# APPENDIX 15

## Pager Power Report

## Navigation Aids Impact Assessment

PAGERPOWER
Urban & Renewables

# Navigation Aids Impact Assessment

Malachy Walsh and Partners

Carrownagowan Wind Farm

November, 2019



## ADMINISTRATION PAGE

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|---|---|
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| Issue | Date | Detail of Changes |
|---|---|---|
| 1 | 8 February, 2019 | Initial issue |
| 2 | 22 November, 2019 | Updated layout |
| 3 | 2 December, 2019 | Meteorological mast added |



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# 1 KEY FINDINGS

## 1.1 Background

Malachy Walsh and Partners are carrying out an environmental impact assessment for a proposed wind farm at Carrownagowan which lies approximately 25 kilometres north east of Shannon Airport in the west of Ireland. Aircraft flying into Shannon will fly just north of the proposed development.

## 1.2 Shannon Airport

Shannon Airport has a range of radio transmitters which pilots use to navigate - one of these systems being an Instrument Landing System (ILS). The proposed wind farm will not affect aircraft using the ILS normally – however the Irish Aviation Authority (IAA) has raised concerns that the wind farm could affect periodic test flights that are used to calibrate and check the ILS.

The diagram below shows the relative locations of the turbines; the meteorological mast; the runway and its extended centre line. The marks on the extended centre line have a spacing of 1 nautical mile.

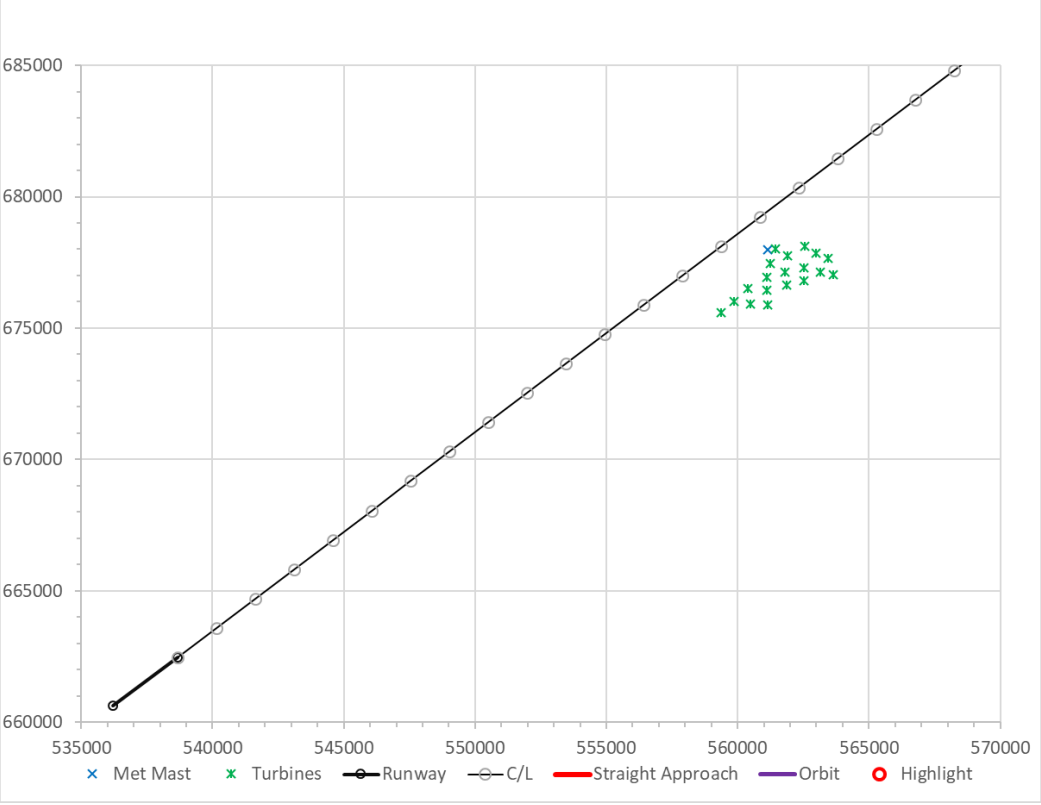


*Figure 1 Chart showing extended centre line and turbines*

## 1.3 Test Flights

These test flights fly a range of trajectories which either fly towards the airport or in an arc, or orbit, centred on the runway threshold[1]. The IAA has provided a schedule of ILS checks and their associated flight trajectories.

## 1.4 Assessment

The aircraft altitude (or height) has no impact on the horizontal separation between wind turbine and aircraft. Similarly the wind turbine altitude (or height) has no impact on horizontal separation.

In this analysis, only the horizontal clearance between aircraft and the turbines has been considered. This means that the results of this analysis apply for aircraft flying at any altitude profile on the specified horizontal trajectory. Similarly, the results apply for any turbine height.

A software tool has been used to calculate the minimum horizontal separation between each specific (horizontally defined) trajectory and the nearest wind turbine[2].

## 1.5 Trajectories beyond 2 Nautical Miles[3]

Most trajectories[4] will not be affected by the proposed wind farm and are more than 2 nautical miles away.

Aircraft flying Centre Line approaches commencing at 10 nautical miles or less will be at least 3.4 nautical miles from the proposed wind farm with turbine 1 being closest.

Aircraft flying approaches 8 degrees right of the runway extended centre line will be at least 2.9 nautical miles from the proposed wind farm with the Met Mast being closest.

Aircraft flying approaches 8 degrees left of the runway extended centre line, commencing at 10 nautical miles or less, will be at least 3.3 nautical miles from the proposed wind farm with turbine 1 being closest.

Aircraft flying orbits of 6 nautical miles will be at least 7.2 nautical miles from the proposed wind farm with turbine 1 being closest.

Aircraft flying orbits of 25 nautical miles will be at least 9.3 nautical miles from the proposed wind farm with turbine 14 being closest.

## 1.6 Trajectories within 2 Nautical Miles

Three trajectories, however, pass less than 2 nautical miles from the proposed wind farm.

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[1] In practice the arcs are centred on the Runway 24 threshold which is the zero reference point for the DME (Distance Measuring Equipment) associated with the Instrument Landing System

[2] Or the Met Mast if closer

[3] 2 nautical miles = 3.7 kilometres

[4] Plots showing these trajectories and the proposed wind turbines are available on request

## 1.7 Extended Runway Centre-Line

Aircraft flying the extended runway centre-line pass 0.623 nautical miles north of the proposed development with the Met Mast being closest. This is highlighted on the figure below:

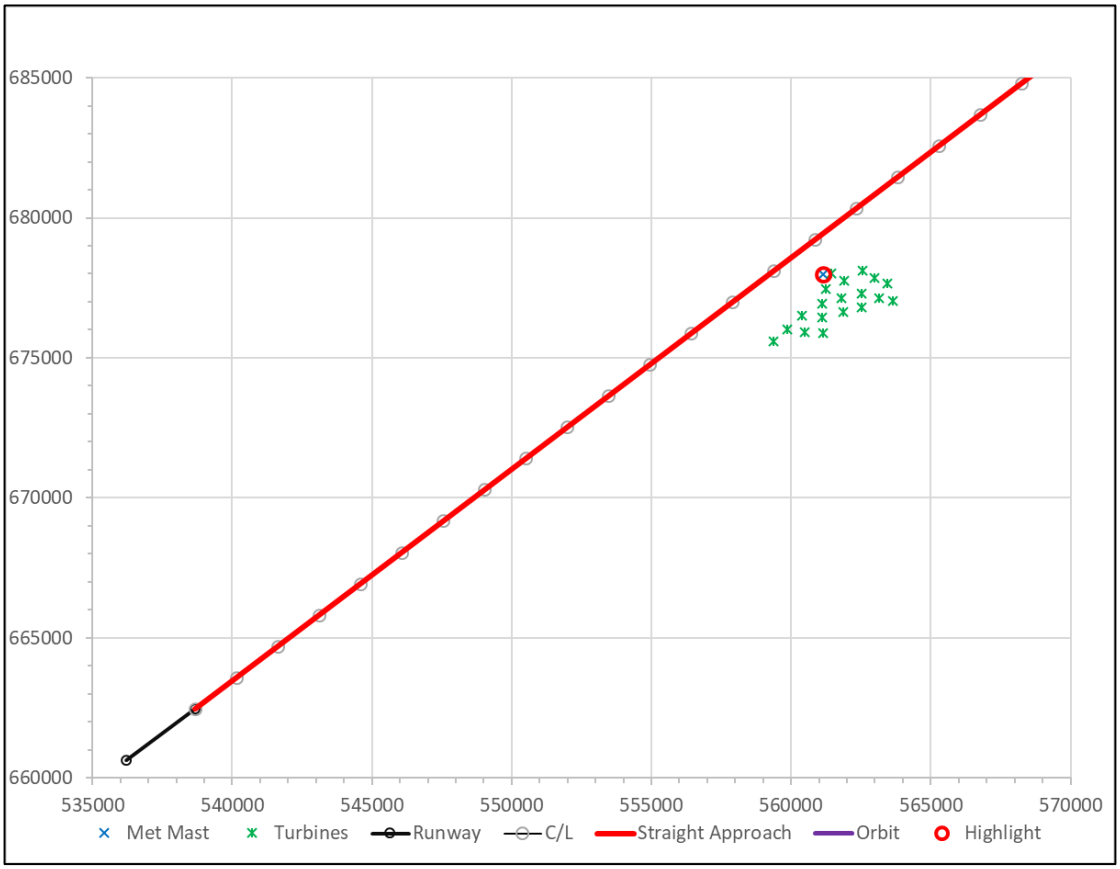


*Figure 2 Chart showing proximity of turbines to Extended Runway Centre-Line*

## 1.8 Seventeen Nautical Mile Orbit

Aircraft flying a seventeen nautical mile orbit pass 1.32 nautical miles east of the proposed wind farm with turbine 14 being closest. Turbine 14 is highlighted on the figure below:

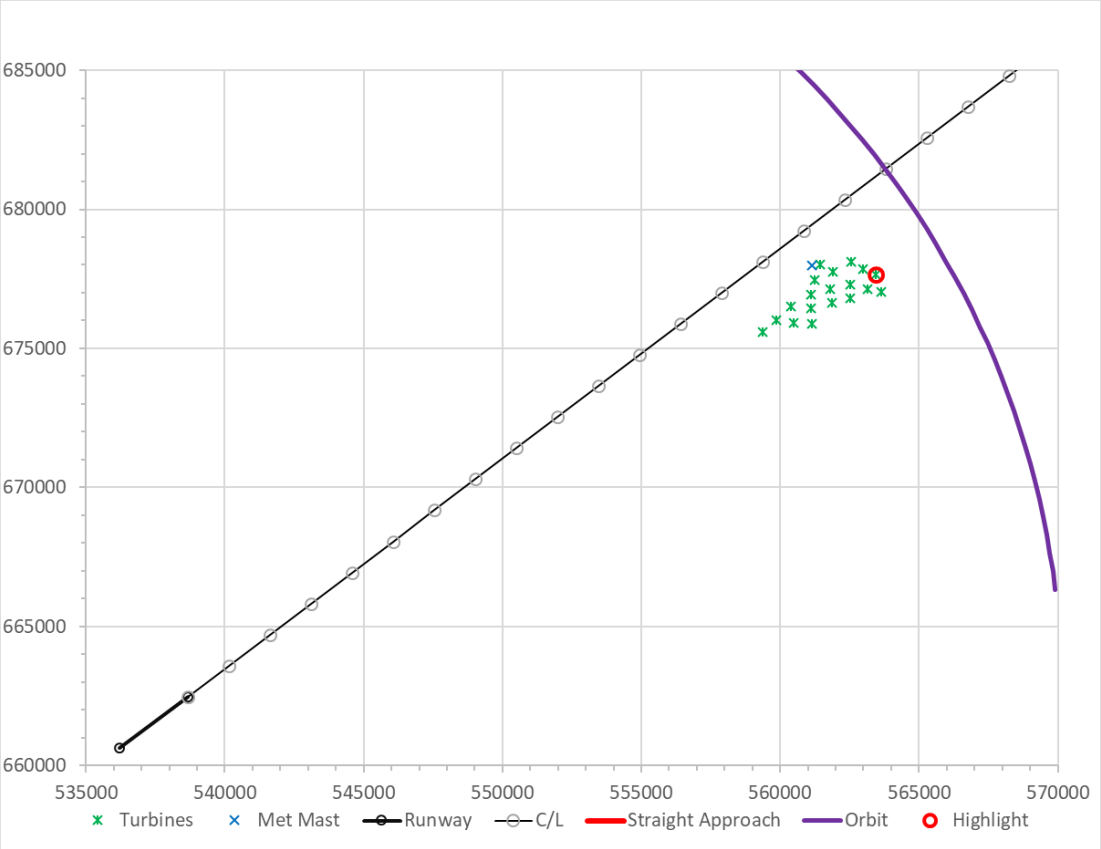


*Figure 3 Chart showing proximity of turbines to 17 nautical mile Orbit*

## 1.9 Eight Degree Left Slice Approach

Aircraft flying an eight degree left slice approach pass 0.563 miles south of the proposed wind farm with turbine 13 being closest. Turbine 13 is highlighted on the figure below:

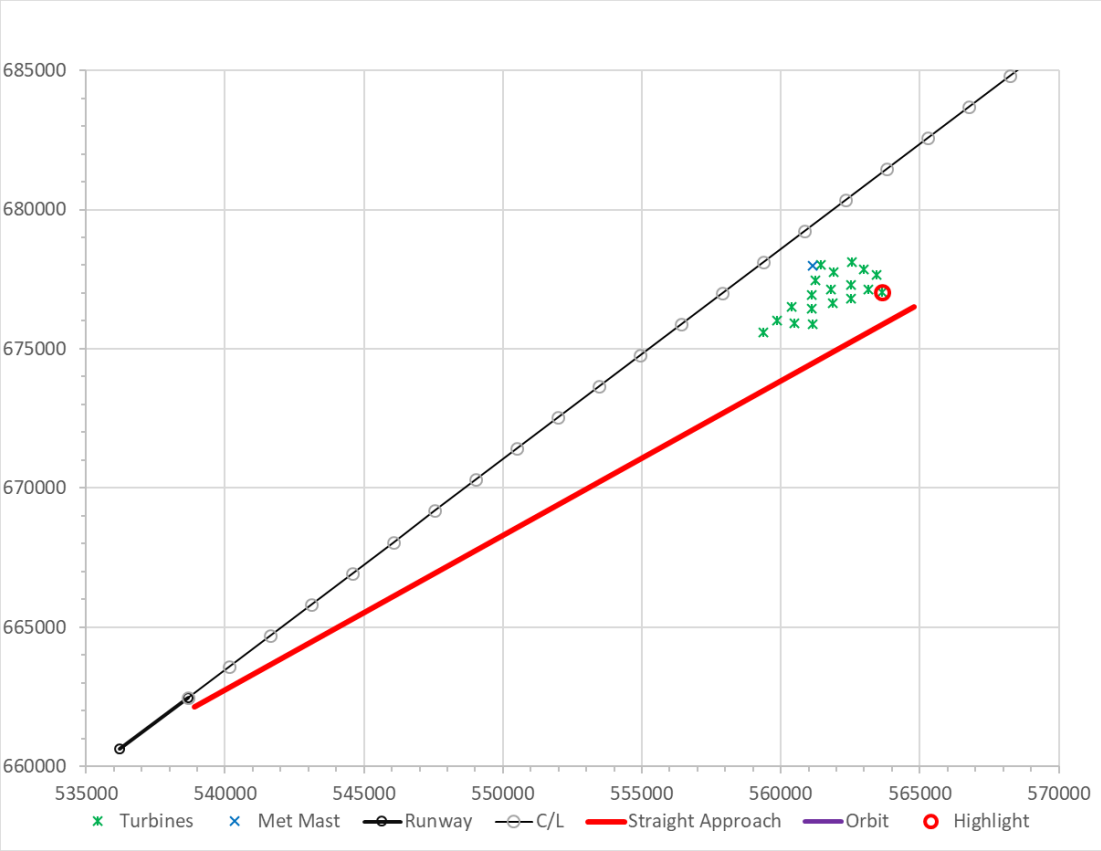


*Figure 4 Chart showing proximity of turbines to 8 degree left slice approach*

## 1.10 Visual Flight Rules

Test flights are conducted under Visual Flight Rules (VFR) whereby pilots rely on their eyesight, rather than instruments[5], to avoid collisions. When flying VFR pilots must ensure that they do not fly within 150 metres of any structure[6].

[5] When relying on instruments pilots fly in accordance with Instrument Flight Rules (IFR)
[6] Irish Aviation Authority (Rules of the Air) Order, 2004 – Rule 3

Wind turbines are complex structures with large moving rotors. The clearance distances in the analysis above relate to the wind turbine bases rather than the entire wind turbine structure. It is necessary to consider the rotor radius of 68 metres when evaluating the calculated clearances[7].

All trajectories are 0.563 nautical miles or more from the proposed wind turbine towers. One nautical mile is 1852 metres which means that all trajectories are 1,042[8] metres from the proposed towers. Taking the rotor into account reduces the clearance distance between trajectory and turbine to 974[9] metres.

## 1.11 Overall Impact

The horizontal clearance between aircraft flying the test trajectories and the turbines is more than six times the minimum horizontal clearance distance of 150 metres applicable for VFR flights in Ireland. The proposed turbines will therefore not affect aircraft flying ILS test trajectories and will therefore not have a significant impact on ILS test flights.

## 1.12 Mitigation

Whilst the proposed development will not impede aircraft flying the test trajectories it would nevertheless be prudent to ensure that pilots of test aircraft are fully aware of the presence of wind turbines, and any associated anemometry masts, before undertaking any test flights. The following mitigation measures are therefore recommended:

- All turbines and meteorological masts having a height of 100m or more are promulgated in the Irish Air Navigation Obstacle database;
- The extremities of the wind farm are lit;
- Meteorological masts are lit;
- Meteorological masts are painted red and white to aid visibility to pilots;
- Locations of meteorological masts having a height of less than 100m are promulgated to the pilots of test aircraft[10];
- Test aircraft are fitted with Terrain Awareness and Warning System (TAWS);
- Test aircraft TAWS obstacle databases are regularly updated to ensure they contain the wind turbine and met mast locations prior to construction.

## 1.13 Conclusions and Recommendations

It is recommended that this report is shared with the Irish Aviation Authority.

[7] Not necessary for the Met Mast - however
[8] 0.563 x 1852 = 1,042
[9] 1,042 - 68 = 974
[10] This could be via the Aeronautical Information Publication or directly to pilots

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## ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company specializes in assessing the impact of wind turbines on aviation and radar - having undertaken projects in 46 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

# 2 INTRODUCTION

The developer provided a layout of 19 wind turbines and a permanent meteorological mast for this assessment. Each turbine will have a maximum height of 168 metres above ground level with tip altitudes rising to approximately 1,700 feet above mean sea level. The proposal lies north east of Shannon and its centre is 28.8 kilometres (15.6 nautical miles) from Shannon Airport.

Wind turbines can impact aviation. This report identifies potential impacts on flights checking the airport's Instrument Landing System (ILS).

The Scope of this report reflects the IAA Engineering requirement to confirm that aircraft flying the test trajectories shown in the Appendix to this report will not be impeded by the proposed wind turbines.

## 2.1 Units of Measurement and Coordinate Systems

Units of measurement and coordinate systems normally used by the aviation and wind farm development industries differ. These differences are set out in the table below:

| Parameter | Aviation | Onshore wind – Ireland | Conversion |
|---|---|---|---|
| Distance | Nautical Mile (nm) | Kilometre (km) | 1nm = 1.852km |
| Height | Feet (ft) | Metres (m) | 1ft = 0.3048m |
| Location | WGS84 Lat/Long | ITM Eastings and Northings | Specialist tool required |

*Table 1 Units of measurement and coordinate systems*

# 3 WIND FARM INFORMATION

The proposed wind farm location is shown on the map below:

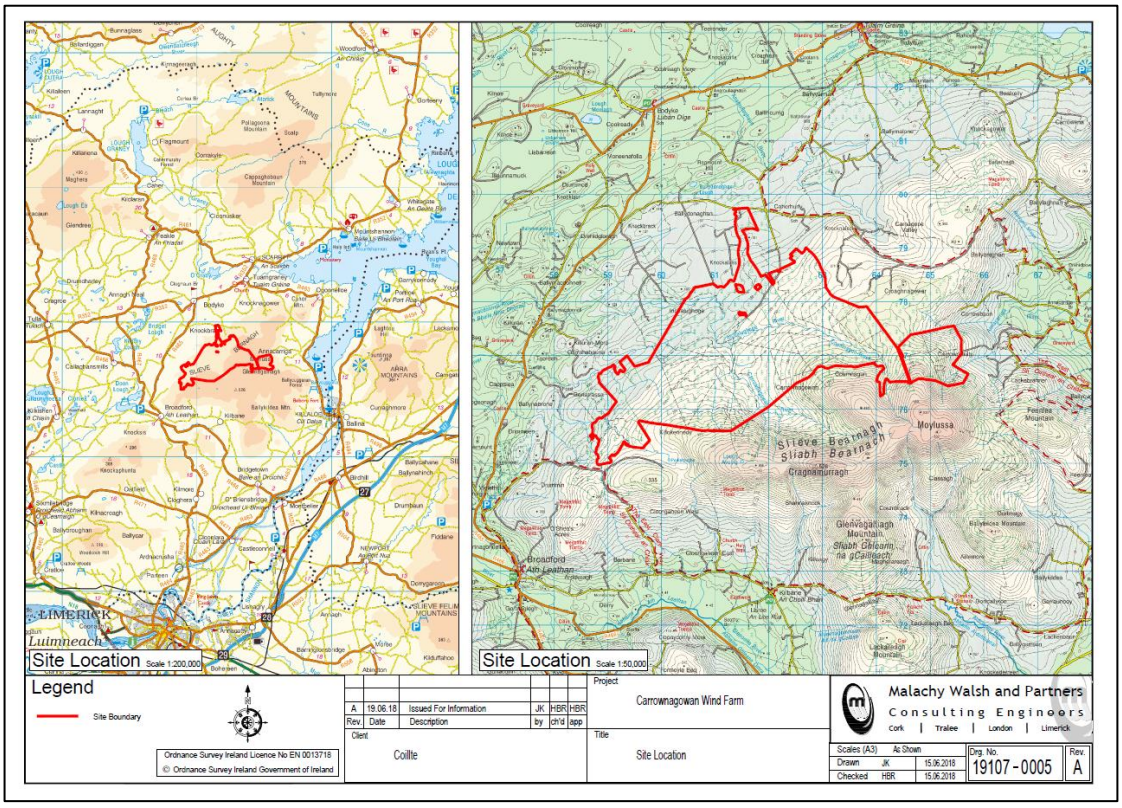


*Figure 5 Maps showing proposed wind farm area*

A 19 turbine wind farm layout has been assessed. This is shown on the chart on the following page.

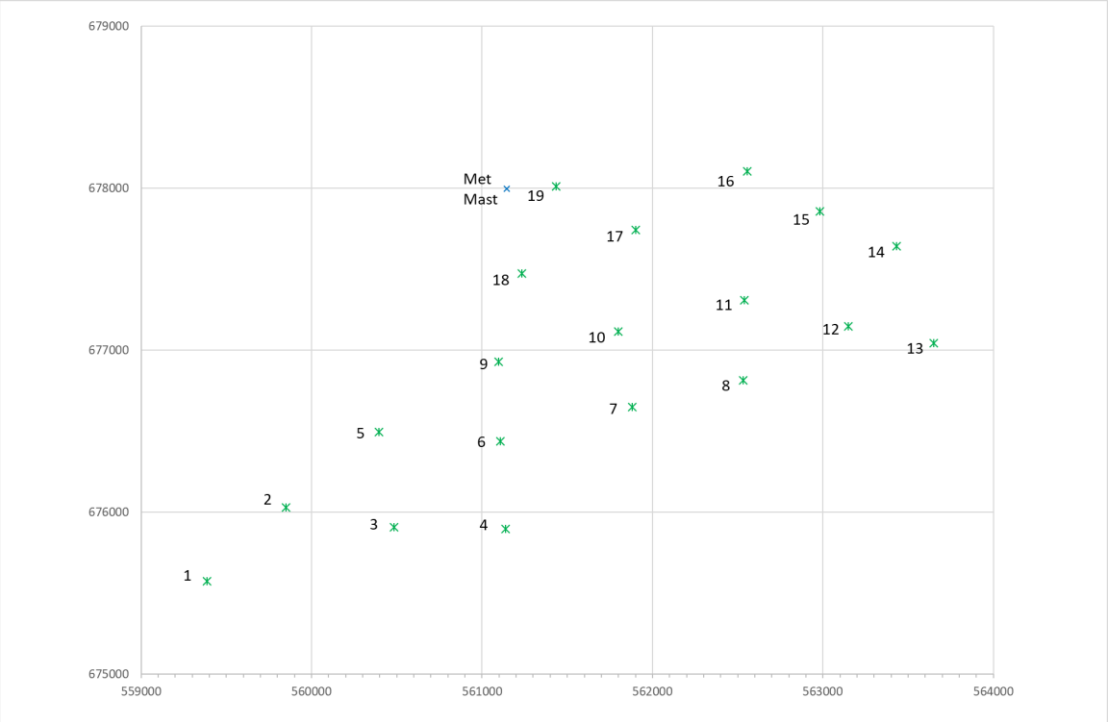


*Figure 6 Chart showing individual turbine locations and numbers*

The wind turbine coordinates are shown in the table below:

| Turbine | ITM Easting | ITM Northing |
|---|---|---|
| 1 | 559385 | 675575 |
| 2 | 559850 | 676030 |
| 3 | 560484 | 675908 |
| 4 | 561137 | 675897 |
| 5 | 560394 | 676494 |
| 6 | 561109 | 676437 |
| 7 | 561881 | 676649 |
| 8 | 562533 | 676815 |
| 9 | 561098 | 676928 |

| Turbine | ITM Easting | ITM Northing |
|---|---|---|
| 10 | 561800 | 677115 |
| 11 | 562539 | 677308 |
| 12 | 563149 | 677146 |
| 13 | 563650 | 677042 |
| 14 | 563431 | 677641 |
| 15 | 562982 | 677858 |
| 16 | 562556 | 678103 |
| 17 | 561903 | 677741 |
| 18 | 561234 | 677472 |
| 19 | 561435 | 678011 |

*Table 2 Wind Turbine Coordinates*

The permanent meteorological mast has coordinates 561144E 677998N and has a height of 100 metres above ground level.

# 4 SHANNON AIRPORT

## 4.1 Airport Information

Shannon Airport is an Irish Aviation Authority (IAA) licensed aerodrome used predominately by private and commercial jet and fixed wing propeller aircraft. An ATC Tower is present on the airport.

## 4.2 Runway Details

Shannon Airport has one runway 06/24 measuring 3,199m by 45m. The runway is shown on the aerodrome chart in Figure 2[11] on the following page.

[11] Source: Irish Aviation Authority IAP.

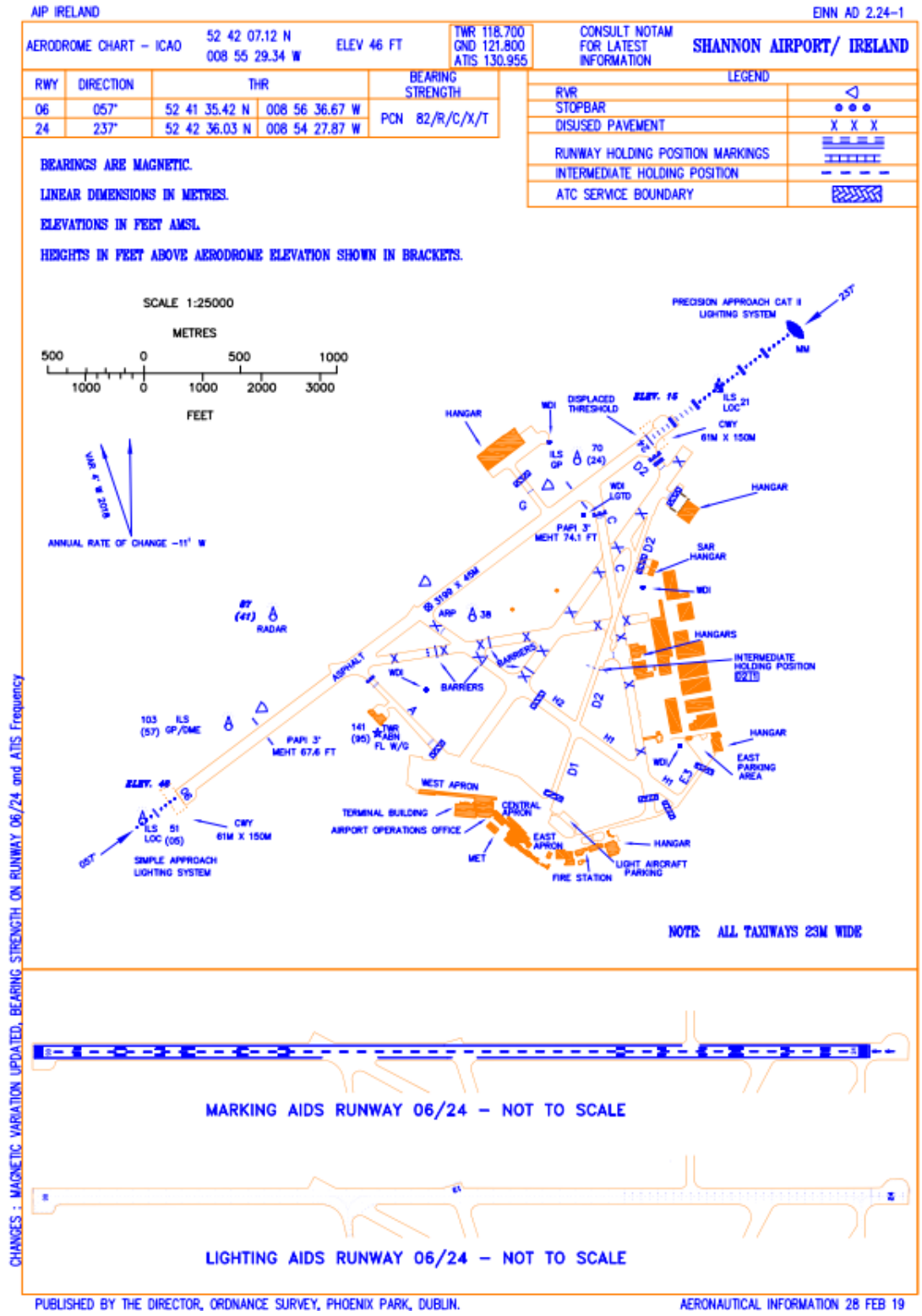


Figure 7 *Shannon Airport aerodrome chart*

## 4.3 Instrument Landing System

Specific parameters pertaining to the Runway 24 Instrument Landing System are shown in the Irish Aviation Authority Aeronautical Information Publication (AIP).

| Parameter | Units | Value |
|---|---|---|
| Designated Operational Coverage | Nautical Miles | 25 |
| ILS Category | n/a | Cat II |
| Slope | Degrees | 3 |
| Threshold Elevation | Feet | 15 |
| Distance to ILS Point A | Nautical Miles | 4 |
| Distance to ILS Point B | Nautical Miles | 0.57 |
| Distance to ILS Point E | Nautical Miles | -1.35[12] |

*Table 3 Instrument Landing System Parameters*

[12] This figure is negative because it refers to a point above the runway lying south west of the Runway 24 threshold

# 5 IAA FLIGHT CHECK SCHEDULE

ILS flight check profiles

**4.2 Routine ILS Inspection Profile Requirements**

Note: Where only 1 transmitter is checked on a routine, subsequently the other transmitter will be checked on the next routine.

| Section | Profile | Description | Procedure | Notes | TX |
|---|---|---|---|---|---|
| 9.1.1 | 01 | Centreline Approach | 10NM-Threshold 3000' | Course Structure, Alignment, GP Angle & RF measurement | 1or2 |
| 9.1.3 | 04 | Loc Orbit | 6NM 1500' +35-35° | Clearance | 1or2 |
| 9.1.1 | 05 | Centreline Approach Cat III only | 2NM to Point E level 50ft down runway Centreline | Loc Course Structure, Alignment | 1or2 |
| 9.1.1 | 12 | Top Edge | 1 NM required between 4NM-Point B 1800' | (75μA) 90Hz width | 1or2 |
| 9.1.1 | 13 | Bottom Edge | 1 NM Required between 4NM-Point B 1500' | (75μA) 150Hz width | 1or2 |
| 9.1.2 | 14 | Slice for 3° GP | 0.3θ ≈12NM-Threshold 1000' | Clearance | 1or2 |
| 9.1.2 | 15 | Left Slice for 3° GP | 10NM-0.45θ 1000' | Coverage 8° of Centreline Both transmitters if M Array | Alt 1or2 |
| 9.1.2 | 16 | Right Slice for 3° GP | 10NM-0.45θ 1000' | Coverage 8° of Centreline Both transmitters if M Array | Alt 1or2 |
| | All | Ident Loc/DME | Co-Pilot listens/Fl | Check ident and synchronization | 1or2 |
| 9.1.1 | 01 | DME | 4NM-1NM 1500' | DME Range Error | 1or2 |

**4.3 Annual ILS Inspection Profile Requirements**

| Section | Profile | Description | Procedure | Notes | TX |
|---|---|---|---|---|---|
| 9.1.1 | 01 | Centreline Approach | 10NM-Threshold 3000' | RF, Course Structure, Alignment Angle GP & Loc | 1&2 |
| 9.1.1 | 01 | Centreline Approach | DOC or 10NM-Threshold on GP | Course Structure, Alignment Angle GP & Loc | 1or2 |
| 9.1.1 | 01 | Centreline Approach | 10-4NM on GP & Loc | Power Ratio check (Two Freq Only) Course Line TX OFF | 1or2 |

| | | | C/L | | |
|---|---|---|---|---|---|
| 9.1.3 | 04 | Loc Orbit | 6NM 1500' +35-35° | Clearance | 1&2 |
| 9.1.3 | 04 | Loc Orbit | 17NM 1500' +35-35° | Clearance & Coverage | 1or2 |
| 9.1.3 | 04 | Loc Orbit | 25NM 2000' +10-10° | Clearance & Coverage | 1or2 |
| 9.1.2 | 14 | Loc Range Run | DOC or 25NM 2000' | Clearance | Alt 1or2 |
| 9.1.2 | 14 | Slice for 3° GP | 0.3θ DOC or 12NM-Threshold 1000' | Course Only (Two Freq Only) | 1or2 |
| 9.1.1 | 05 | Centreline Approach Cat III only | 10NM to Point E level 50ft down runway Centreline | Course Structure, Alignment, GP Angle & RF measurement | 1&2 |
| 9.1.1 | 12 | Top Edge | 4NM-Point B 1800' | (75μA) 90Hz width | 1or2 |
| 9.1.1 | 13 | Bottom Edge | 4NM-Point B 1500' | (75μA) 150Hz width. See Note | 1or2 |
| 9.1.2 | 14 | Slice for 3° GP | 0.3θ DOC or 12NM-Threshold 1000' | Course, Clearance & Coverage | 1&2 |
| 9.1.2 | 14 | Slice for 3° GP | 0.3θ DOC or 12NM-Threshold 1000' | Course Only (Two Freq Only) | 1or2 |
| 9.1.2 | 15 | Left Slice for 3° GP | 10NM-0.45θ 1000' | Coverage 8° of Centreline | Alt 1or2 |
| 9.1.2 | 16 | Right Slice for 3° GP | 10NM-0.45θ 1000' | Coverage 8° of Centreline | Alt 1or2 |
| 9.1.1 | 11 | Centreline Approach | 4NM-Threshold 1500' | Low & Wide, then Low & High Angle Alarm | 1or2 |
| 9.1.1 | 12 | Top Edge | 4NM-Point B 1800' | Low & Wide then Wide & Narrow Alarm | 1or2 |
| 9.1.1 | 13 | Bottom Edge | 4NM-Point B 1500' | Low & Wide, then Wide & Narrow Alarm | 1or2 |
| 9.1.2 | 14 | Slice | DOC or 10-2NM @ 1000' | Low & Wide Alarm for Clearance | 1or2 |
| 9.1.2 | 14 | Slice | DOC or 10NM-THD @ 1000' | Normal | 1or2 |

| | | | | | |
|---|---|---|---|---|---|
| 9.1.1 | 01 * | Centreline Approach | 4NM-Threshold 1500' | Fly Left & Right Alarms | 1or2 |
| 9.1.3 | 04 * | Loc Orbit | 6NM 1500' +35-35° | Wide Alarm | 1or2 |
| 9.1.3 | 04 * | Loc Orbit | 6NM 1500' +35-35° | Narrow Alarm | 1or2 |
| 9.1.3 | 04 * | Loc Orbit | 6NM 1500' +35-35° | Normal Check | 1or2 |
| | All | Ident LOC/DME | Co-Pilot/FI listens | Check ident and synchronisation | 1&2 |
| 9.1.1 | 01 | DME | 4NM-1NM 1500' | DME Range Error | 1or2 |
| 9.1.4 | | Promulgated procedure | Procedure-Threshold | Pilot comments | 1 or2 |
| 9.1.5 | | Promulgated procedure & DME IFPs | Procedure-Threshold | Pilot comments | 1or2 |

**4.4 Commissioning ILS Inspection Profile Requirements**

| Section | Profile | Description | Procedure | Notes | TX |
|---|---|---|---|---|---|
| 9.1.1 | 01 | Centreline Approach | DOC or 10NM-Threshold on GP | RF, Course Structure, Alignment Angle GP & Loc | 1&2 |
| 9.1.1 | 01 | Centreline Approach | 2000' 25NM-Threshold | Course Structure, Alignment Angle GP & Loc | 1or2 |
| 9.1.1 | 01 | Centreline Approach | 10-4NM on GP & Loc C/L | Power Ratio check (Two Freq Only) Course Line TX OFF | 1or2 |
| 9.1.1 | 01* | Centreline Approach | 4NM-Theshold on GP & Loc C/L | Polarisation Check Roll 20° Left & Right | 1or2 |
| 9.1.1 | 02 | Left Edge | 4NM-Point B 1500' | (150µA) 90Hz course width | 1&2 |
| 9.1.1 | 03 | Right Edge | 4NM-Point B 1500' | (150µA) 150Hz course width | 1&2 |
| 9.1.3 | 04 | Loc Orbit | 6NM 1500' +35-35° | Clearance & Coverage | 1&2 |
| 9.1.3 | 04 | Loc Orbit | 17NM 1500' | Clearance & Coverage | 1or2 |

| | | | | | |
|---|---|---|---|---|---|
| | | | +35-35° | | |
| 9.1.3 | 04 | Loc Orbit | 25NM 2000' +10-10° | Clearance & Coverage | 1or2 |
| 9.1.2 | 14 | Loc Range Run | DOC or 25NM 2000' | Clearance | Alt 1or2 |
| 9.1.1 | 05 | Centreline Approach Cat III only | 2NM to Point E level 50ft down runway Centreline | Loc Course Structure, Alignment | 1&2 |
| 9.1.1 | 12 | Top Edge | 4NM-Point B 1800' | (75µA) 90Hz width | 1&2 |
| 9.1.1 | 13 | Bottom Edge | 4NM-Point B 1500' | (75µA) 150Hz width | 1&2 |
| 9.1.2 | 14 | Slice for 3° GP | 0.3θ DOC or 12NM-Threshold 1000' | Course, Clearance & Coverage | 1&2 |
| 9.1.2 | 14 | Slice for 3° GP | 0.3θ DOC or 12NM-Threshold 1000' | Course Only (Two Freq Only) | 1or2 |
| 9.1.2 | 15 | Left Slice for 3° GP | 16NM-0.45θ 1000' | Coverage 8° of Centreline | 1&2 |
| 9.1.2 | 16 | Right Slice for 3° GP | 16NM-0.45θ 1000' | Coverage 8° of Centreline | 1&2 |
| 9.1.1 | 11 | Centreline Approach | 4NM-Threshold 1500' | Low & Wide, then Low & High Angle Alarm | 1or2 |
| 9.1.1 | 12 | Top Edge | 4NM-Point B 1800' | Low & Wide then Wide & Narrow Alarm | 1or2 |
| 9.1.1 | 13 | Bottom Edge | 4NM-Point B 1500' | Low & Wide, then Wide & Narrow Alarm | 1or2 |
| 9.1.2 | 14 | Slice | DOC or 10-2NM @ 1000' | Low & Wide Alarm for Clearance | 1or2 |
| 9.1.2 | 14 | Slice | DOC or 10NM-THD @ 1000' | Normal | 1or2 |
| 9.1.1 | 01 * | Centreline Approach | 4NM-Threshold 1500' | Fly Left & Right Alarms | 1or2 |
| 9.1.3 | 04 * | Loc Orbit | 6NM 1500' +35-35° | Wide Alarm | 1or2 |
| 9.1.3 | 04 * | Loc Orbit | 6NM 1500' +35-35° | Narrow Alarm | 1or2 |
| 9.1.3 | 04 * | Loc Orbit | 6NM 1500' +35-35° | Normal Check | 1or2 |
| 9.1.3 | 20 | Orbit | 5NM @1500' 360° | DME Coverage check 20° only on 2nd TX | 1&2 |
| 9.1.4 | | Promulgated procedure | Procedure-Threshold | Pilot comments | 1or2 |
| 9.1.5 | | Promulgated procedure | Procedure distance spot checks for:- | IFP's, Missed Approach, Direct arrivals, Hold, En-Route | 1or2 |

**4.5 Additional Commissioning ILS Inspection Profile Requirements**

**For Side Band Reference & M Array Glide Paths**

| | Profile | Description | Procedure | Notes | TX |
|---|---|---|---|---|---|
| 9.1.2 | 14 | Slice | DOC or 10-2NM @ 1000' | Dephase Upper Antenna with monitor in Alarm | 1or2 |
| 9.1.2 | 14 | Slice | DOC or 10-2NM @ 1000' | Dephase Lower Antenna with Monitor in Alarm | 1or2 |
| 9.1.2 | 14 | Slice | DOC or 10-2NM @ 1000' | Advance Middle Antenna | 1or2 |
| 9.1.2 | 14 | Slice | DOC or 10-2NM @ 1000' | Retard Middle Antenna | 1or2 |


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