gain is maximum. Any reduction in gain will further reduce the probability of turbine detection. For example, a reduction in gain of 10dB at the turbine elevations can be envisaged. The revised PD calculation results incorporating this gain reduction are shown in Table 3.

	Turbine Nacelle	Blade mid-point	Blade Tip	TOTAL
Turbine ID	Path Loss dB	Path Loss dB	Path Loss dB	dB over RX threshold
T07	165.0	162.0	158.1	**-25.87**
T08	159.6	157.0	153.4	**-16.33**
T10	161.6	158.7	154.9	**-19.43**
T11	162.8	158.4	152.0	**-14.24**
T12	155.7	150.3	141.9	**5.81**
T13	161.2	156.7	149.8	**-9.89**
T14	149.7	143.6	137.3	**15.15**
T15	157.0	151.2	145.6	**-1.35**

Table 3: Lowther Hill PSR PD results with 5dB gain reduction

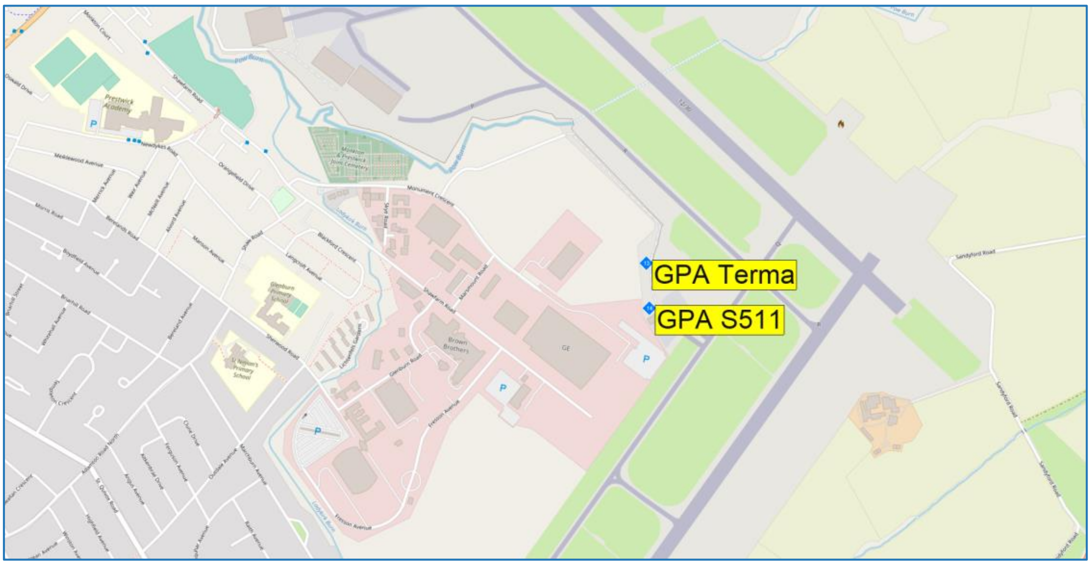
3.5.19. From Table 3 it now appears that only turbines T12 and T14 have a high probability of detection, while there is a possibility that turbine T15 will be detected. These results confirm the findings of the TOPA for turbines T12 and T14.

4. GPA Modelling

4.1. Radar Locations

4.1.1. There are two PSR facilities at GPA: a Marconi S511 radar used for planning purposes while a Terma Scanter 4002 radar is used for approach control.

4.1.2. The locations of the two GPA PSRs are shown in Figure 11.



© OpenStreetMap contributors

Figure 11: Locations of GPA Terma PSR and S511 PSR

4.1.3. The closest turbine within the Proposed Development area is approximately 71.6km south-east of the GPA PSRs, as shown in Figure 12.

Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 12: Location of GPA PSRs and Harestanes South Development

4.2. Radar Line of Sight

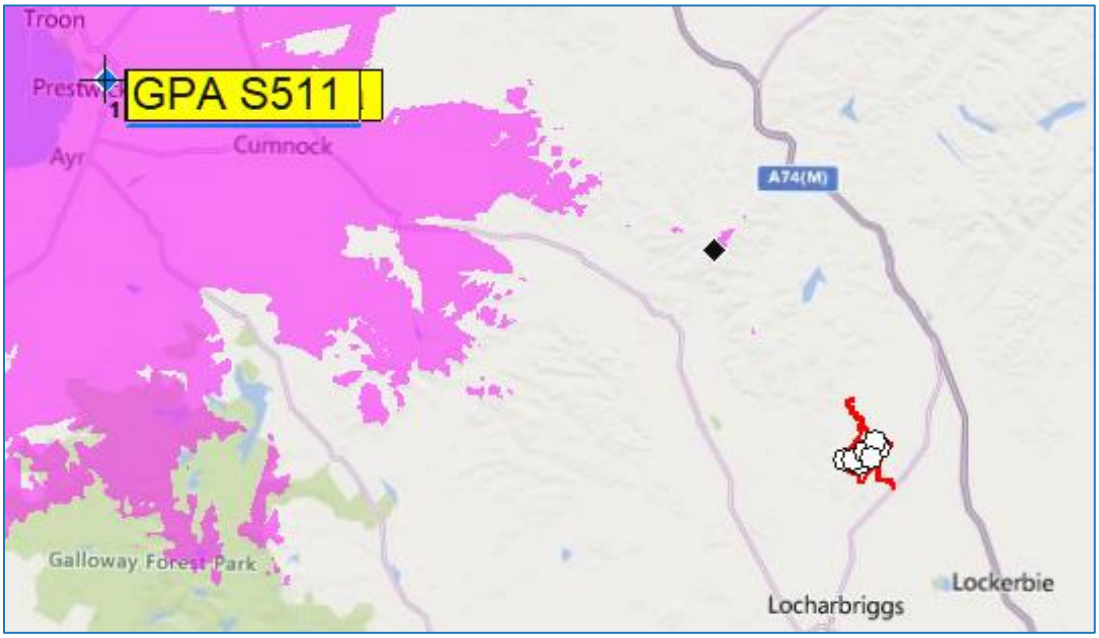
4.2.1. RLoS is determined from a radar propagation model (ATDI ICS telecom EV) using 3D DTM data with 30m horizontal resolution. Radar data is entered into the model and RLoS to the turbines from the radar is calculated.

4.2.2. Note that by using a DTM no account is taken of possible further shielding of the turbines due to the presence of structures or vegetation that may lie between the radars and the turbines. Thus, the RLoS assessments are worst-case results.

4.2.3. For PSR, the principal sources of adverse windfarm effects are the turbine blades, so RLoS is calculated for the maximum tip height of the turbines, i.e. 200m AGL.

4.3. RLoS – GPA S511 PSR

4.3.1. The magenta shading in Figure 13 illustrates the RLoS coverage from the GPA S511 PSR to turbines with a blade tip height of 200m AGL.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 13: GPA S511 PSR RLoS to 200m AGL

4.3.2. Figure 13 shows that RLoS does not exist between the GPA S511 PSR and any of the turbines.

4.3.3. Given that RLoS does not exist, it can be assumed that the GPA S511 PSR is unlikely to detect any of the HSWE turbines.

4.4. RLoS – GPA Terma PSR

4.4.1. The magenta shading in Figure 14 illustrates the RLoS coverage from the GPA Terma PSR to turbines with a blade tip height of 200m AGL.

Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 14: GPA Terma PSR RLoS to 200m AGL

4.4.2. Figure 14 shows that RLoS does not exist between the GPA Terma PSR and any of the turbines.

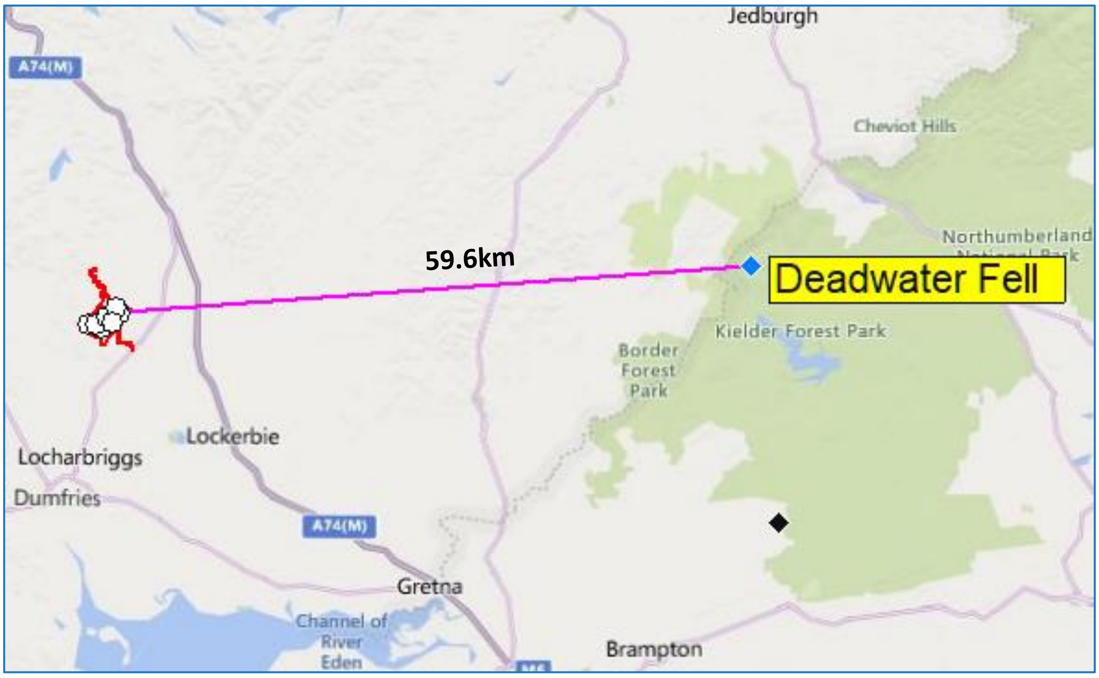
4.4.3. Given that RLoS does not exist, it can be assumed that the GPA Terma PSR is unlikely to detect any of the HSWE turbines.

5. MOD Modelling

5.1. Radar Location

5.1.1. The closest MOD facilities to the Proposed Development that require assessment are the ATC PSRs at Deadwater Fell and Berry Hill utilised by RAF Spadeadam.

5.1.2. The closest turbine within the Proposed Development area is approximately 59.6km west of Deadwater Fell PSR, as shown in Figure 15.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 15: Location of Deadwater Fell PSR and Proposed Development

5.1.3. The closest turbine within the Proposed Development area is approximately 65.1km west of Berry Hill PSR, as shown in Figure 16.

Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 16: Location of Berry Hill PSR and Proposed Development

5.2. Radar Line of Sight

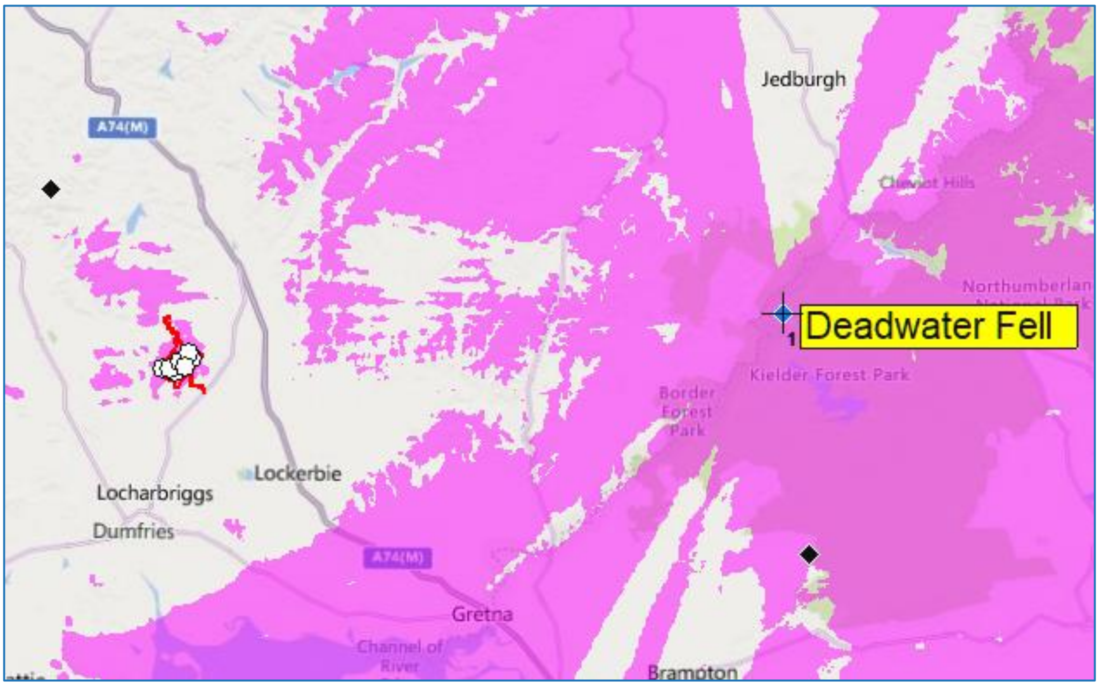
5.2.1. RLoS is determined from a radar propagation model (ATDI ICS telecom EV) using 3D DTM data with 30m horizontal resolution. Radar data is entered into the model and RLoS to the turbines from the radar is calculated.

5.2.2. Note that by using a DTM no account is taken of possible further shielding of the turbines due to the presence of structures or vegetation that may lie between the radars and the turbines. Thus, the RLoS assessments are worst-case results.

5.2.3. For PSR, the principal sources of adverse windfarm effects are the turbine blades, so RLoS is calculated for the maximum tip height of the turbines, i.e. 200m AGL.

5.3. RLoS – Deadwater Fell PSR

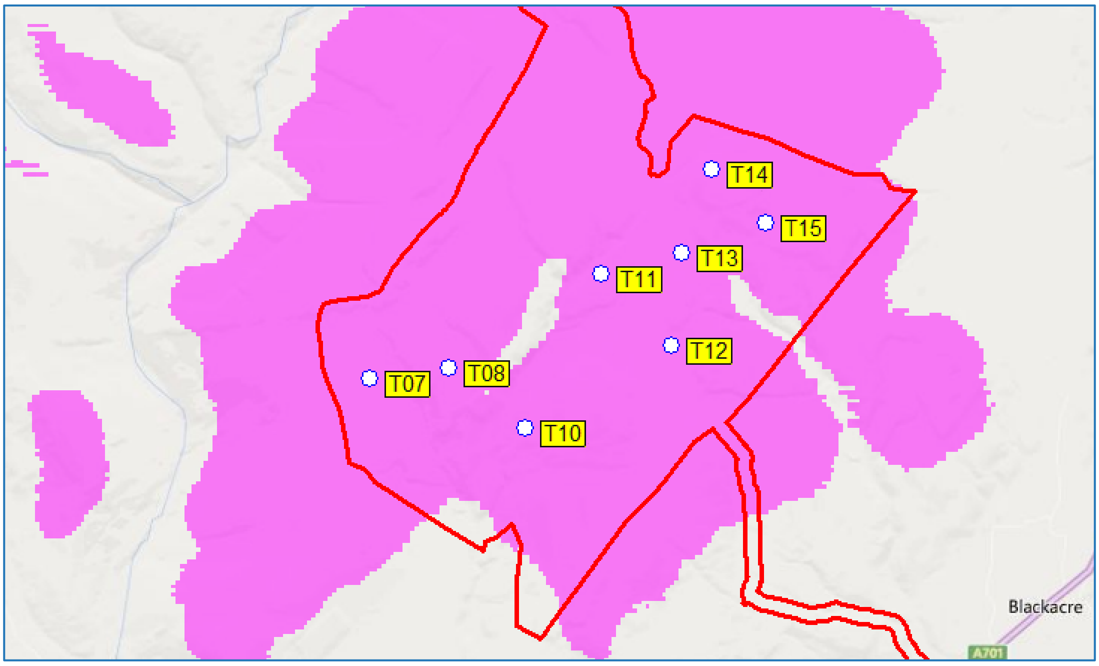
5.3.1. The magenta shading in Figure 17 illustrates the RLoS coverage from Deadwater Fell PSR to turbines with a blade tip height of 200m AGL.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 17: Deadwater fell PSR RLoS to 200m AGL

5.3.2. The zoomed view of the Proposed Development in Figure 18 shows that RLoS exists between Deadwater Fell PSR and all of the turbines.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

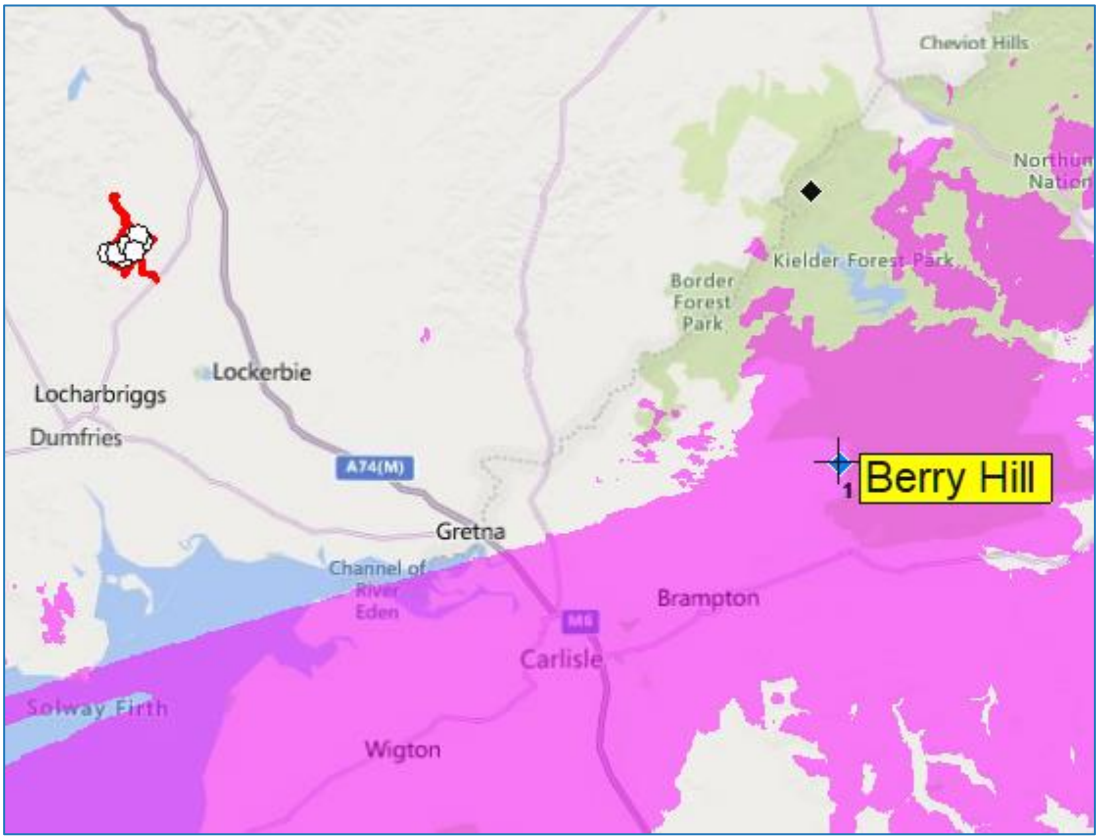
Figure 18: Deadwater Fell PSR RLoS to 200m AGL – zoomed

5.3.3. Given that RLoS exists to all the turbines, it can be assumed that Deadwater Fell PSR will also detect all of the HSWE turbines.

5.3.4. The Spadeadam Range, where Deadwater Fell PSR is used to control aircraft engaged in electronic warfare operations, is approximately 35km to the east of the HSWE development site. The distance from the Range boundary suggests that HSWE is not in an operationally significant area in terms of required Deadwater Fell PSR coverage for ATC purposes.

5.4. RLoS – Berry Hill PSR

5.4.1. The magenta shading in Figure 19 illustrates the RLoS coverage from Berry Hill PSR to turbines with a blade tip height of 200m AGL.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 19: Berry Hill PSR RLoS to 200m AGL

5.4.2. Figure 19 shows that RLoS does not exist between Berry Hill PSR and any of the turbines.

5.4.3. Given that RLoS does not exist, it can be assumed that Berry Hill PSR is unlikely to detect any of the HSWE turbines.

6. Airspace Analysis

6.1. Overview

6.1.1. As already noted, the significance of any radar impact depends on airspace usage in the vicinity of the windfarm site and the nature of the ATS provided in that airspace.

6.1.2. This section of the report will examine the potential impact to aviation, including civil and military operations.

6.1.3. The airspace surrounding the Proposed Development is contained in the UK Aeronautical Information Publication (AIP). The type (airspace classification), usage and dimensions are contained within various sections of the En-Route (ENR) section of the AIP.

6.1.4. The airspace immediately above the Proposed Development consists of two types of airspace. The first portion is classified as Class G and extends from ground level to Flight Level (FL)85 (atmospheric pressure equivalent of 8500ft above mean sea level).

6.1.5. The higher portion of airspace is classified as Class A and extends from FL85 up to FL195. This airspace is defined by the Lower ATS Routes within the airspace above, namely N864/T256/L612/N601.

6.1.6. The Class A airspace is under the control of Scottish Control, located at Prestwick Centre, and requires aircraft to be transponder equipped[3].

6.1.7. The Class G airspace is commonly referred to as 'uncontrolled airspace' and is predominantly used by General Aviation and military aircraft. There is no defined ATS within this area as it falls outside the support provided by Lower Airspace Radar Service units.

6.1.8. To the north, by approximately 4 Nautical Miles (NM) is Scottish TMA-2 where the base of the airspace steps up to 5500ft and is managed by NERL. The airspace is Class D and is a Transponder Mandatory Zone (TMZ) from 6000ft and above.

6.1.9. Class A and D Airspace is commonly referred to as 'controlled airspace' and is under a Radar Control Service. A clearance to enter controlled airspace from ATC and follow the instructions is required. It is a 'known traffic' environment meaning that ATC is aware of all traffic operating within the designated airspace.

6.2. Provision of Air Traffic Services

6.2.1. Figure 20 indicates the approximate location of the Proposed Development in relation to the airspace structure and nearby airports. The nearest airports are Glasgow Prestwick, approximately 71km north west, and Carlisle 56km to the south east of the Proposed Development.

[3] UK AIP, GEN 1.5, 5.3 Carriage of Transponder Equipment.

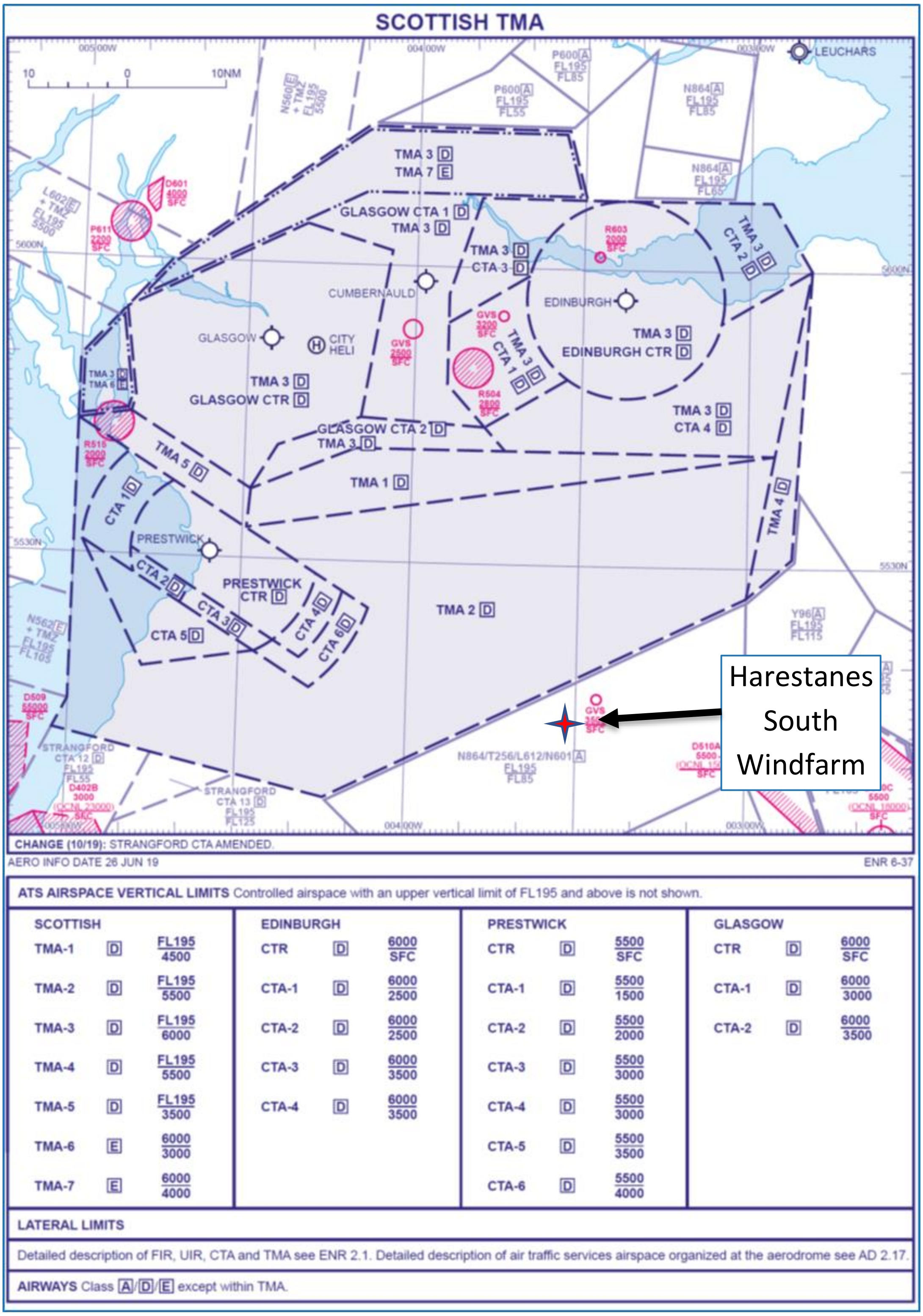


Figure 20: HSWE location relative to the Scottish TMA

6.2.2. Figure 21 and Figure 22 depict the Lower ATS Route and Airspace structure. Figure 21 shows that Harestanes South is laterally clear of any of the ATS Routes by at least 5NM.

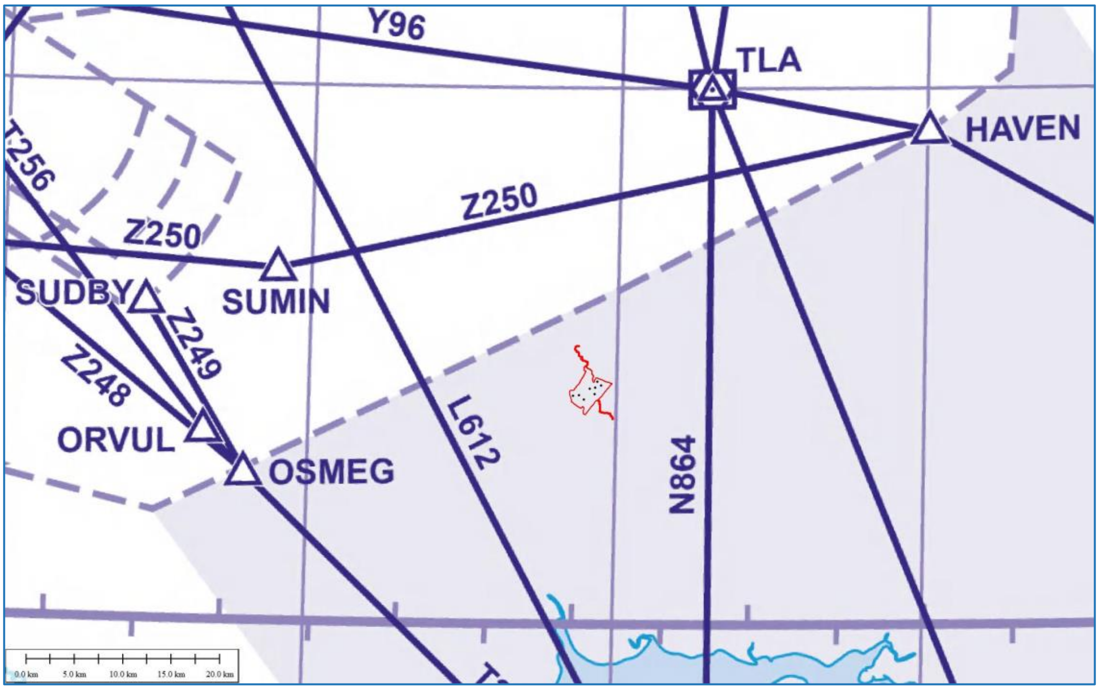


Figure 21: Lower ATS Routes (AIP ENR 6-69)

6.2.3. Figure 22 shows that the lowest available flight level is FL85, as this is within a TMZ there should be no impact on the provision of ATS within this airspace.

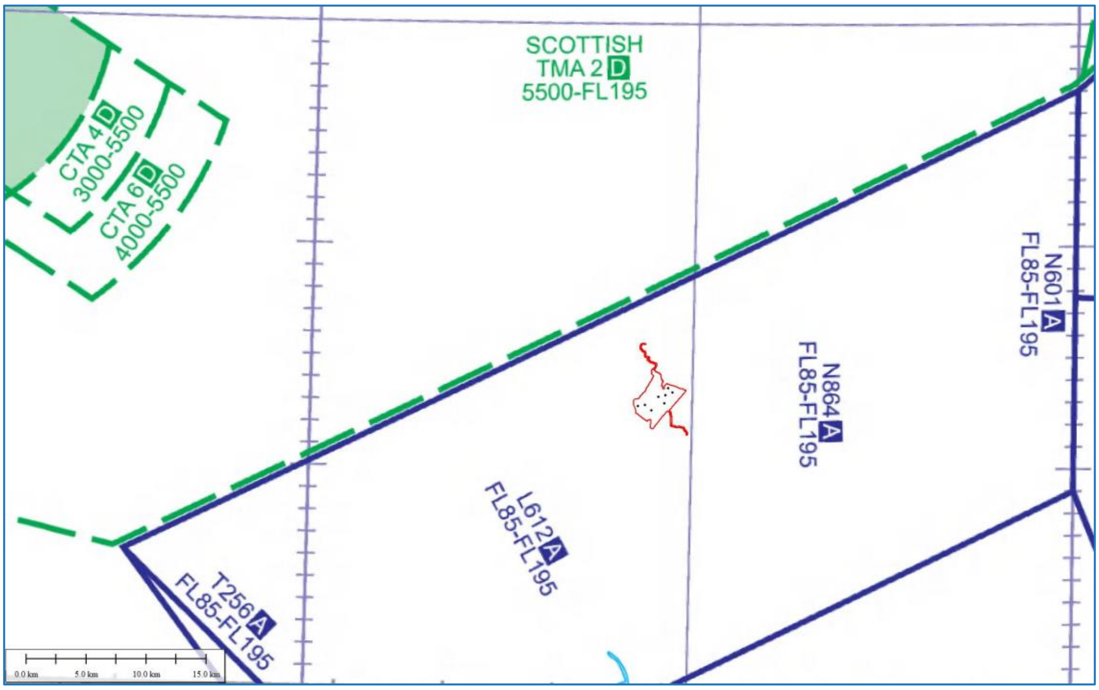


Figure 22: Lower ATS Chart (AIP ENR 6-7)

6.2.4. As there is no direct conflict with ATS Routes or any controlled airspace, the focus of this report switches to those users of the uncontrolled airspace below FL85 with consideration to any potential impact.

6.3. Other Airspace Considerations

6.3.1. The Proposed Development is not in the immediate vicinity of any aerodromes. It is situated between Carlisle Airport and Glasgow Prestwick Airport but does not impact upon the procedures associated with either. The nearest private airstrip depicted on the UK VFR chart is at Glenswinton to the West of Dumfries and there is a glider launch site, due south of Dumfries, at Falgunzeon. The operations at these sites will not be impacted by the Proposed Development.

6.3.2. Figure 23 indicates the Proposed Development location in relation to Areas of Intense Air Activity (AIAA) and Aerial Tactics Areas (ATA). AIAA Spadeadam is some distance away to the East-South-East (approximately 35km). There are a number of operational or proposed windfarms significantly closer to AIAA Spadeadam (e.g. Ewe Hill, Faw Side) and in RLoS which have not attracted MOD ATC objections. The Proposed Development is therefore considered to be of no impact to Spadeadam range activities.

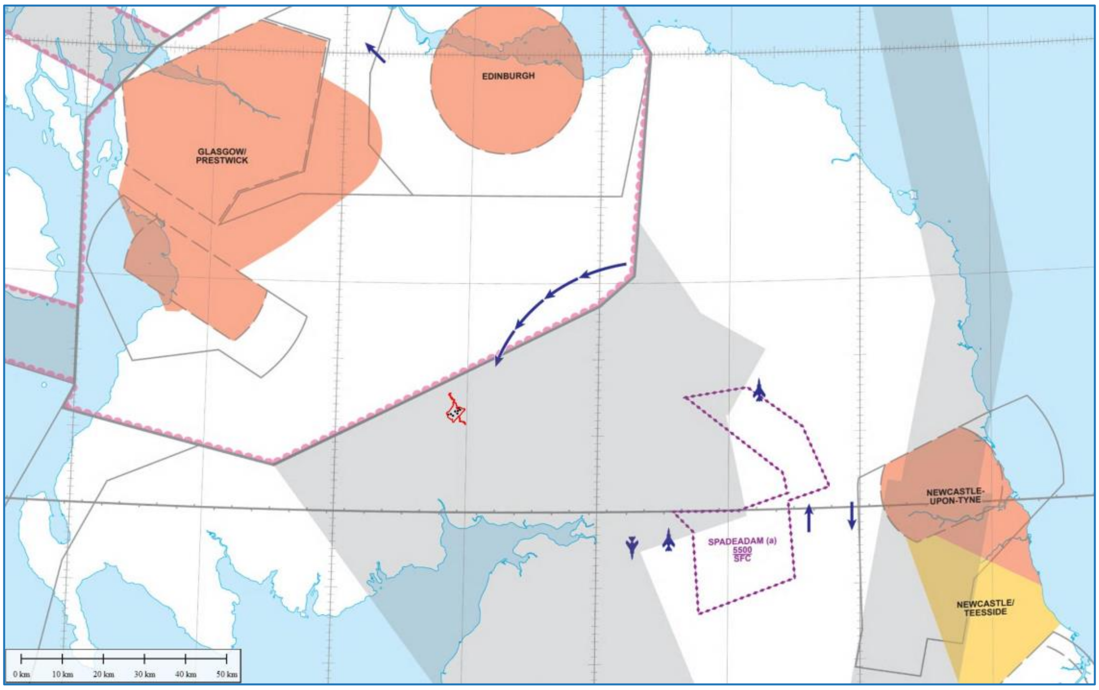


Figure 23: Areas of Intense Air Activity (AIAA) and Aerial Tactics Areas (ATA) – AIP ENR 6-76

6.3.3. The Proposed Development is, however, situated in a Red Low Flying Zone, see Figure 24, within the Tactical Training Area associated with Low Flying Area 20T (and Area 2B at night) as depicted in Figure 25. Military aircraft do occasionally conduct tactical low flying training down to 100ft Minimum Separation Distance in this region. SPR has indicated that it will light the periphery HSWE turbines with Infra-Red lights, in addition to lighting in accordance with Air Navigation Order Article 222.

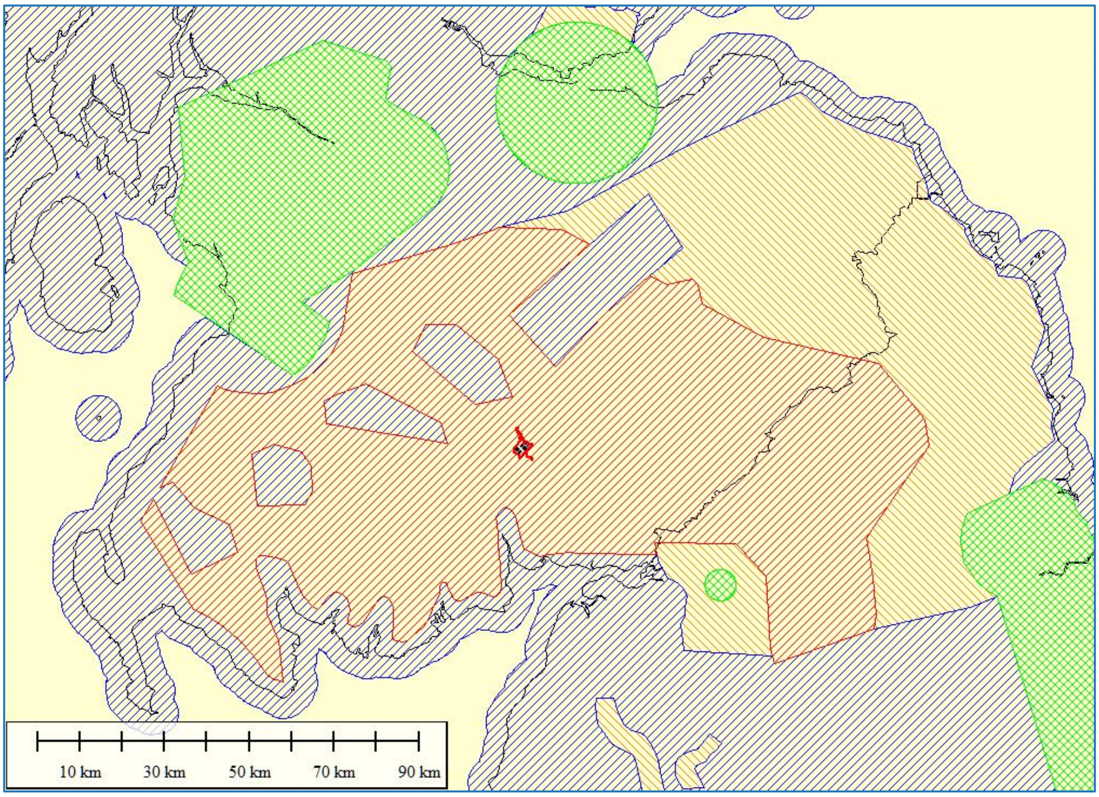


Figure 24: UK Military Low Flying Zones

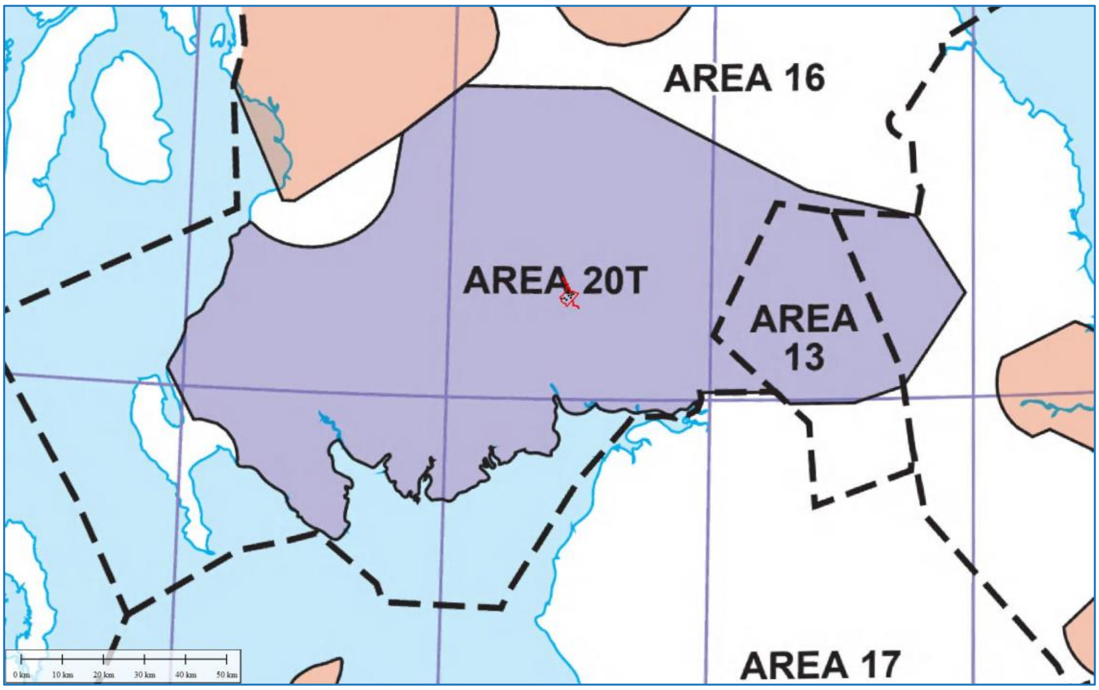


Figure 25: PINS Areas and UK Day Low Flying System - AIP ENR 6-20

7. Mitigation Options

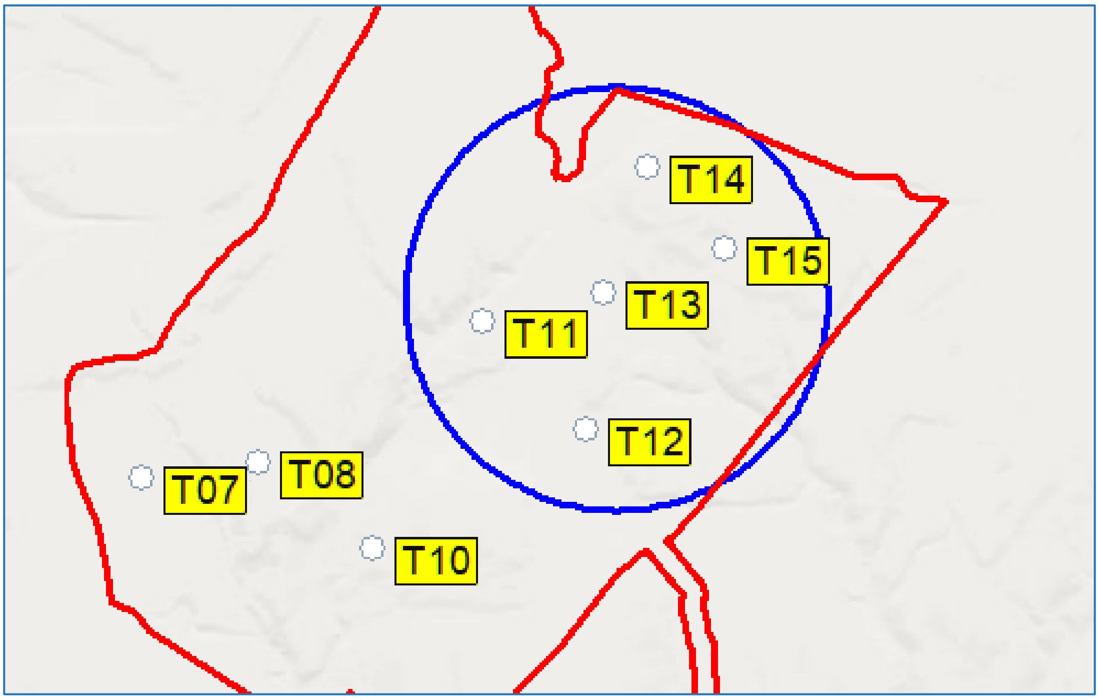
7.1. Mitigation Requirement

7.1.1. Mitigation may be required where radar clutter generated by HSWE's turbines has a detrimental impact on the ATS provided. As discussed above, only NERL and MOD's ATS may be impacted by the Proposed Development. If the impact on ATS provided is sufficiently detrimental, mitigation may be required. This section analyses the available mitigation options.

7.2. NERL Mitigation – Small Area Blanking

7.2.1. To mitigate the effect of turbines T12 and T14 on Lowther Hill PSR, NERL has the ability to apply small area blanking of up to $1NM^2$ in the vicinity of the turbines. This area is equivalent to a circle of radius 1,045m.

7.2.2. The blue circle in Figure 26 shows the application of $1NM^2$ blanking centred halfway between turbines T12 and T14. Note that turbine T15 (possibility of detection) would also fall within this blanked area.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 26: $1NM^2$ area blanking

7.2.3. Blanking mitigation may also be combined with infill from another radar, as explored in the following sections.

7.3. NERL Mitigation – Potential Infill Radars

7.3.1. A potential option for mitigating the impact on Lowther Hill PSR is to use an infill radar feed that does not have RLoS of the HSWE turbines but has adequate coverage over the HSWE site to satisfy Air Traffic Control requirements.

7.3.2. The base of controlled airspace immediately above HSWE is at an altitude of 8,500ft Above Mean Sea Level (AMSL) and is 5,500ft AMSL in the Scottish Terminal Manoeuvring Area (TMA), approximately 8km north of the site. This airspace is under the control of NERL, based at Prestwick Centre. The airspace in the vicinity of the Proposed Development is discussed further in Section 6.

7.3.3. Cyrrus understands that NATS' units optimally require circa 2,000ft of additional PSR coverage below the base of NERL TMA controlled airspace to provide a safety buffer for controllers. In controlled airspace outside of the Scottish TMA, the NERL requirement is for a 3,000ft coverage buffer. This coverage buffer is to enable lateral incursions into the TMA, by aircraft that are below controlled airspace, to be predicted.

7.3.4. As the HSWE turbines are to the south of the Scottish TMA, this means that PSRs must be capable of detecting airborne targets at a minimum altitude of 5,500ft over HSWE.

7.3.5. Surveillance coverage requirements in the en-route environment are summarised in the Civil Aviation Authority document CAP 670[4]. Section 3: SUR 01 states that below Flight Level 100 (approximately 10,000ft AMSL) in areas of high traffic density and/or complexity, coverage shall be provided with at least a single layer of coverage by a non-cooperative surveillance technique, i.e. PSR, together with data from a suitable co-operative surveillance technique (e.g. Secondary Surveillance Radar [SSR]). Redundancy is only required for the co-operative surveillance provision, e.g. in the form of dual SSR, which suggests that a single layer of infill PSR coverage is sufficient to provide coverage over a blanked area.

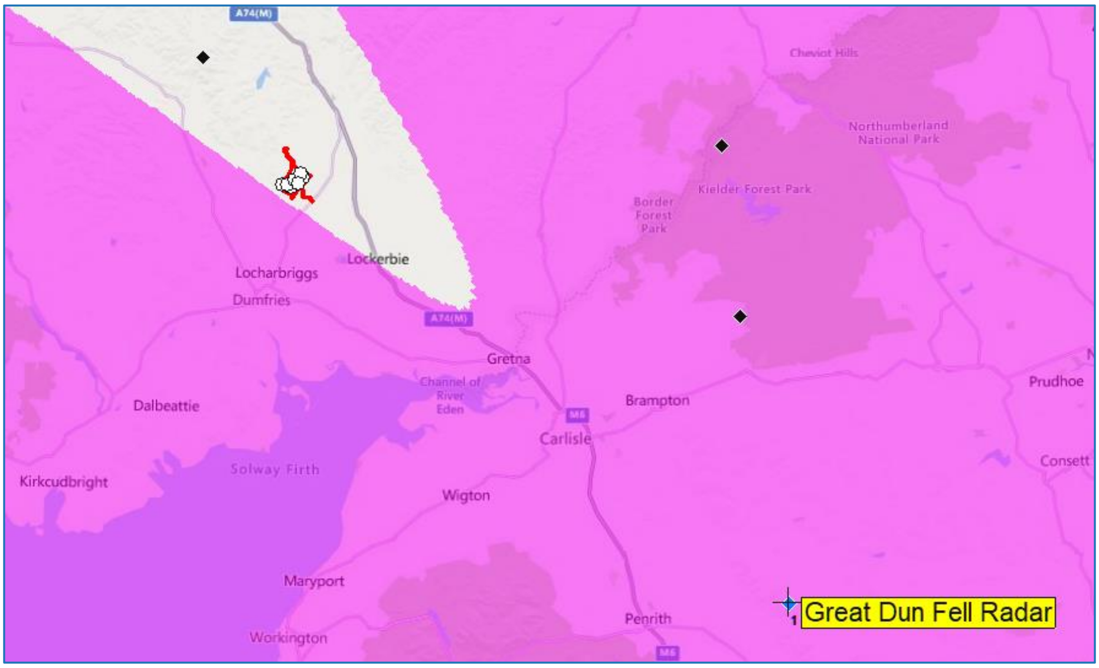
7.3.6. Candidate radars for infill coverage over HSWE are Great Dun Fell PSR, Kincardine PSR, Cumbernauld PSR, Glasgow PSR and GPA Terma PSR.

7.4. NERL Potential Infill Radars – Great Dun Fell PSR

7.4.1. It has already been shown in Section 3.4 that Great Dun Fell PSR is unlikely to detect any of the HSWE turbines.

7.4.2. The magenta shading in Figure 27 illustrates the RLoS coverage for Great Dun Fell PSR at the minimum required altitude of 5,500ft.

[4] CAP 670, Air Traffic Services Safety Requirements, Issue 3 Amendment 1/2019, June 2019

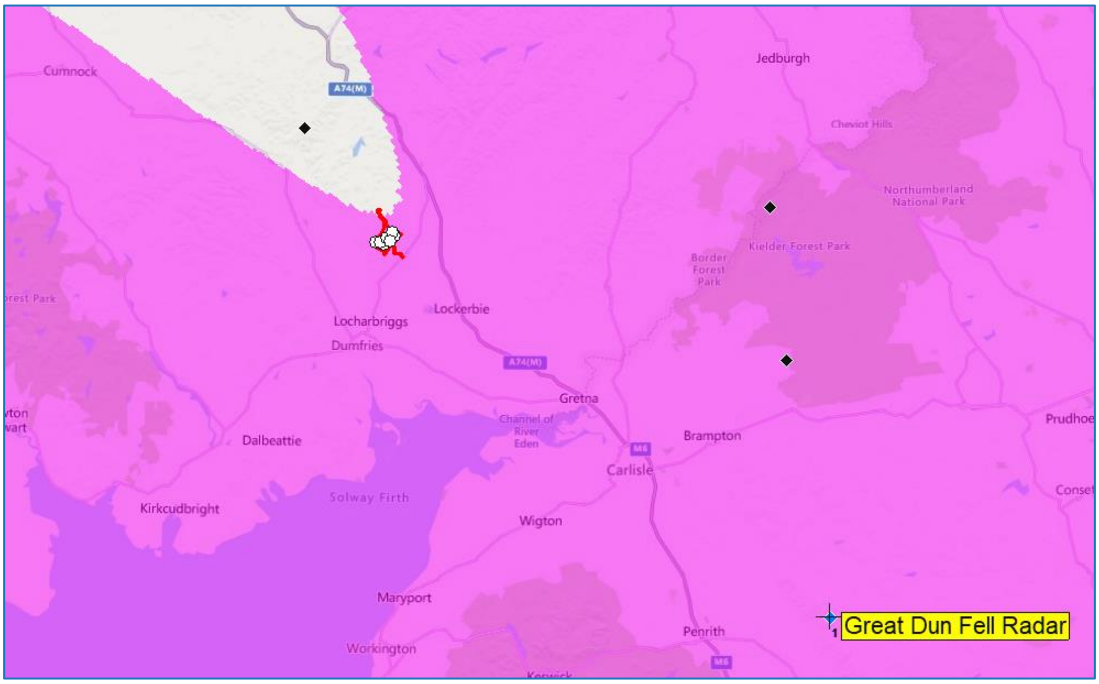


Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 27: Great Dun Fell PSR RLoS at 5,500ft AMSL

7.4.3. It can be seen in Figure 27 that Great Dun Fell PSR cannot provide the minimum required radar coverage in the vicinity of the HSWE turbines.

7.4.4. The magenta shading in Figure 28 shows that the base of radar coverage over the HSWE turbines is 7,500ft AMSL.

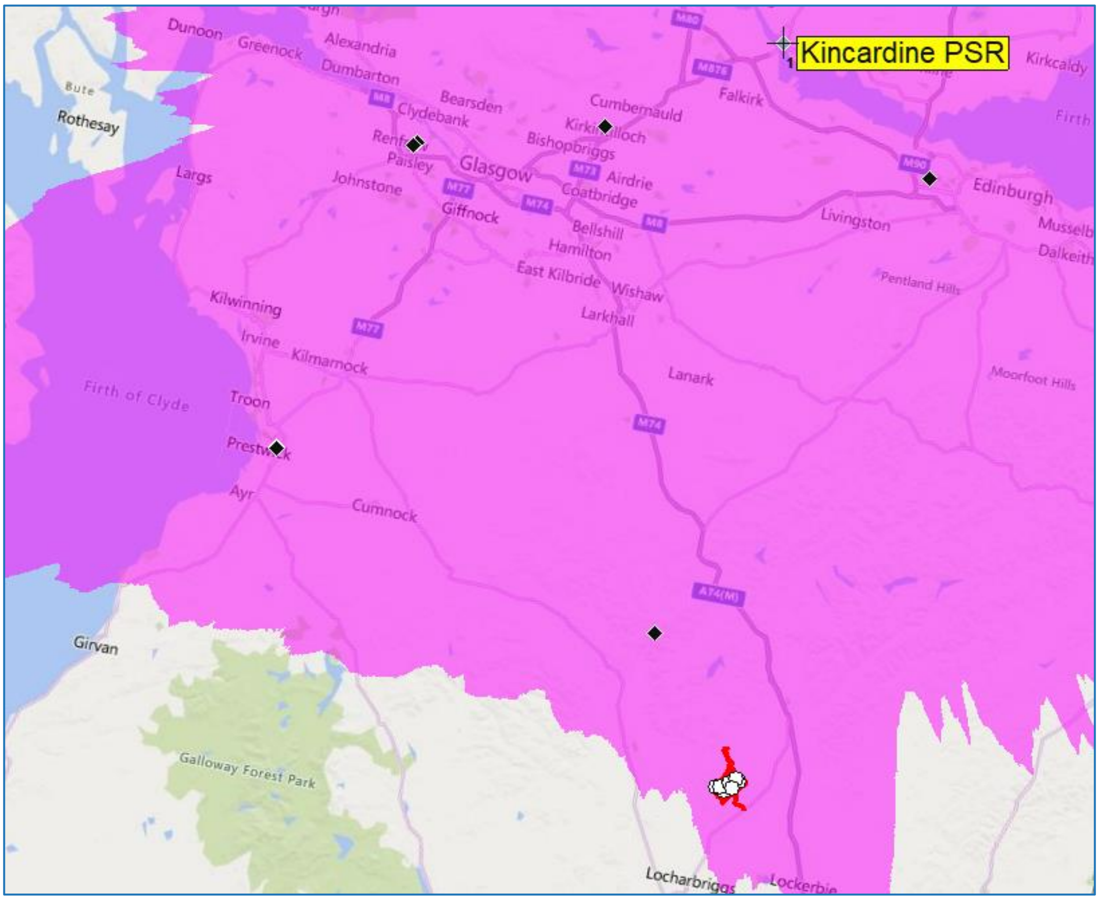


Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 28: Great Dun Fell PSR RLoS at 7,500ft AMSL

7.5. NERL Potential Infill Radars – Kincardine PSR

7.5.1. The closest turbine within the Proposed Development area is approximately 94.8km south of Kincardine PSR. The magenta shading in Figure 29 illustrates the RLoS coverage for Kincardine PSR at an altitude of 5,500ft.

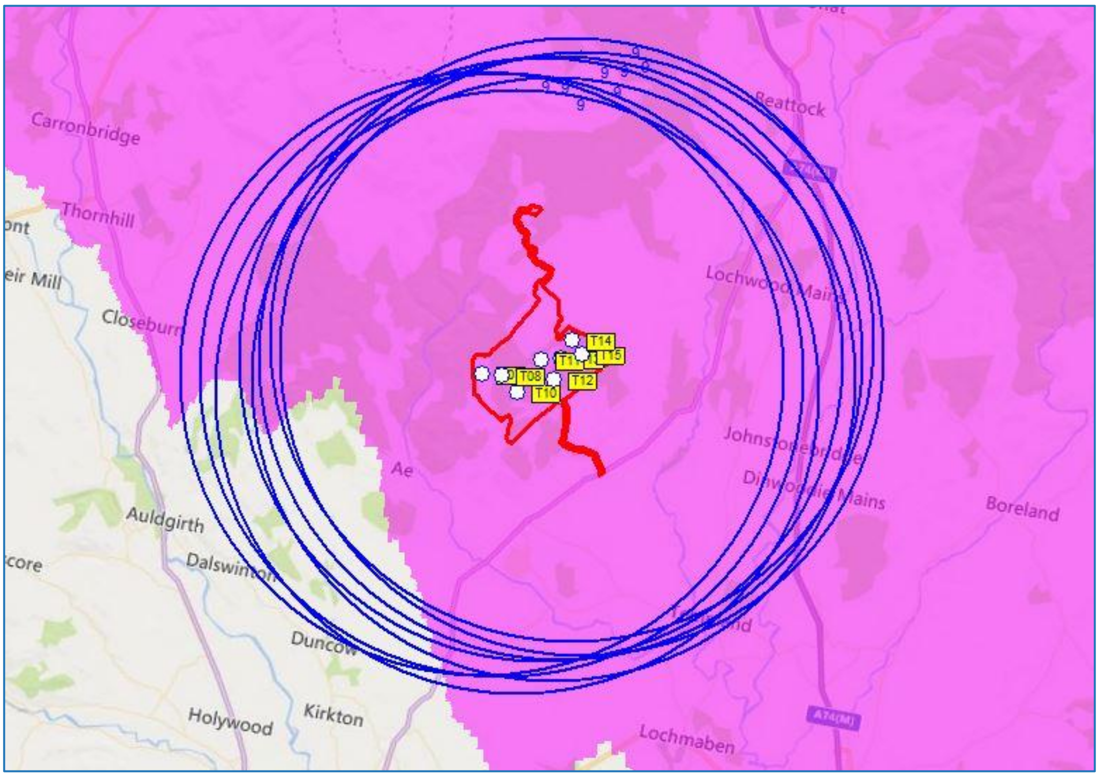


Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 29: Kincardine PSR RLoS at 5,500ft AMSL

7.5.2. Historically, there has been a NERL requirement that infill coverage is extended to include a 5NM buffer on all the mitigated wind turbines. It is not known how strictly this requirement is currently being applied.

7.5.3. The zoomed view of the Kincardine PSR 5,500ft coverage in Figure 30 includes range rings centred on each turbine to illustrate where the 5NM buffer may be required to extend to.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

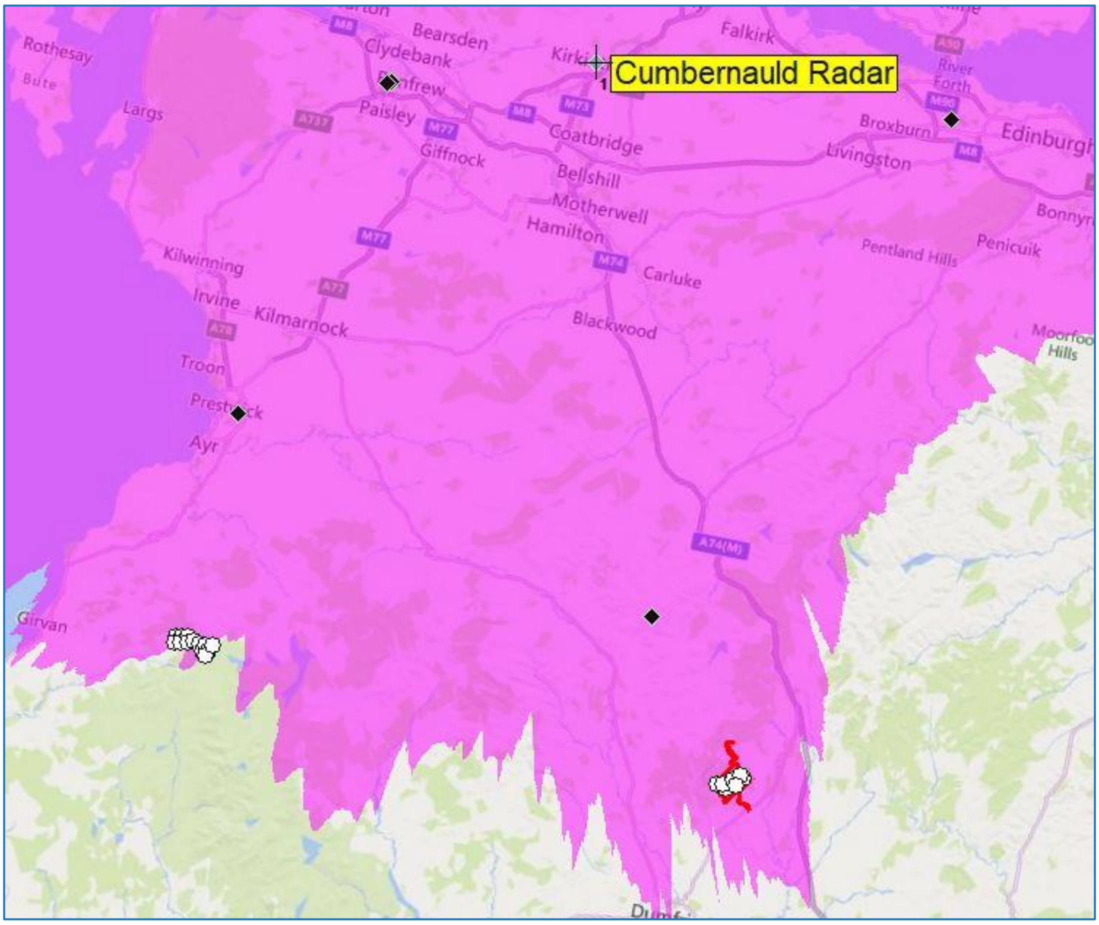
Figure 30: Kincardine PSR RLoS at 5,500ft AMSL – zoomed

7.5.4. Kincardine PSR coverage at 5,500ft AMSL does not quite extend to 5NM southwest of the turbines.

7.5.5. Notwithstanding the 5NM buffer requirement, Kincardine PSR can provide the required minimum 5,500ft AMSL infill coverage over the HSWE turbines.

7.6. NERL Potential Infill Radars – Cumbernauld PSR

7.6.1. The closest turbine within the Proposed Development area is approximately 85.7km south of Cumbernauld PSR. The magenta shading in Figure 31 illustrates the RLoS coverage for Cumbernauld PSR at an altitude of 3,500ft.

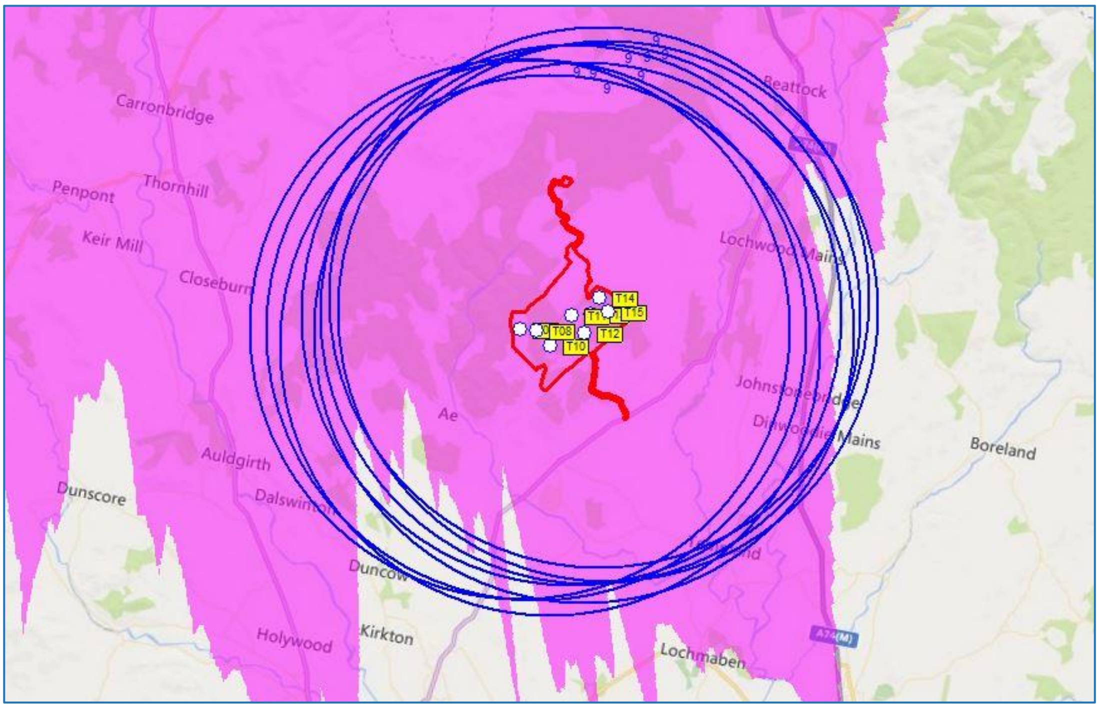


Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 31: Cumbernauld PSR RLoS at 3,500ft AMSL

7.6.2. It can be seen in Figure 31 that Cumbernauld PSR can provide radar coverage down to an altitude of 3,500ft in the vicinity of the HSWE turbines.

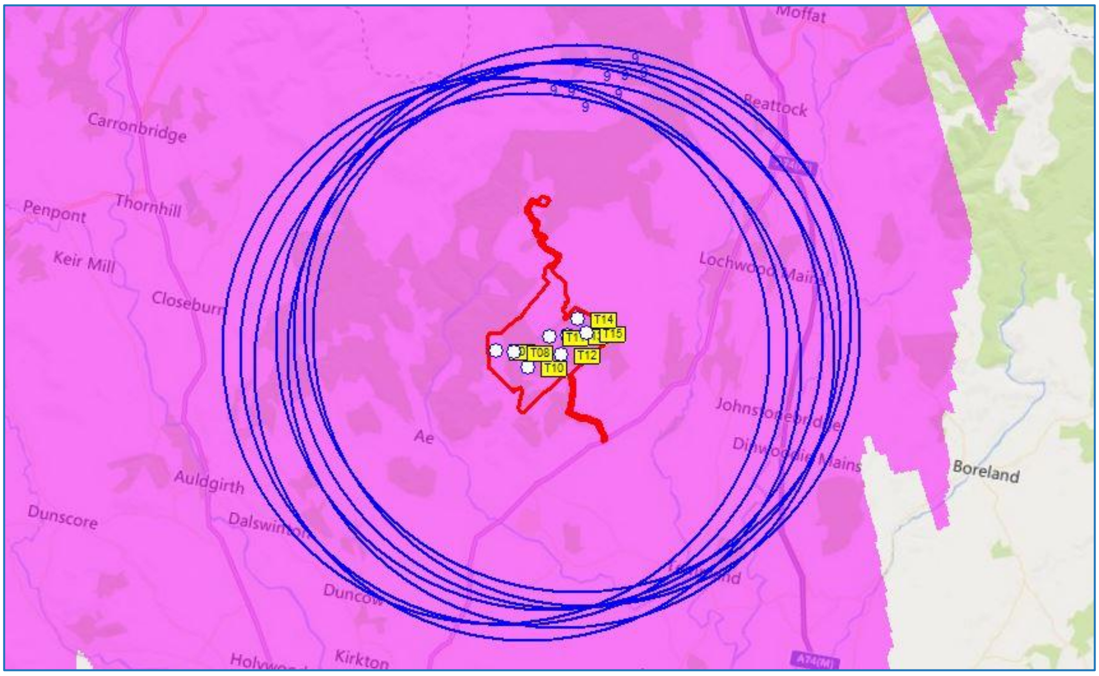
7.6.3. The zoomed view of the Cumbernauld PSR 3,500ft coverage in Figure 32 includes 5NM circles centred on each turbine to illustrate where the buffer may be required to extend to.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 32: Cumbernauld PSR RLoS at 3,500ft AMSL – zoomed

7.6.4. As can be seen, coverage at altitude 3,500ft does not quite extend to 5NM east or southwest of the turbines. Figure 33 shows that the 5NM buffer is achieved for coverage at 4,000ft AMSL.



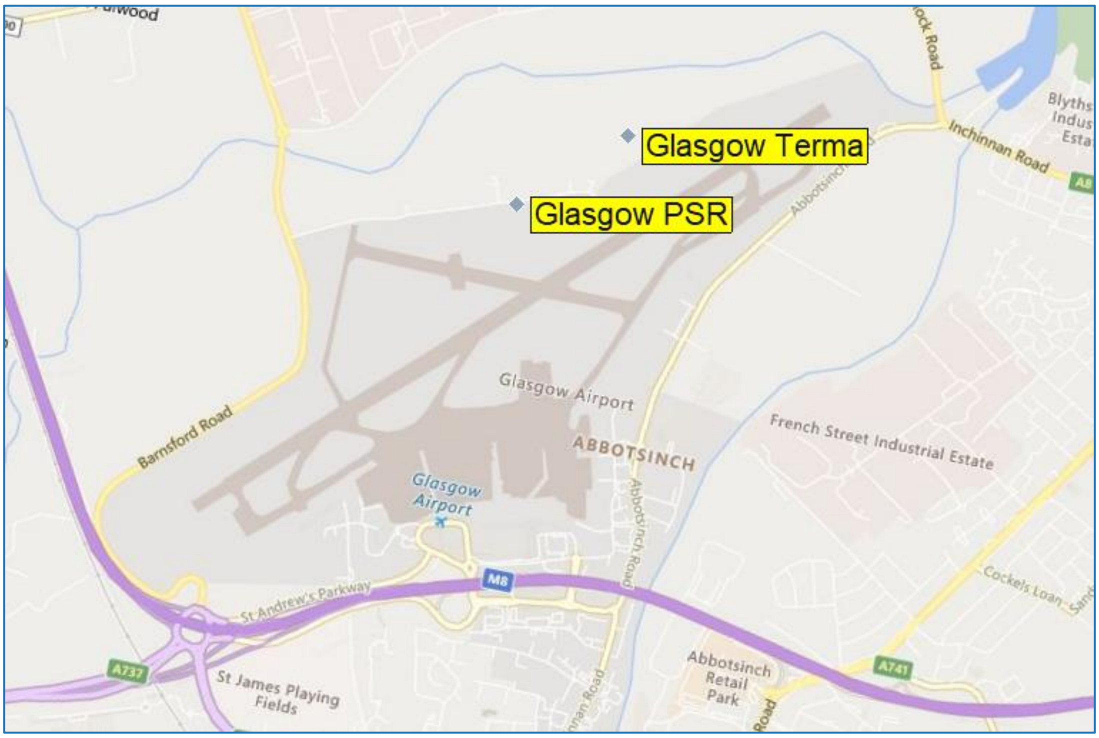
Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 33: Cumbernauld PSR RLoS at 4,000ft AMSL – zoomed

7.6.5. Cumbernauld PSR can provide a minimum of 3,500ft AMSL infill coverage over the HSWE turbines. If the 5NM buffer is enforced then minimum coverage is 4,000ft AMSL.

7.7. NERL Potential Infill Radars – Glasgow PSR

7.7.1. The locations of the Glasgow PSR and Glasgow Terma are shown in Figure 34.

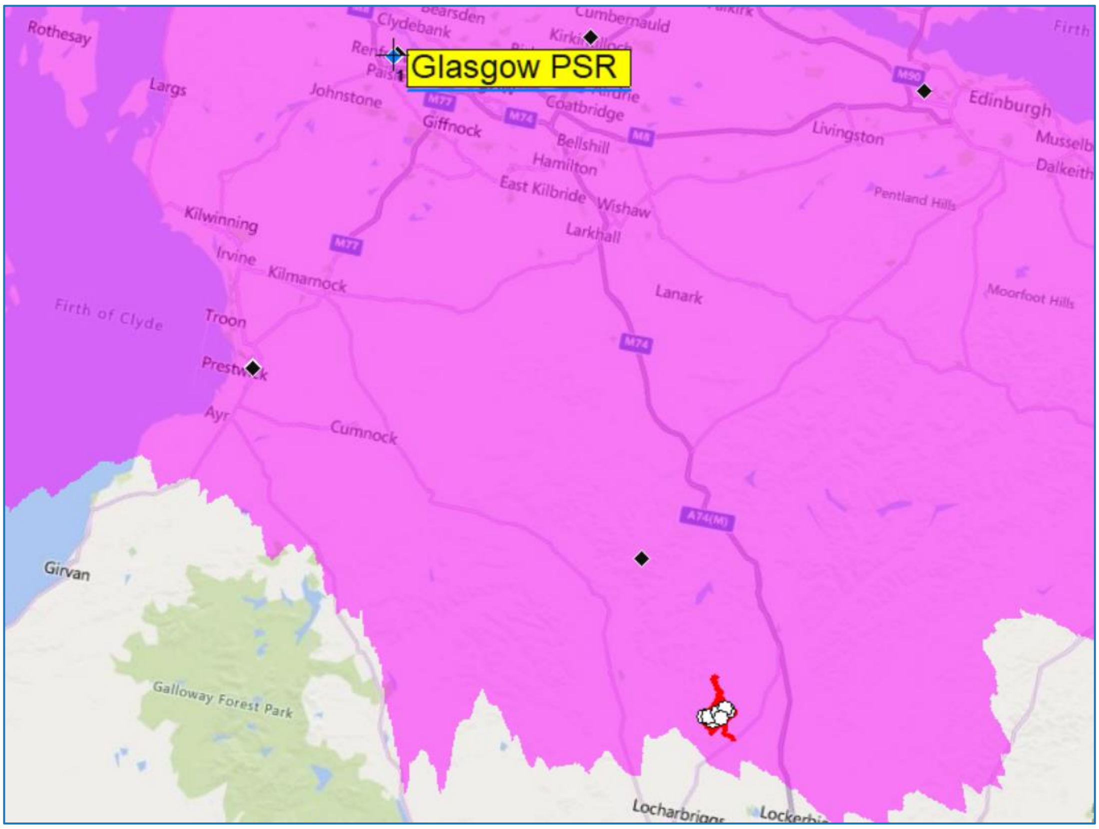


Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 34: Locations of Glasgow PSR and Glasgow Terma

7.7.2. The closest turbine within the Proposed Development area is approximately 91.3km south of the Glasgow radars.

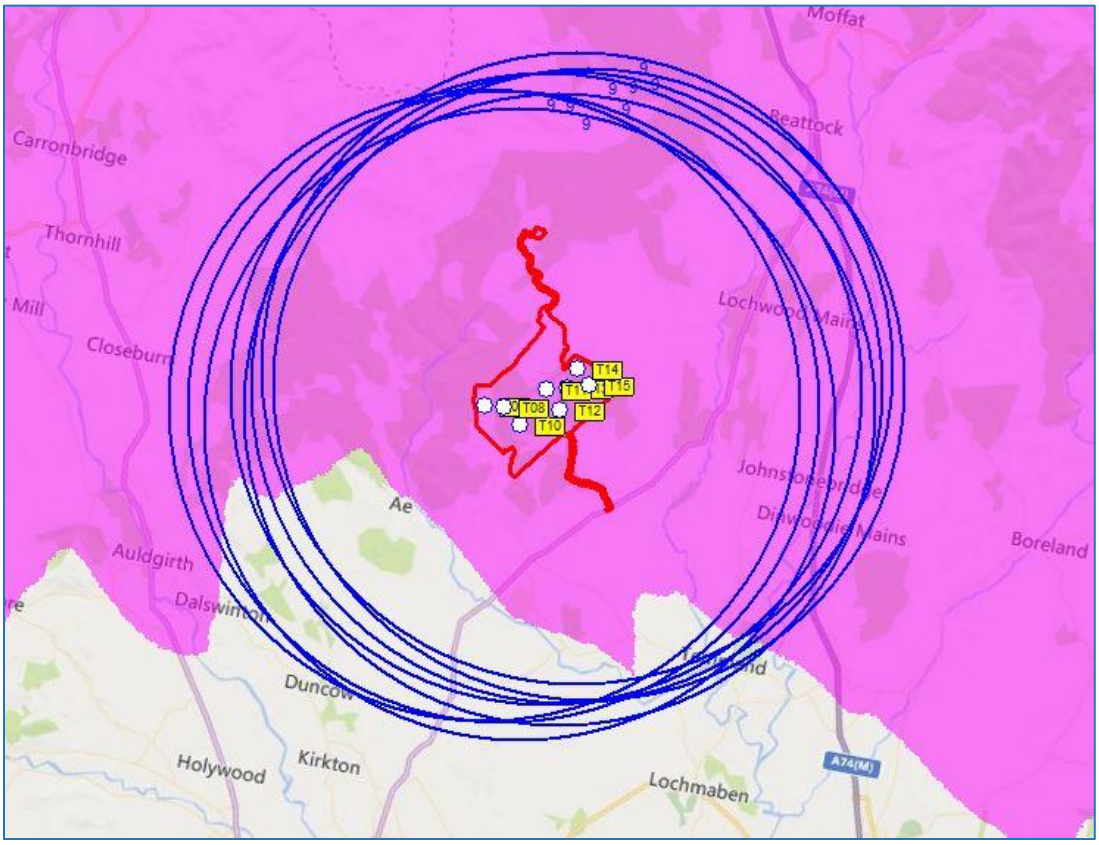
7.7.3. The magenta shading in Figure 35 illustrates the RLoS coverage for Glasgow PSR at an altitude of 5,500ft.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 35: Glasgow PSR RLoS at 5,500ft AMSL

7.7.4. The zoomed view of the Glasgow PSR 5,500ft coverage in Figure 36 includes range rings centred on each turbine to illustrate where the 5NM buffer may be required to extend to.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 36: Glasgow PSR RLoS at 5,500ft AMSL – zoomed

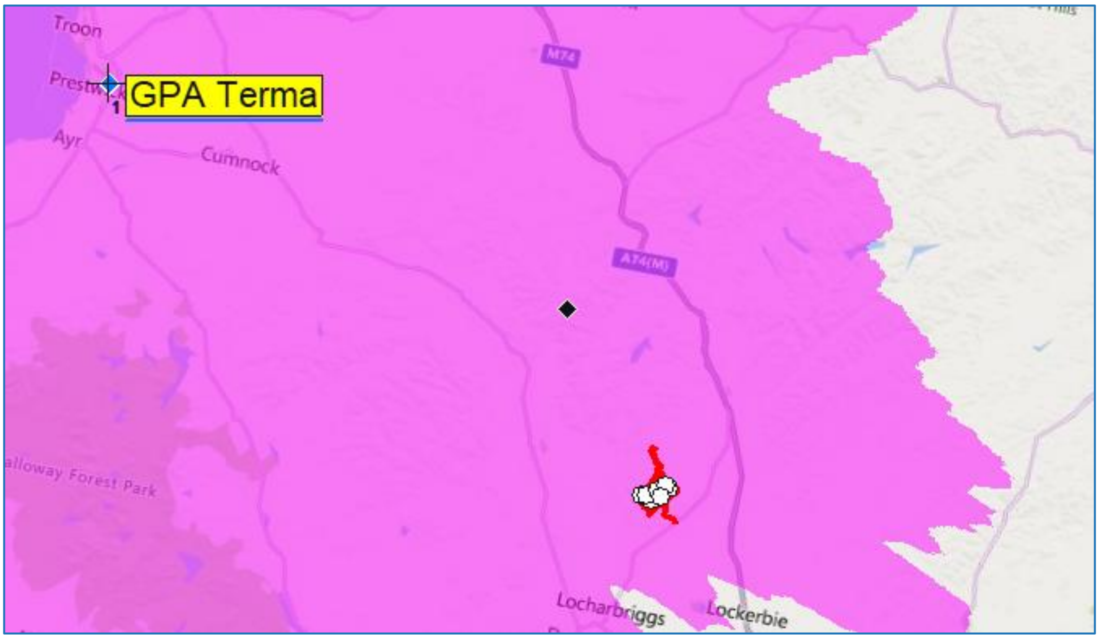
7.7.5. Glasgow PSR coverage at 5,500ft AMSL does not quite extend to 5NM south and west of the turbines. Notwithstanding the 5NM buffer requirement, Glasgow PSR can provide the required minimum 5,500ft AMSL infill coverage over the HSWE turbines.

7.7.6. Although the Glasgow Terma is sited in close proximity to the Glasgow PSR, it is an X-band radar, which means that its range of cover is unlikely to exceed 40NM (75km). The Glasgow Terma can thus be discounted as a possible infill radar for the HSWE turbines.

7.8. NERL Potential Infill Radar – GPA Terma

7.8.1. There is potential for the GPA Terma PSR to provide infill coverage to mitigate the impact of HSWE turbines on Lowther Hill PSR.

7.8.2. The magenta shading in Figure 37 illustrates the RLoS coverage for the GPA Terma PSR at an altitude of 5,500ft.

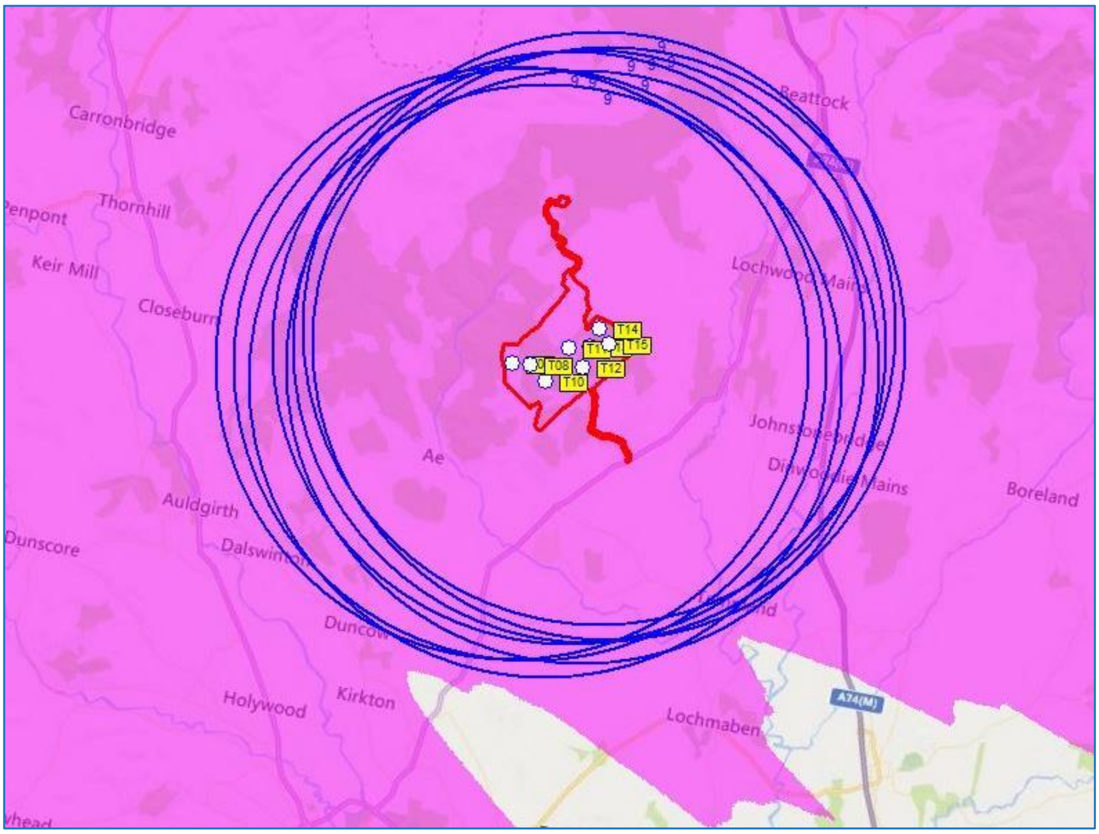


Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 37: GPA Terma RLoS at 5,500ft AMSL

7.8.3. It can be seen in Figure 37 that the GPA Terma PSR can potentially provide radar coverage down to an altitude of 5,500ft in the vicinity of the HSWE turbines.

7.8.4. The zoomed view of the GPA Terma 5,500ft coverage in Figure 38 includes range rings centred on each turbine to illustrate where the 5NM buffer may be required to extend to.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 38: GPA Terma RLoS at 5,500ft AMSL – zoomed

7.8.5. The GPA Terma PSR can potentially provide coverage at 5,500ft AMSL over the HSWE turbines that satisfies the 5NM buffer requirement, however the range of HSWE from the GPA Terma may be towards the limit of its coverage performance when considering all possible weather conditions.

7.9. NERL Potential Infill Radar – Summary

7.9.1. Cumbernauld PSR has the lowest base of radar coverage, 3,500ft AMSL, in the vicinity of the Proposed Development. Glasgow PSR and Kincardine PSR can both provide the required minimum coverage of 5,500ft AMSL over HSWE. These three PSRs are integrated into NERL's Multi-Radar Tracking (MRT) infrastructure.

7.9.2. The GPA Terma PSR can provide the required minimum radar coverage of 5,500ft AMSL, however the Proposed Development site is at the edge of the radar's range and the Terma has not been integrated into NERL's MRT infrastructure.

7.10. NERL Mitigation – Project RM

7.10.1. Lowther Hill PSR has undergone Project RM modification which may be used to mitigate the impact of turbines on radar. Turbines in RLoS of modified radars can be technically mitigated by Project RM provided that they are outside 9NM or 16.7km from the radar head, and that the vertical angle between the base of required cover and the turbine tips is 2° or more measured from the horizontal.

7.10.2. Calculations show that a 2° sterile zone above the tips of the HSWE turbines results in a minimum detection altitude above the turbines of approximately 4,300ft.

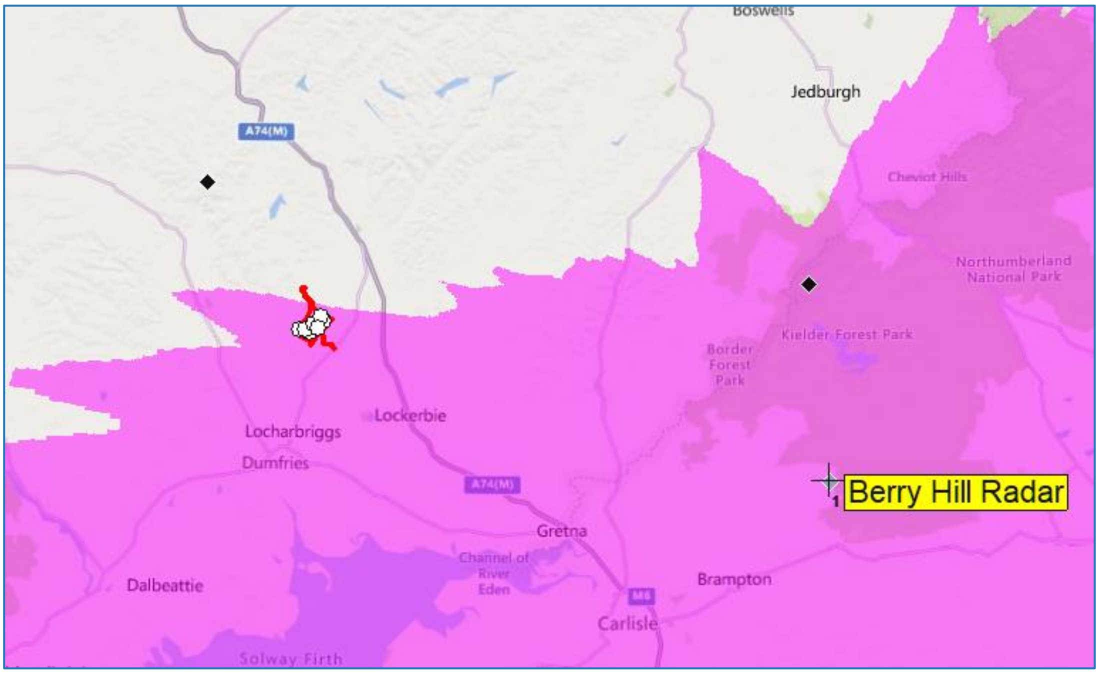
7.10.3. Project RM mitigation may not be an option as the existing Lowther Hill PSR is due to be replaced by a new radar model which is expected to be operational by the end of 2021.

7.11. MOD Mitigation

7.11.1. Should turbine clutter have a detrimental impact on the operational use of Deadwater Fell PSR then there are mitigation options available.

7.11.2. Following a Freedom of Information (FOI) request, details released by the MOD[5] on the installation of upgraded radars as part of Project Marshall show that the existing Deadwater Fell Thales STAR 2000 PSR is due to be upgraded to a Thales STAR NG PSR by October 2021. This advanced radar model utilises a windfarm filter which could be used to mitigate the impact of the HSWE turbines.

7.11.3. An alternative mitigation would be to use Berry Hill PSR as an infill radar. The magenta shading in Figure 39 illustrates the RLoS coverage for Berry Hill PSR at an altitude of 3,500ft.



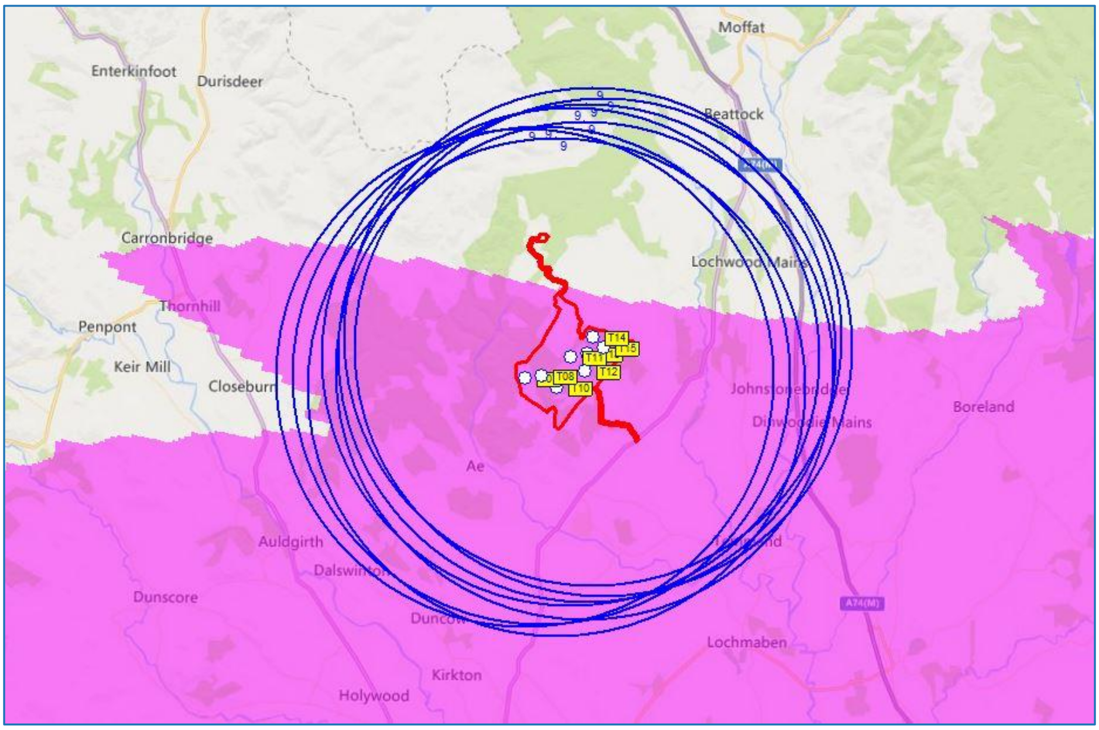
Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 39: Berry Hill PSR RLoS at 3,500ft AMSL

7.11.4. It can be seen in Figure 39 that Berry Hill PSR can provide radar coverage down to an altitude of 3,500ft in the vicinity of the HSWE turbines. The zoomed view in Figure 40 shows that, if

[5] FOI response reference FOI2019/06870, dated 28 June 2019

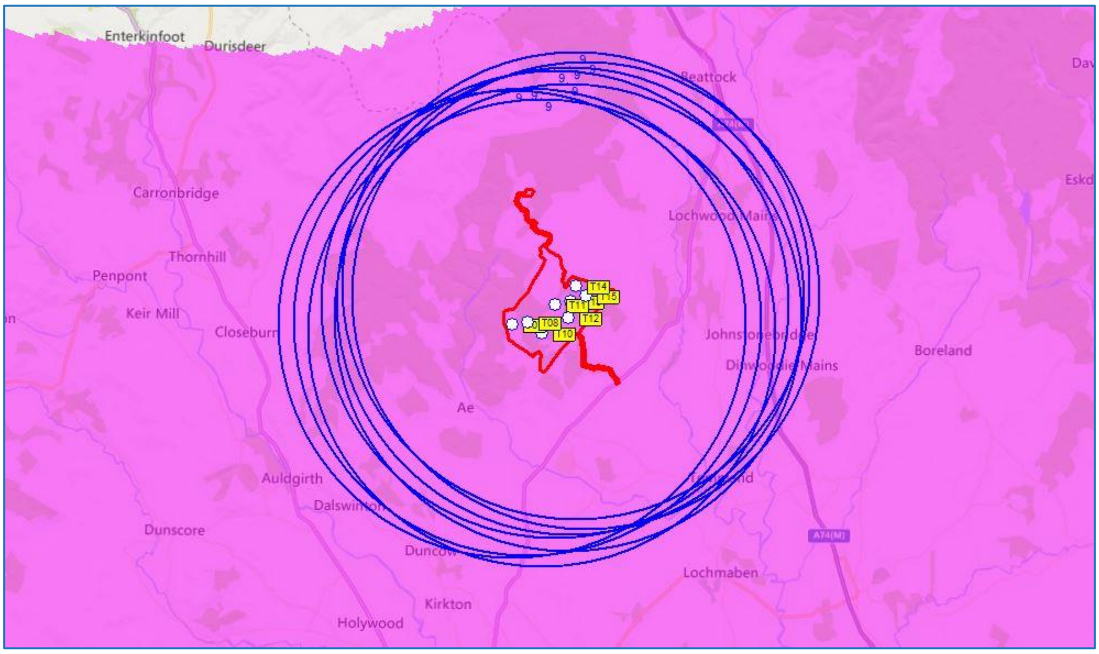
the NERL 5NM buffer requirement is applied, coverage at 3,500ft AMSL does not extend to 5NM north of the turbines.



Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 40: Berry Hill PSR RLoS at 3,500ft AMSL – zoomed

7.11.5. Figure 41 shows that the 5NM buffer is achieved for a base of cover of 5,000ft AMSL.



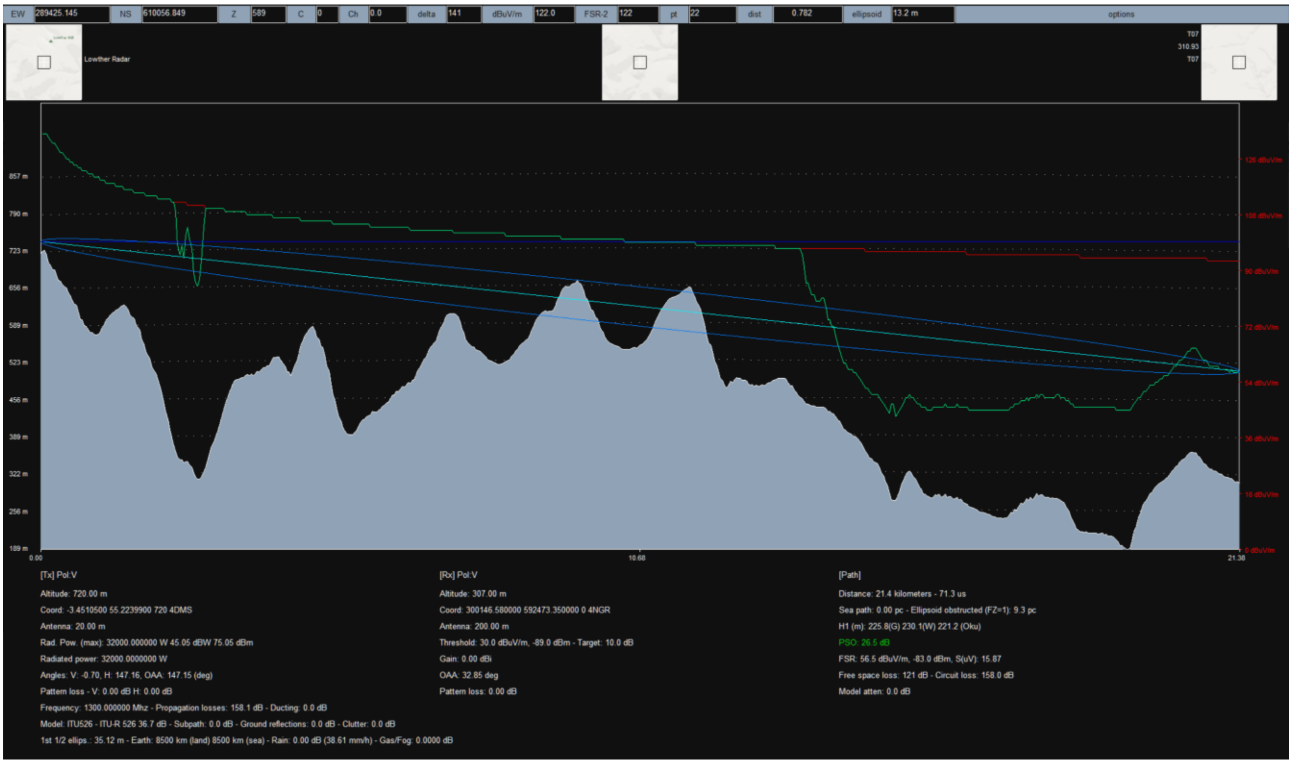
Microsoft® Bing™ screen shot reprinted with permission from Microsoft Corporation

Figure 41: Berry Hill PSR RLoS at 5,000ft AMSL – zoomed

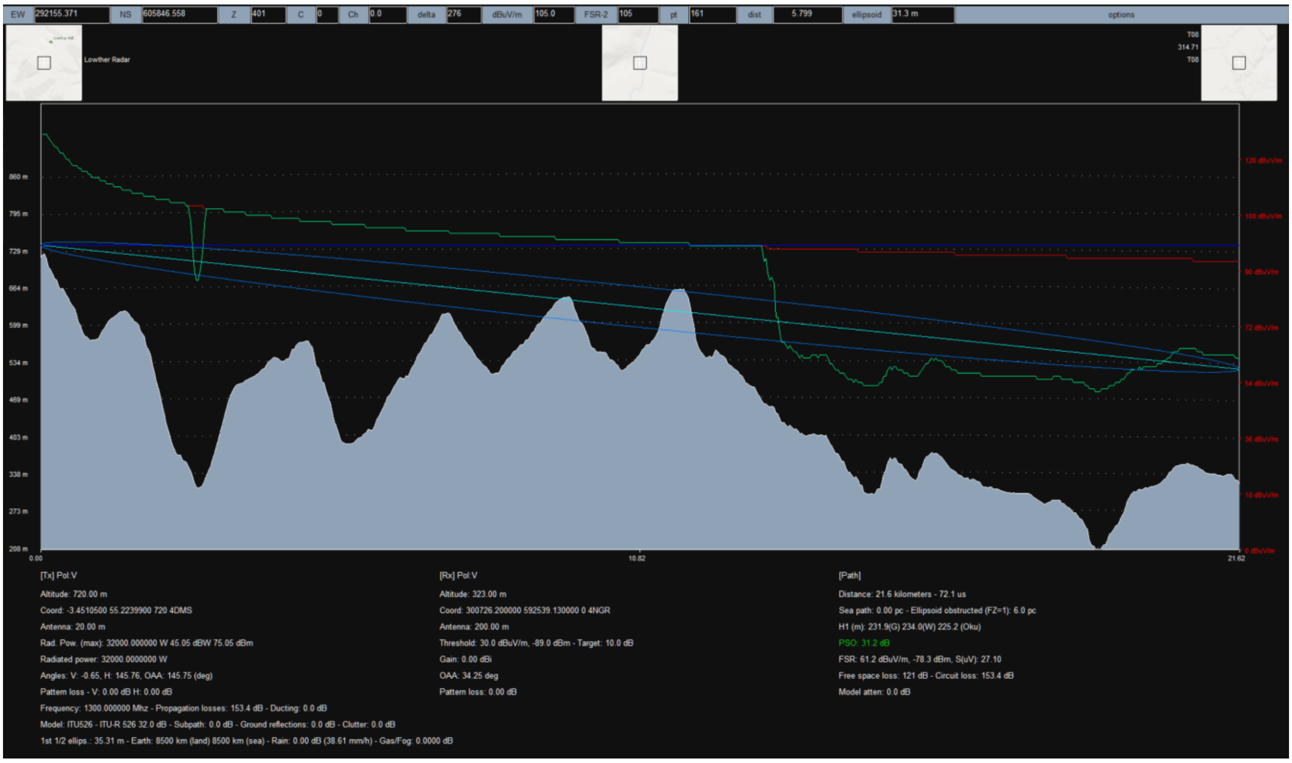
7.11.6. If the base of radar cover provided by Berry Hill PSR is acceptable, then 2D infill from Berry Hill PSR can be employed in a mosaic patch. This mitigation is understood to be being deployed for two other windfarms (Solway Bank and Hallburn).

A. Annex A – Lowther Hill PSR Path Profiles

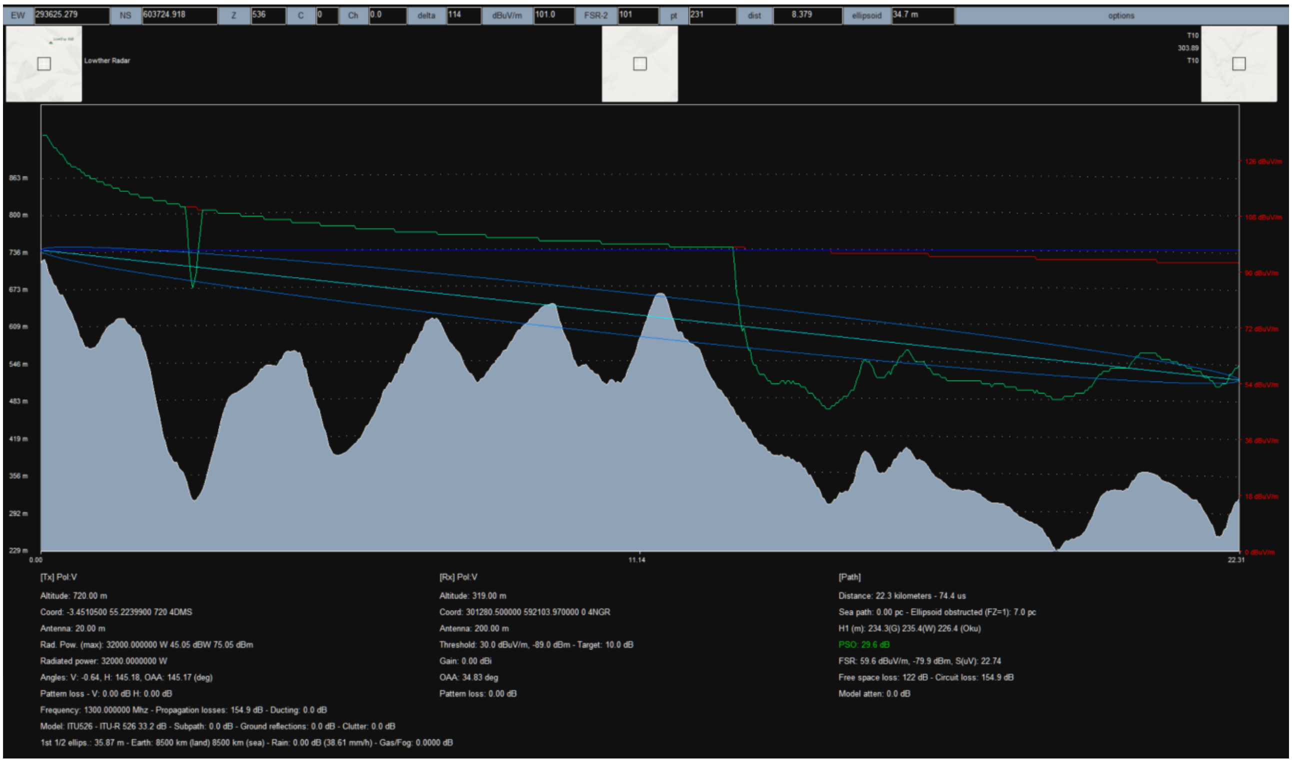
A.1. Turbine T07



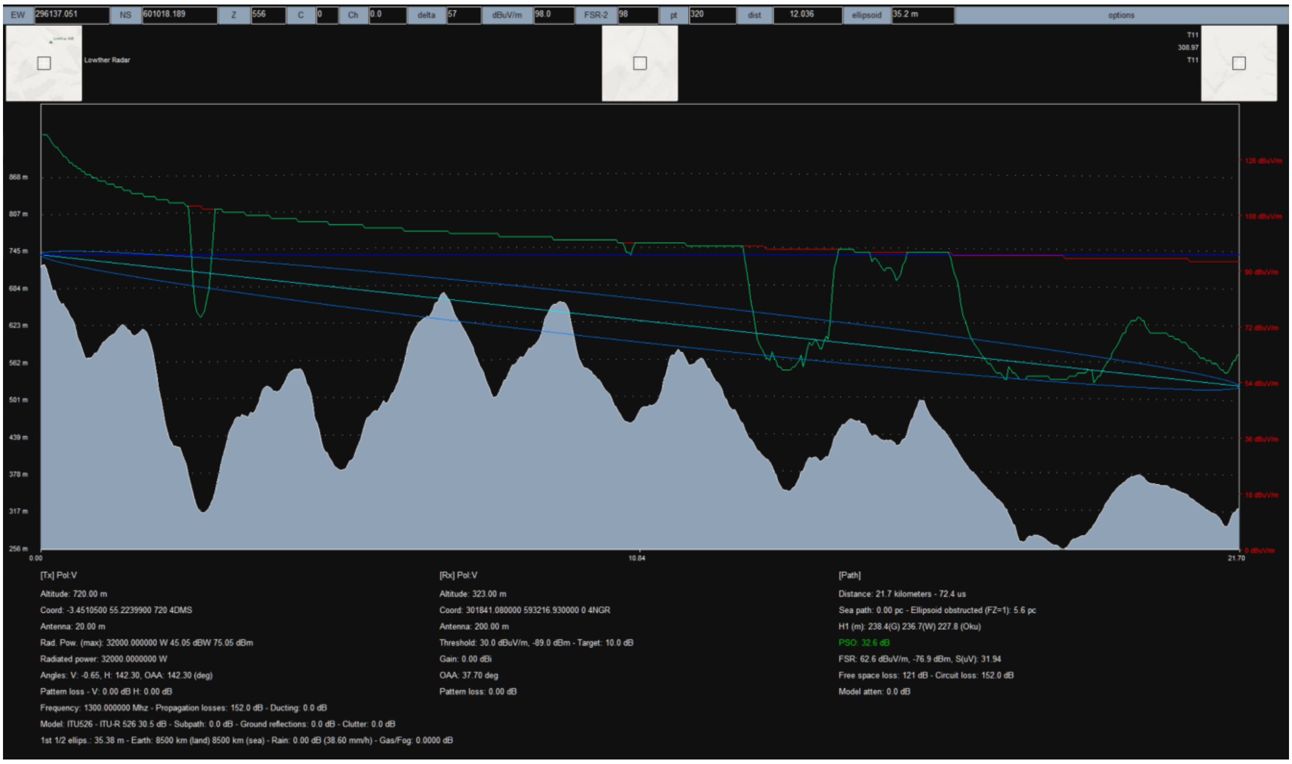
A.2. Turbine T08



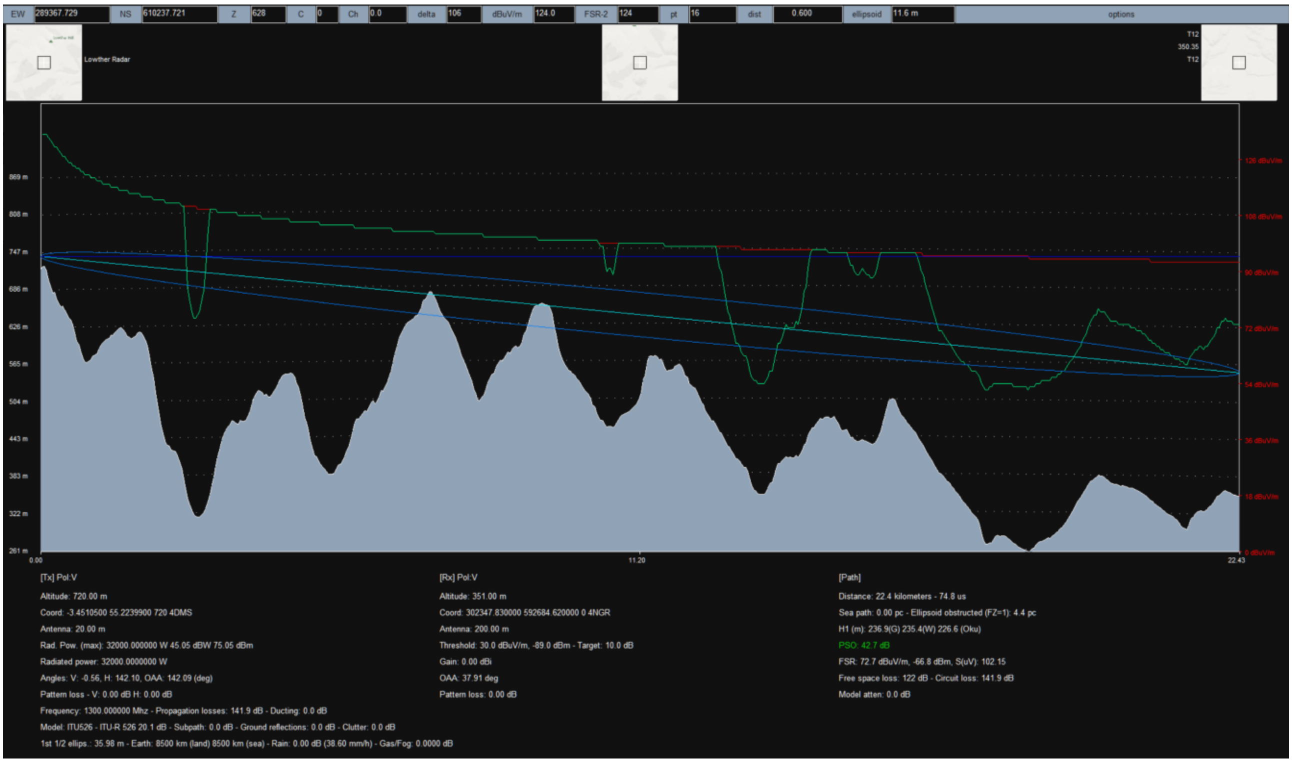
A.3. Turbine T10



A.4. Turbine T11

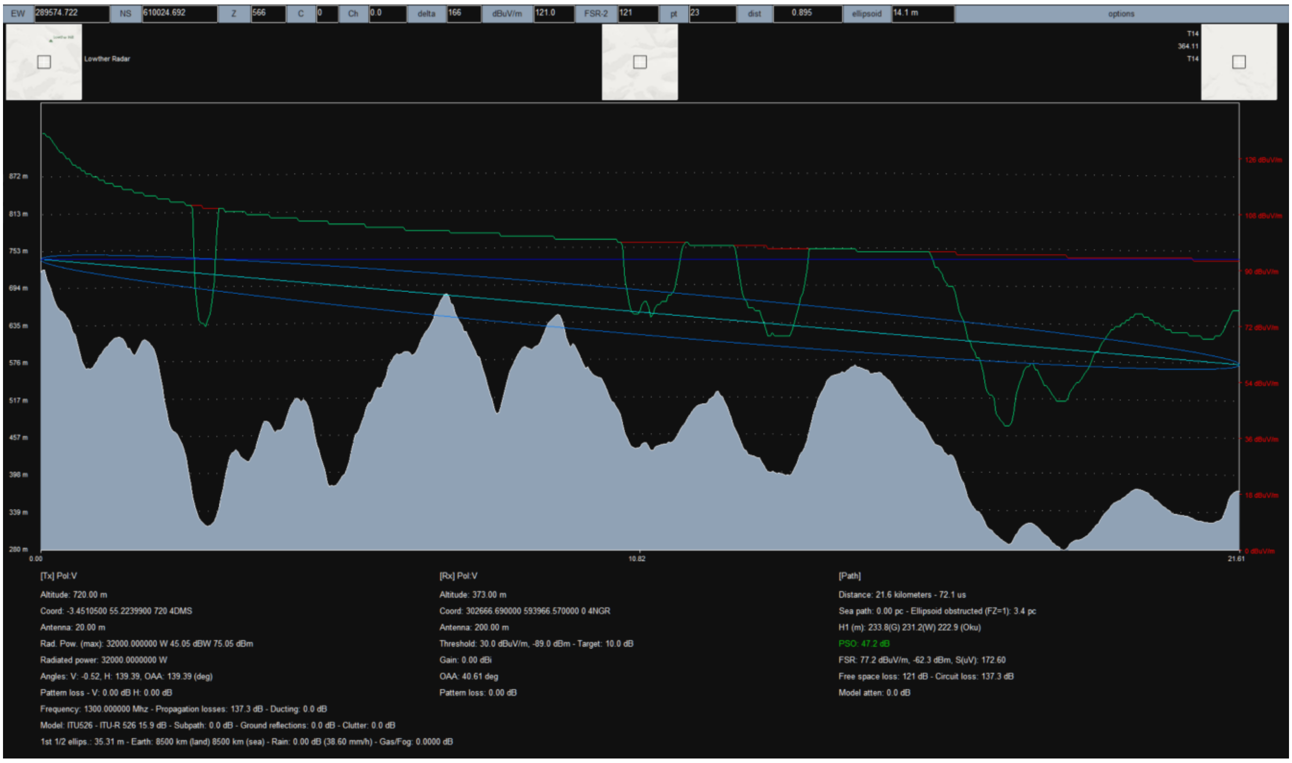


A.5. Turbine T12

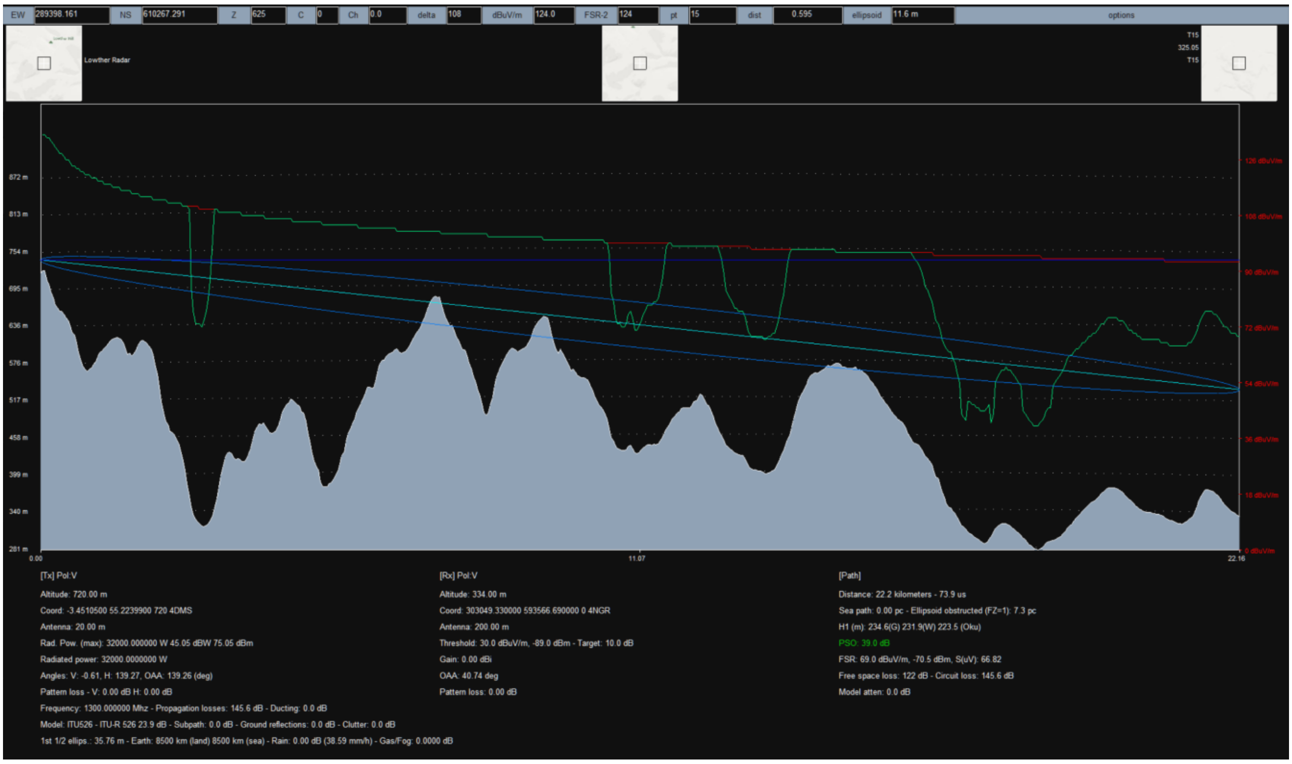


A.6. Turbine T13

A.7. Turbine T14



A.8. Turbine T15



This Page Is Intentionally Blank