PAGERPOWER

Seagreen (Lowther)

Radar Line of Sight Assessment (Eurocontrol, CAA, RAF, NATS) Lowther Hill PSR (NATS)

Pager Power

Seagreen (Lowther)

7th February 2018

Without Expert Commentary

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Report Issue	Date and Time of Request
1	07 Feb 2018 at 09:25 BST

This assessment was requested by Mike Watson of Pager Power on 7th February 2018.

1 SUMMARY (EXECUTIVE)

Pager Power
Pager Power was registered in England in 1997 and is made up of a team of specialist professionals, based near Cambridge. We are a truly international business with more than 250 clients from across the globe. Our reputation has been established as experts able to assess and provide solutions to issues that can arise with any combination of wind turbines, radar, radio communications and construction interaction. We strongly believe that our greatest assets are our people and our software.

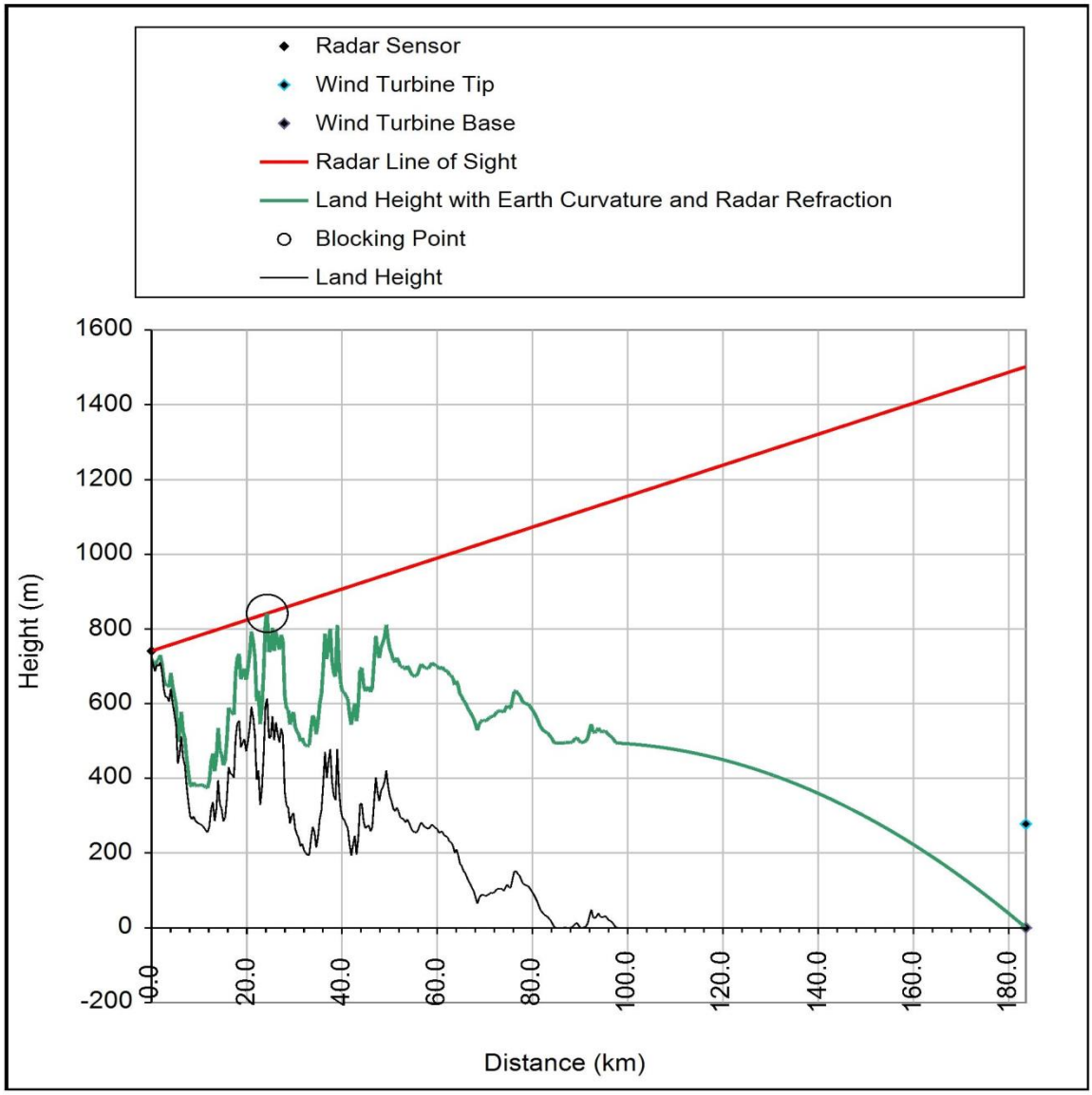
Purpose
The purpose of this assessment is to enable swift and cost effective decision making by wind turbine developers and radar operators. The optional Expert Commentary offers advice as to the next steps that should be taken as a result of the findings of this report. Radar Line of Sight Calculations are used extensively in the planning stages of wind farm development and are referenced by many leading authorities and organisations, including civil and military radar operators.

Wind Turbine	Result
A1	**HIDDEN**
A2	**HIDDEN**
A3	**HIDDEN**
A4	**HIDDEN**
A5	**HIDDEN**
A6	**HIDDEN**
A7	**HIDDEN**
A8	**HIDDEN**

B1	**HIDDEN**
B2	**HIDDEN**
B3	**HIDDEN**
B4	**HIDDEN**
B5	**HIDDEN**
B6	**HIDDEN**
Explanation: There is one Radar Line of Sight Calculation page for each turbine assessed. Each calculation shows whether the turbine is **VISIBLE** or **HIDDEN**. Visible turbines are likely to affect the radar whereas hidden turbines are unlikely to affect the radar.	

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A1
Result	HIDDEN
Certainty	1224.4 metres



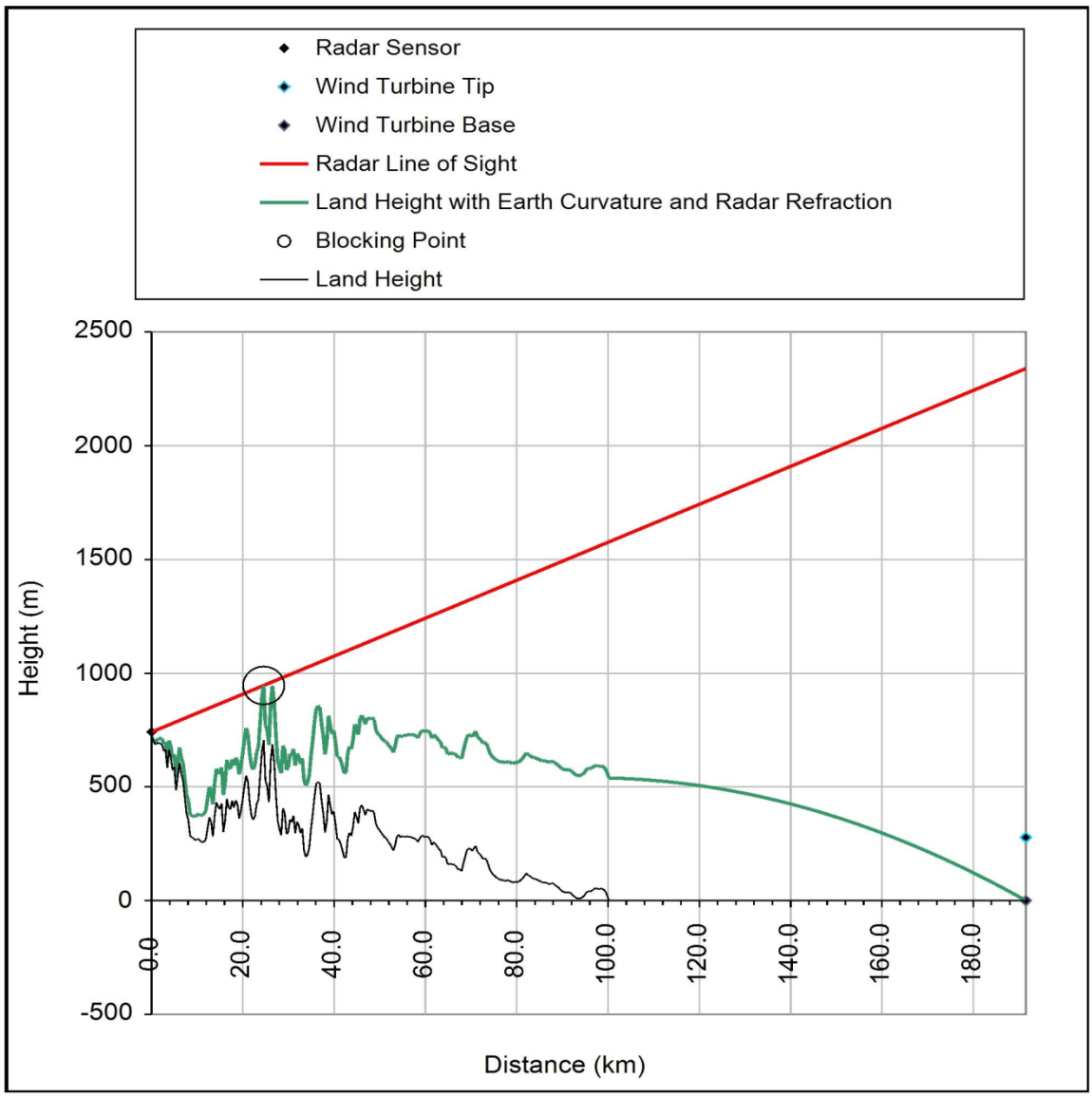
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E405537 N752516
Distance to radar (km)	183.6
Blocking Point Location	E304432 N629460
Distance to BP (km)	159.3

Additional Analysis	
Angle (Radar to Tip)	0.764 degrees down
Maximum Tip Height	1502.09 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A2
Result	HIDDEN
Certainty	2061.9 metres



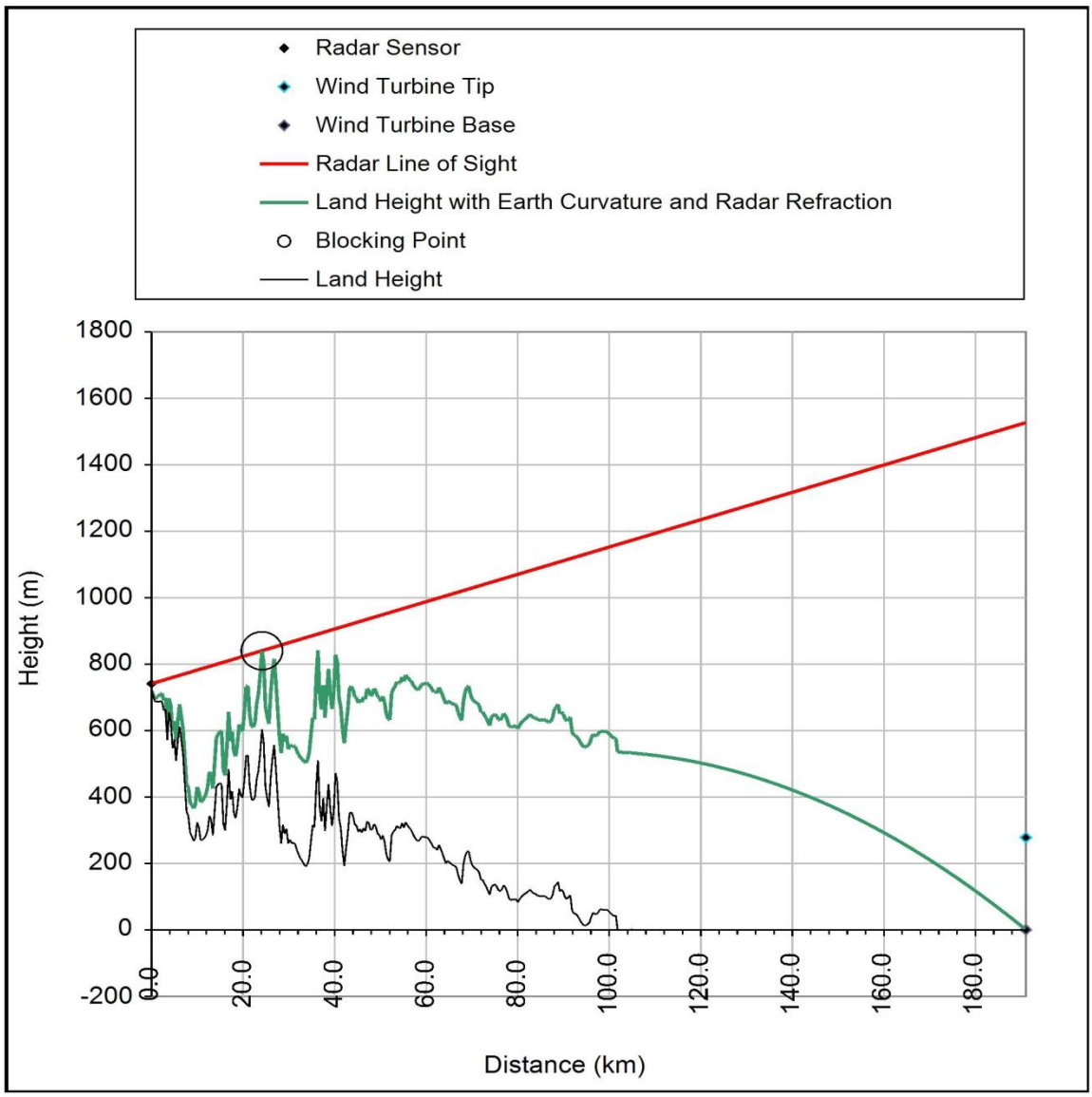
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E416645 N753421
Distance to radar (km)	191.5
Blocking Point Location	E305390 N629007
Distance to BP (km)	166.9

Additional Analysis	
Angle (Radar to Tip)	0.784 degrees down
Maximum Tip Height	2339.61 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A3
Result	HIDDEN
Certainty	1249.6 metres



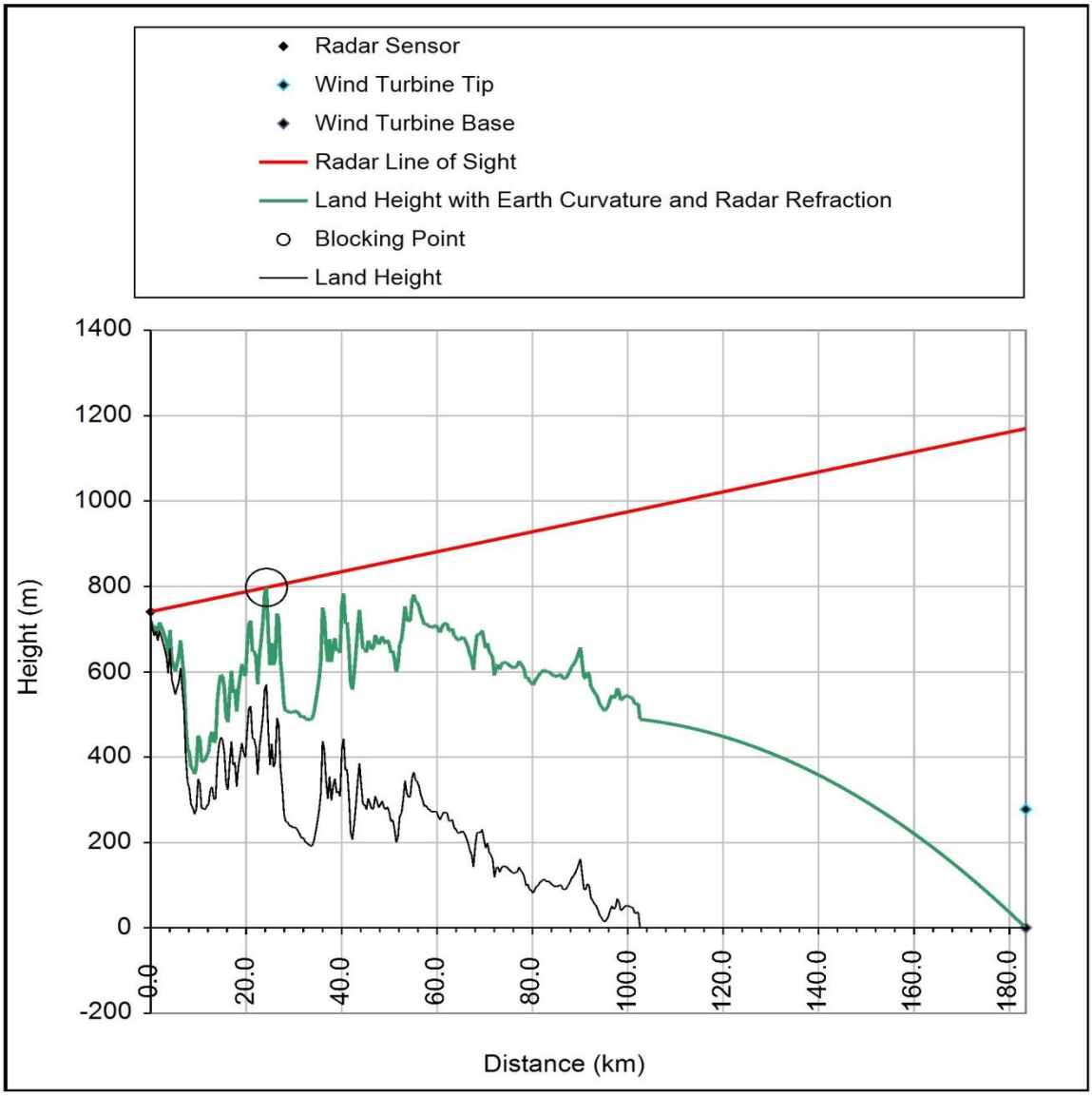
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E418820 N750751
Distance to radar (km)	191.0
Blocking Point Location	E305409 N628384
Distance to BP (km)	166.8

Additional Analysis	
Angle (Radar to Tip)	0.783 degrees down
Maximum Tip Height	1527.32 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A4
Result	HIDDEN
Certainty	892.4 metres



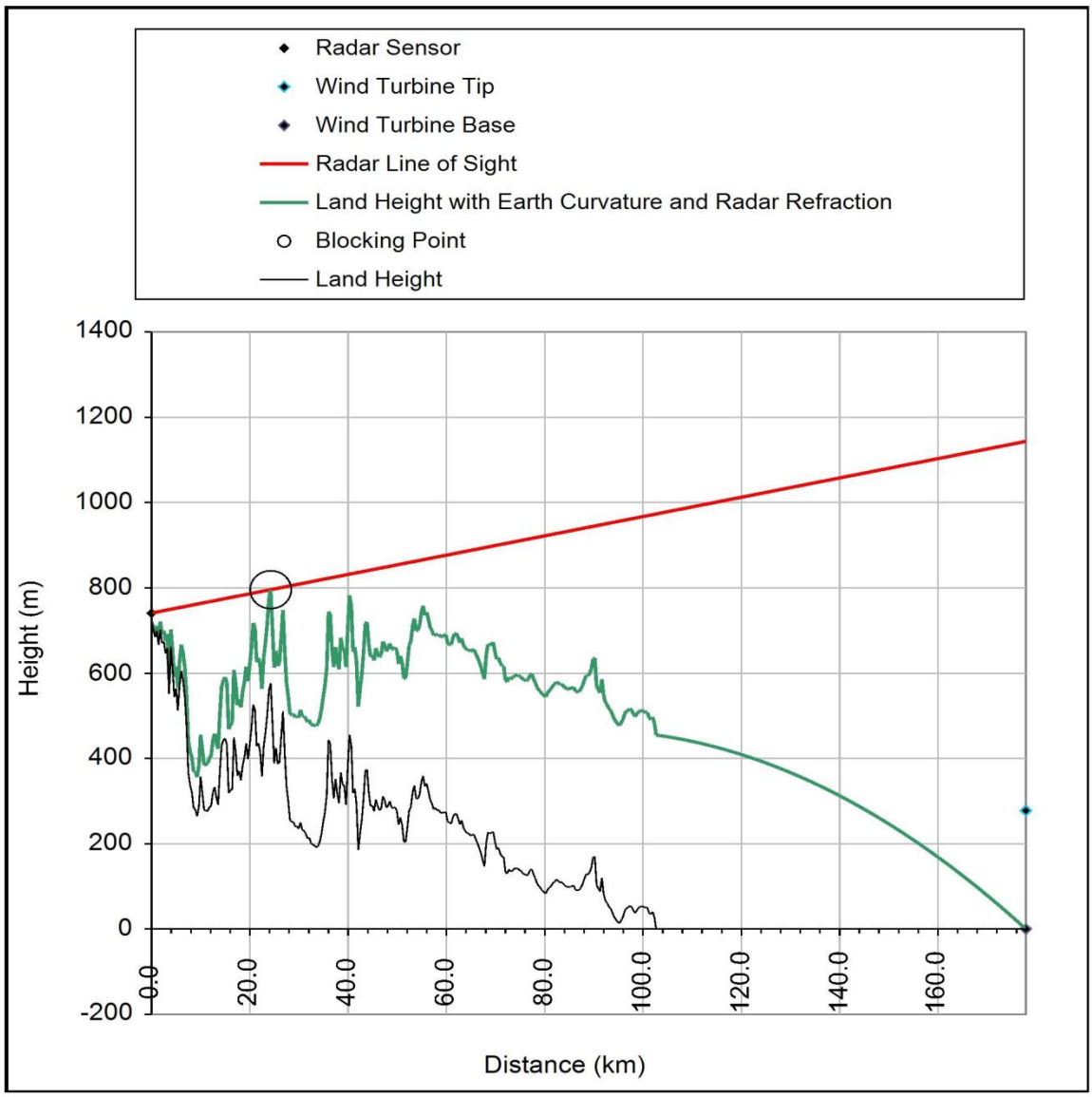
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E414574 N744331
Distance to radar (km)	183.4
Blocking Point Location	E305628 N628377
Distance to BP (km)	159.1

Additional Analysis	
Angle (Radar to Tip)	0.763 degrees down
Maximum Tip Height	1170.06 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A5
Result	HIDDEN
Certainty	866.0 metres



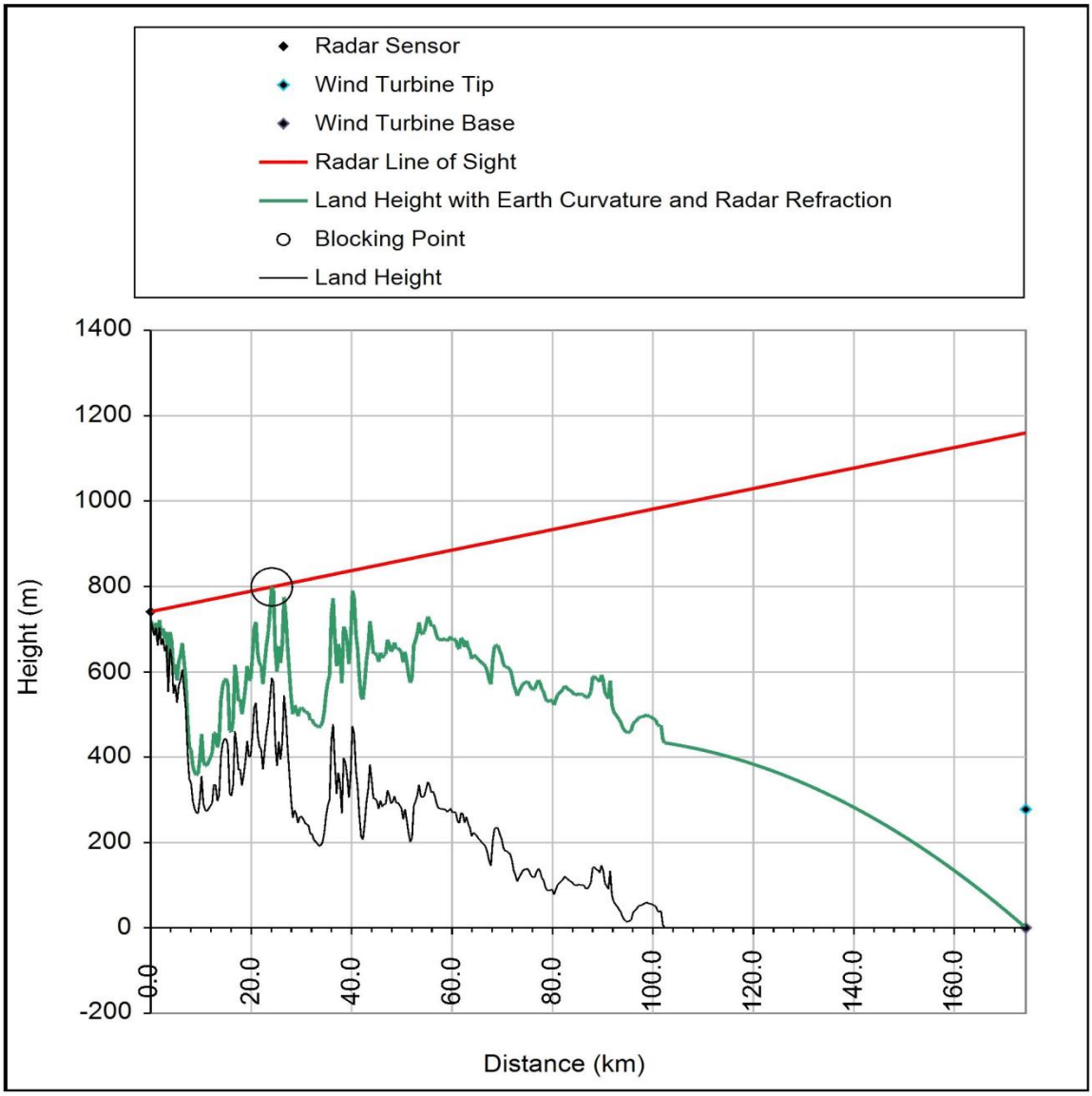
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E410664 N740406
Distance to radar (km)	177.9
Blocking Point Location	E305598 N628378
Distance to BP (km)	153.6

Additional Analysis	
Angle (Radar to Tip)	0.749 degrees down
Maximum Tip Height	1143.67 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A6
Result	HIDDEN
Certainty	882.1 metres



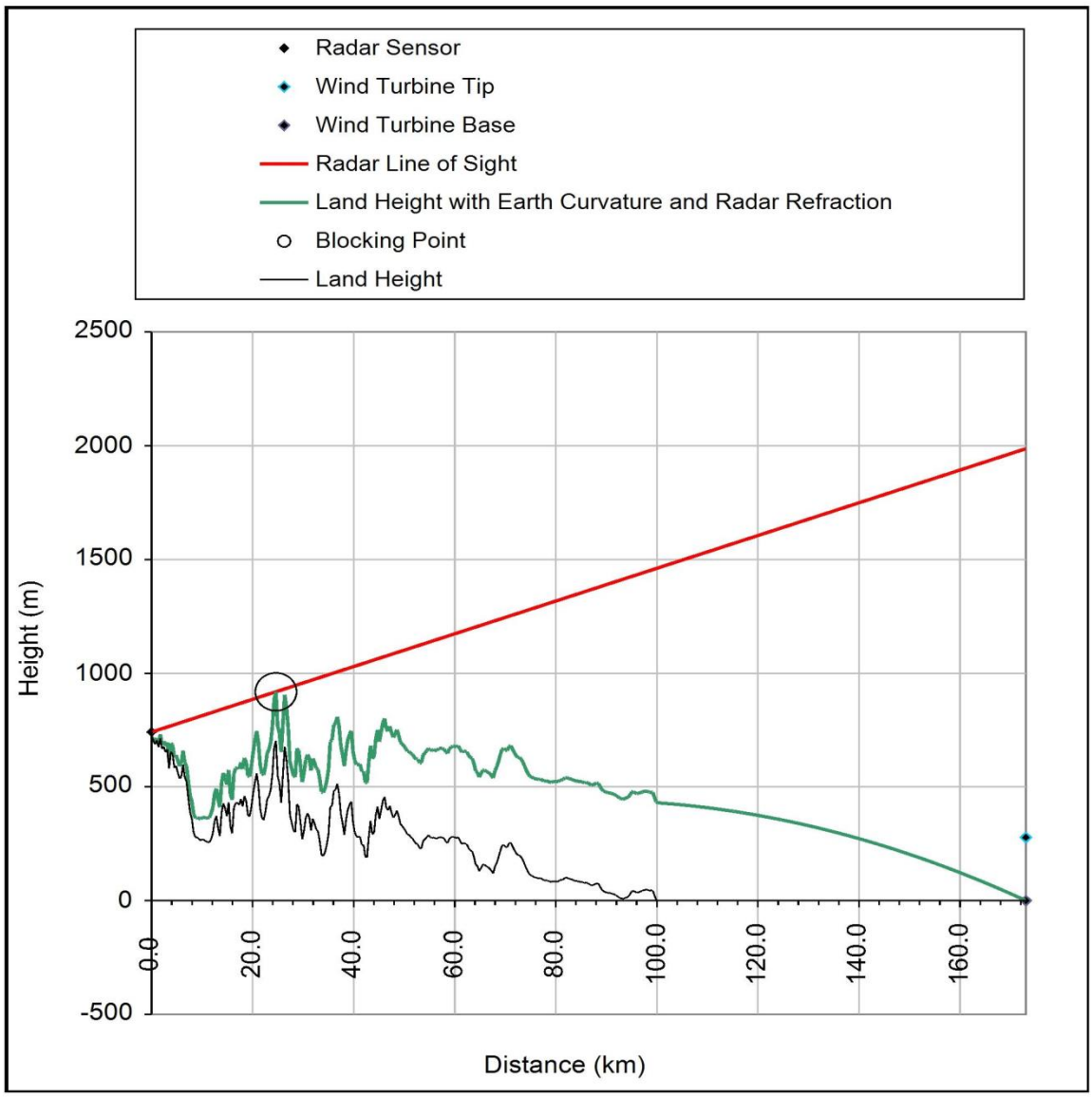
Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E407815 N738086**
Distance to radar (km)	**174.2**
Blocking Point Location	**E305448 N628317**
Distance to BP (km)	**150.1**

Additional Analysis	
Angle (Radar to Tip)	**0.740 degrees down**
Maximum Tip Height	**1159.81 metres**

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A7
Result	HIDDEN
Certainty	1709.4 metres



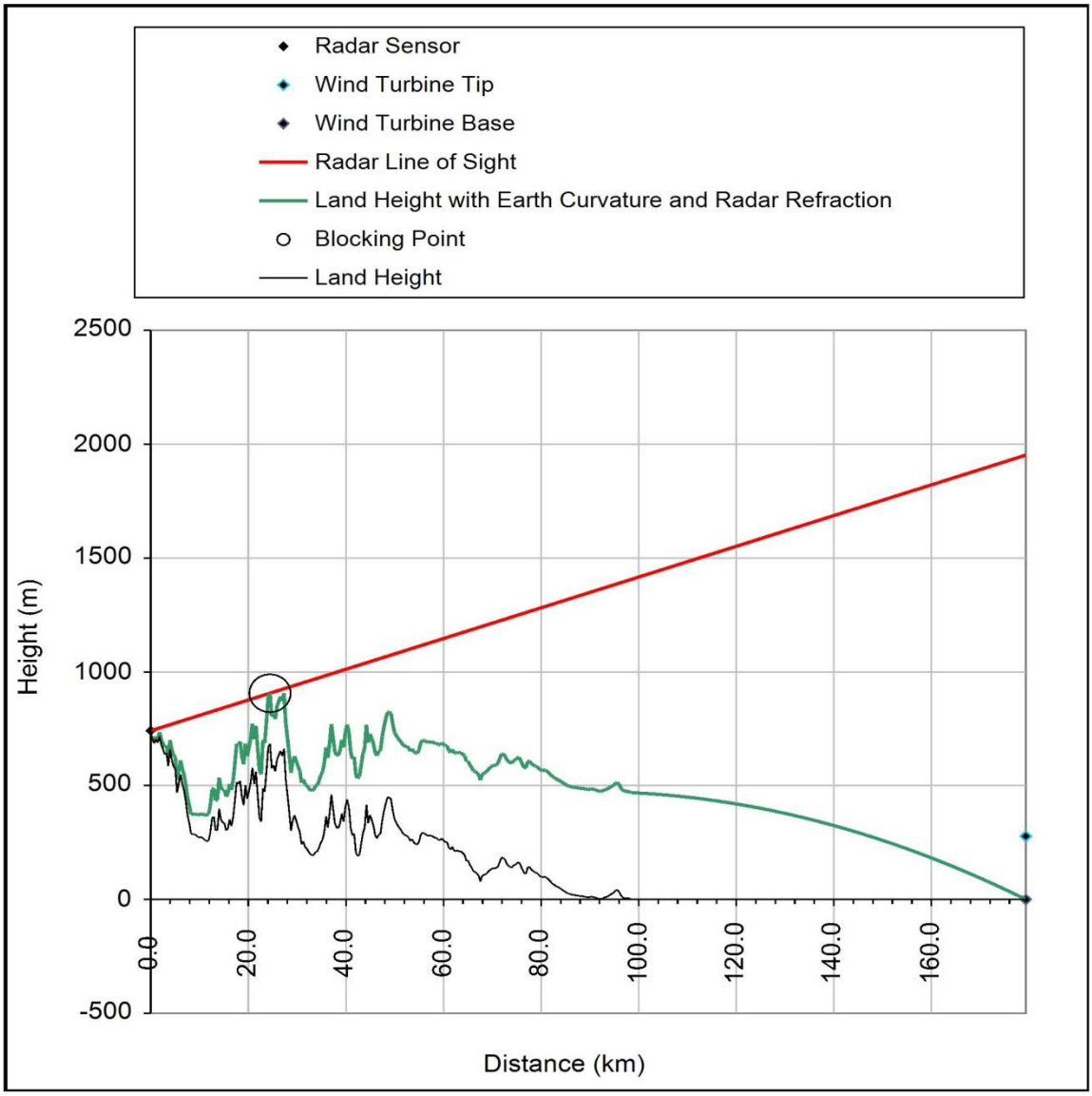
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E403854 N740041
Distance to radar (km)	173.0
Blocking Point Location	E305360 N629106
Distance to BP (km)	148.3

Additional Analysis	
Angle (Radar to Tip)	0.737 degrees down
Maximum Tip Height	1987.14 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	A8
Result	HIDDEN
Certainty	1674.4 metres



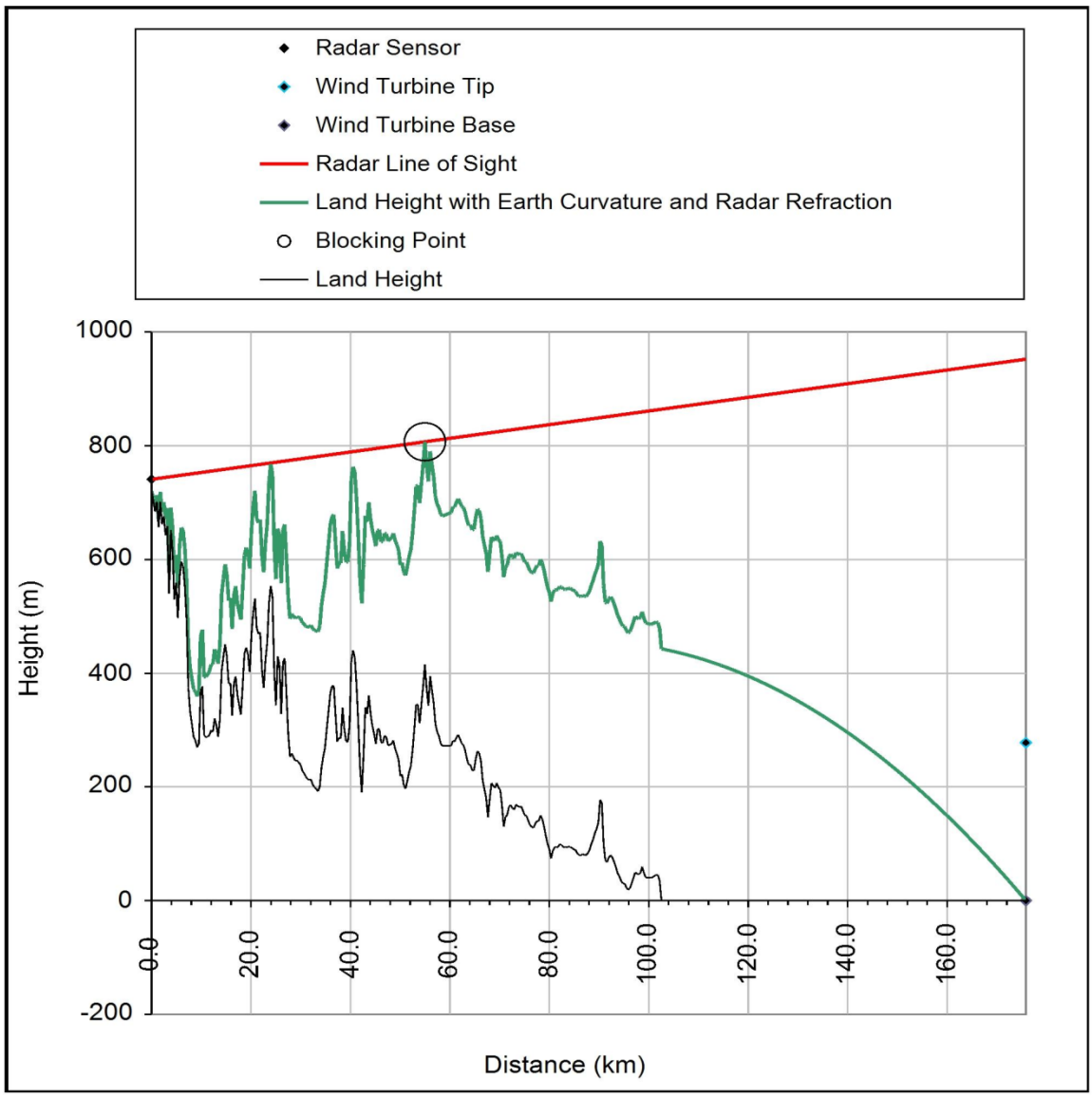
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E404864 N747526
Distance to radar (km)	179.3
Blocking Point Location	E304808 N629348
Distance to BP (km)	154.8

Additional Analysis	
Angle (Radar to Tip)	0.753 degrees down
Maximum Tip Height	1952.06 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	B1
Result	HIDDEN
Certainty	674.6 metres



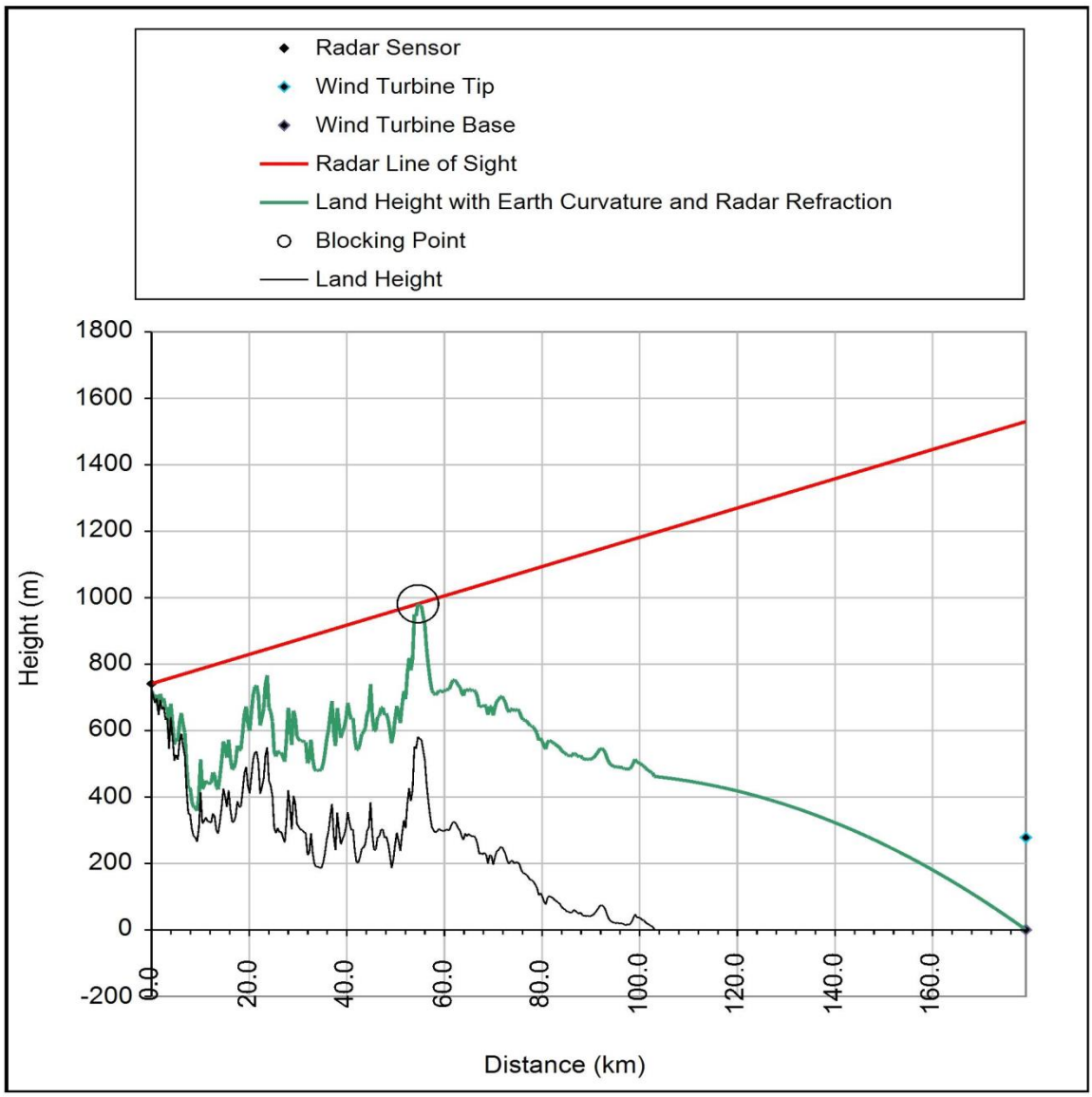
Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E410328 N737911**
Distance to radar (km)	**175.8**
Blocking Point Location	**E326945 N650474**
Distance to BP (km)	**120.8**

Additional Analysis	
Angle (Radar to Tip)	**0.744 degrees down**
Maximum Tip Height	**952.29 metres**

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	B2
Result	HIDDEN
Certainty	1252.9 metres



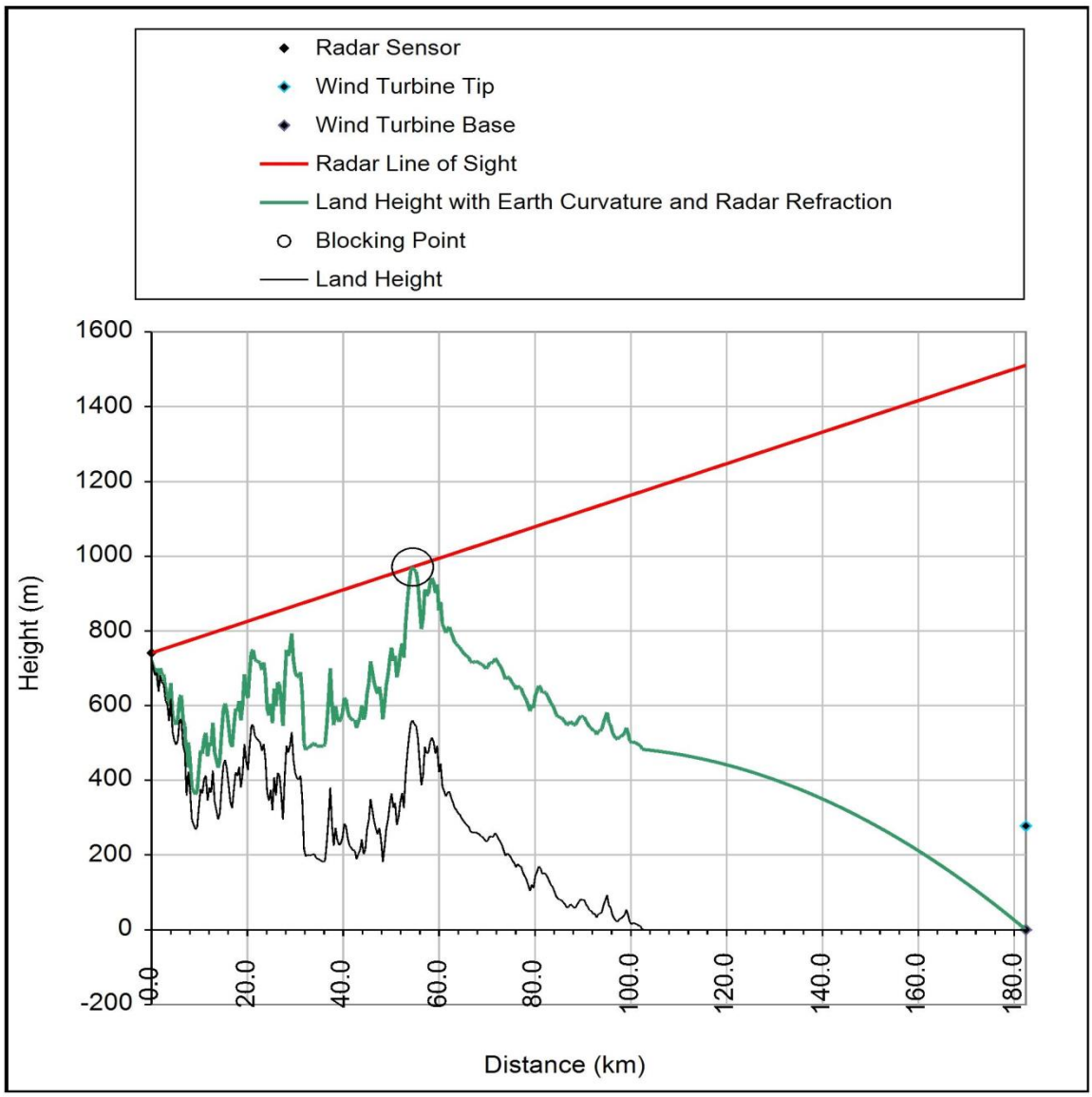
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E415351 N737561
Distance to radar (km)	179.1
Blocking Point Location	E327503 N649347
Distance to BP (km)	124.5

Additional Analysis	
Angle (Radar to Tip)	0.752 degrees down
Maximum Tip Height	1530.57 metres

See Appendix for further information

Radar Line of Sight Calculation	
Prepared for Pager Power Lowther Hill PSR (NATS)	

Seagreen (Lowther)	
Turbine	B3
Result	HIDDEN
Certainty	1233.5 metres



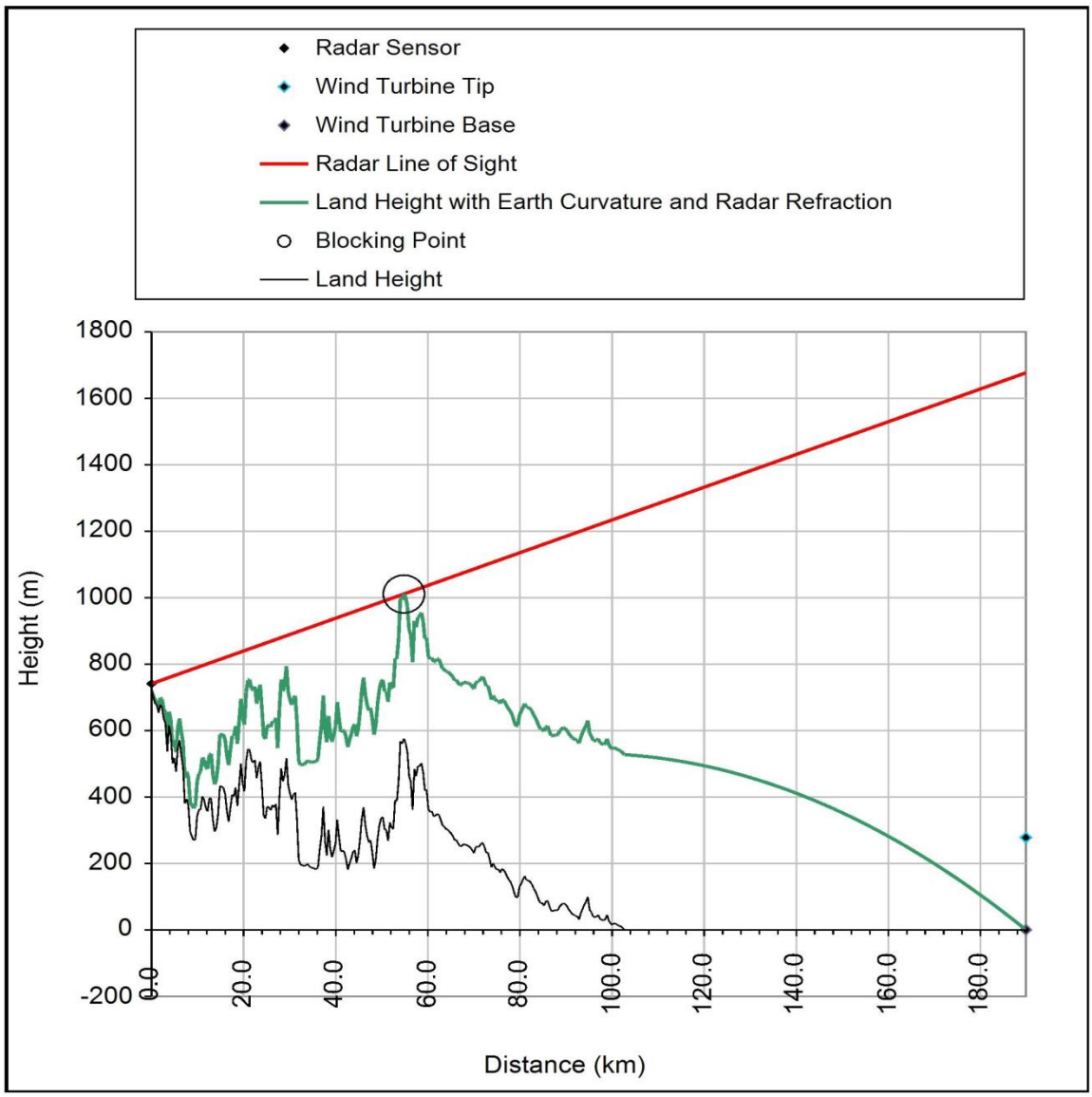
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E420374 N737211
Distance to radar (km)	182.4
Blocking Point Location	E328243 N648480
Distance to BP (km)	127.9

Additional Analysis	
Angle (Radar to Tip)	0.761 degrees down
Maximum Tip Height	1511.24 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	B4
Result	HIDDEN
Certainty	1399.5 metres



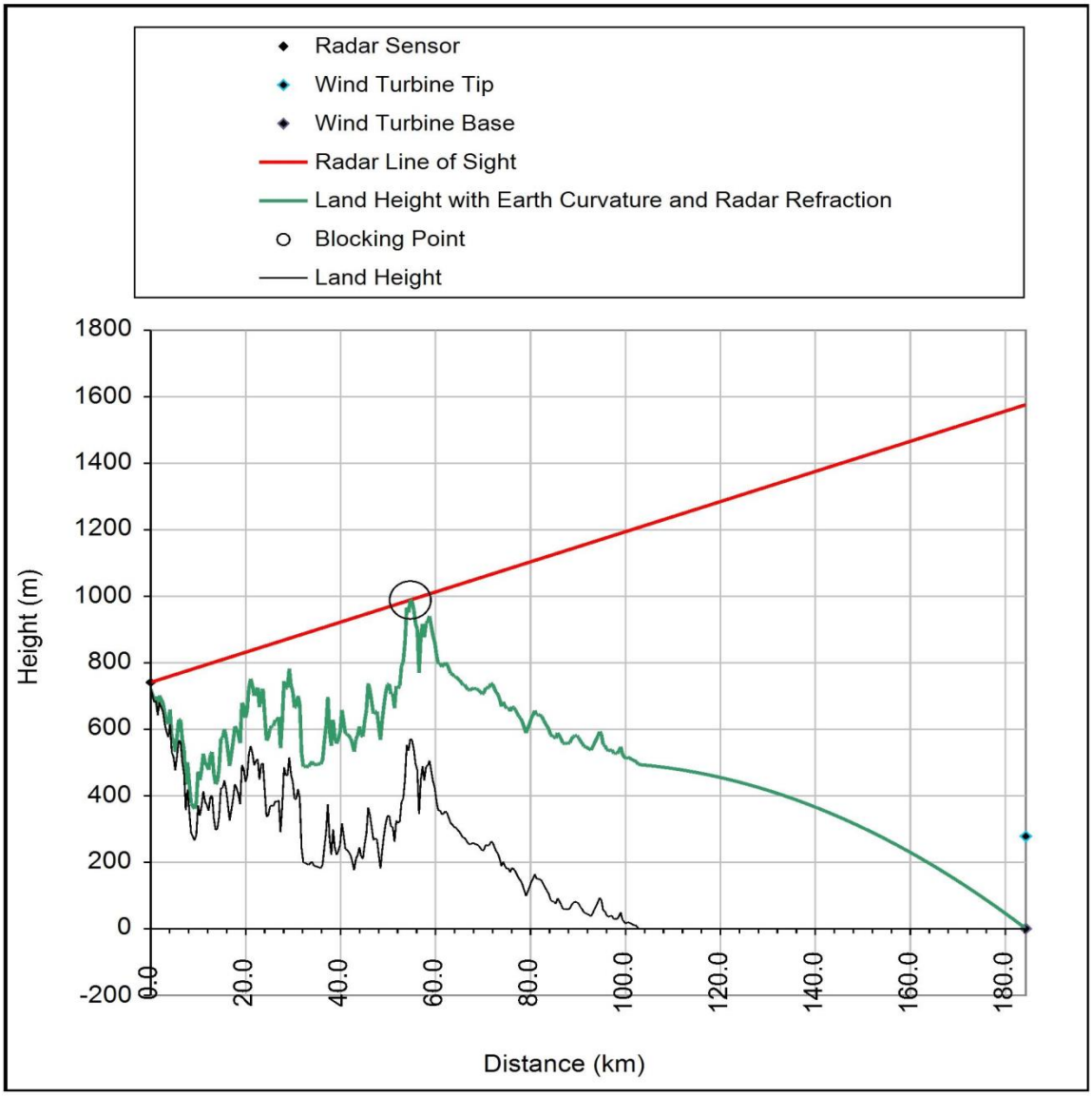
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E425345 N742741
Distance to radar (km)	189.9
Blocking Point Location	E328362 N648808
Distance to BP (km)	135.0

Additional Analysis	
Angle (Radar to Tip)	0.780 degrees down
Maximum Tip Height	1677.25 metres

See Appendix for further information

Radar Line of Sight Calculation
Prepared for Pager Power Lowther Hill PSR (NATS)

Seagreen (Lowther)	
Turbine	B5
Result	HIDDEN
Certainty	1298.9 metres



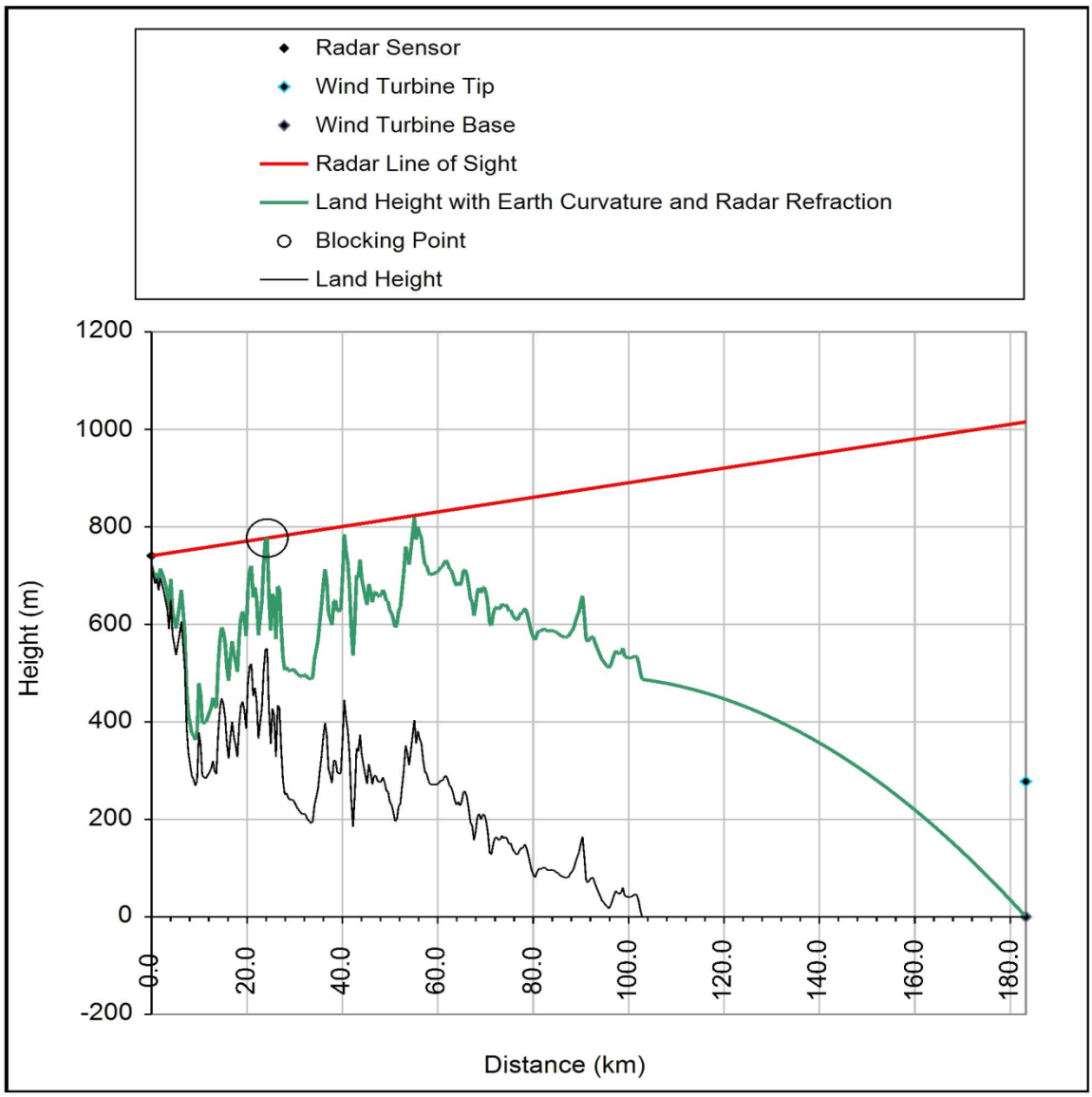
Turbine Height (m)	277.7
Hub Height (m)	220
Rotor Diameter (m)	115.4
Turbine Elevation (m)	0.0
Turbine Location	E421435 N738816
Distance to radar (km)	184.3
Blocking Point Location	E328295 N648702
Distance to BP (km)	129.6

Additional Analysis	
Angle (Radar to Tip)	0.766 degrees down
Maximum Tip Height	1576.63 metres

See Appendix for further information

Radar Line of Sight Calculation	
Prepared for Pager Power Lowther Hill PSR (NATS)	

Seagreen (Lowther)	
Turbine	B6
Result	HIDDEN
Certainty	737.9 metres



Turbine Height (m)	**277.7**
Hub Height (m)	**220**
Rotor Diameter (m)	**115.4**
Turbine Elevation (m)	**0.0**
Turbine Location	**E415299 N743441**
Distance to radar (km)	**183.3**
Blocking Point Location	**E305724 N628259**
Distance to BP (km)	**159.0**

Additional Analysis	
Angle (Radar to Tip)	**0.763 degrees down**
Maximum Tip Height	**1015.62 metres**

See Appendix for further information

2 RESULTS SUMMARY

Wind Turbine	Result	Certainty	Angle (Radar to Tip)	Maximum Height
A1	HIDDEN	1224.4 metres	0.764 degrees down	1502.09 metres
A2	HIDDEN	2061.9 metres	0.784 degrees down	2339.61 metres
A3	HIDDEN	1249.6 metres	0.783 degrees down	1527.32 metres
A4	HIDDEN	892.4 metres	0.763 degrees down	1170.06 metres
A5	HIDDEN	866.0 metres	0.749 degrees down	1143.67 metres
A6	HIDDEN	882.1 metres	0.740 degrees down	1159.81 metres
A7	HIDDEN	1709.4 metres	0.737 degrees down	1987.14 metres
A8	HIDDEN	1674.4 metres	0.753 degrees down	1952.06 metres
B1	HIDDEN	674.6 metres	0.744 degrees down	952.29 metres
B2	HIDDEN	1252.9 metres	0.752 degrees down	1530.57 metres
B3	HIDDEN	1233.5 metres	0.761 degrees down	1511.24 metres
B4	HIDDEN	1399.5 metres	0.780 degrees down	1677.25 metres
B5	HIDDEN	1298.9 metres	0.766 degrees down	1576.63 metres
B6	HIDDEN	737.9 metres	0.763 degrees down	1015.62 metres

Column Descriptions	
Wind Turbine	Turbine Number as entered or uploaded
Result	**VISIBLE** turbines are likely to affect the radar whereas **HIDDEN** turbines are unlikely to affect the radar.

Certainty	This is a vertical distance in metres and is the distance from the turbine tip to the line of sight. The higher the number the greater the certainty.
Angle (Radar to Tip)	This is the vertical angle from the radar to the wind turbine tip. Some radar are less likely to be affected by a wind turbine if this angle is down and more likely to be affected if this angle is up.
Maximum Height	A turbine having this tip height would be **HIDDEN**. A turbine that was any higher would be **VISIBLE**.

3 REQUESTED ASSESSMENT

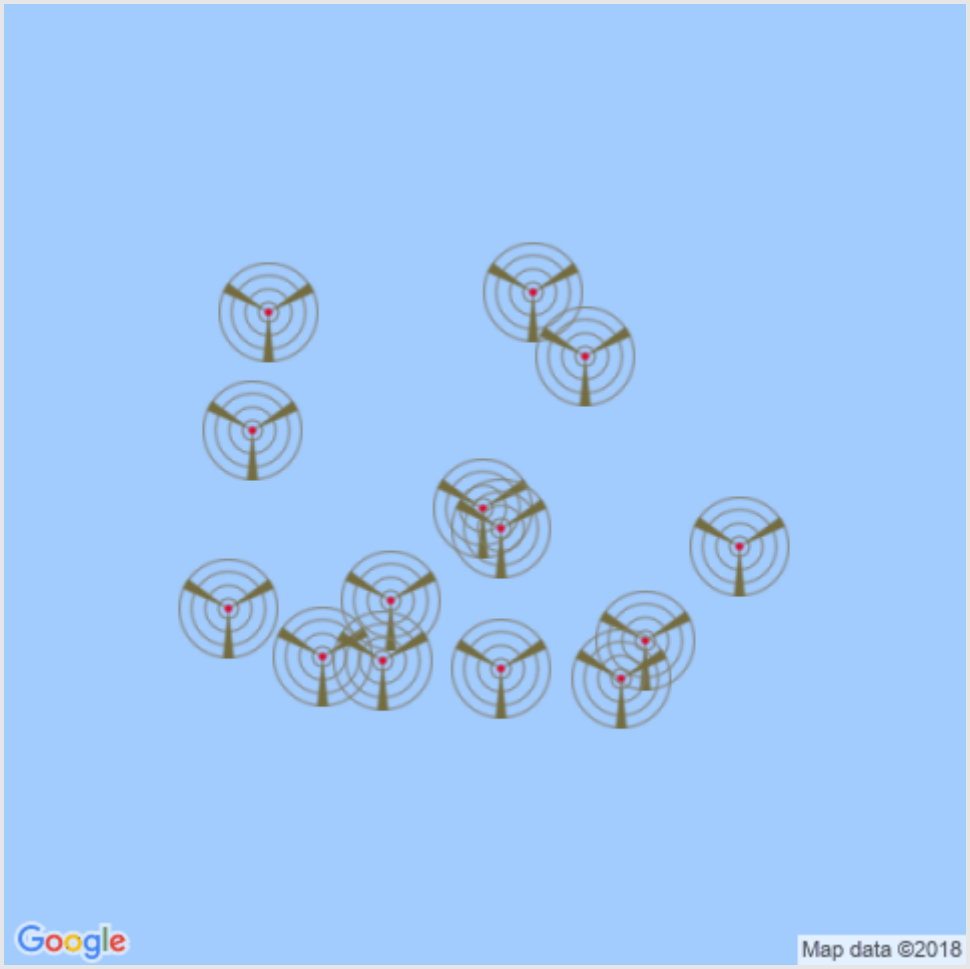
Key Parameters
• This Radar Line of Sight Assessment for Seagreen (Lowther) was requested by Mike Watson of Pager Power on 7th February 2018. • Assessment Methodology = Radar Line of Sight Calculation using advanced terrain data processing algorithm. • Coordinate System = Local Grid • Vertical Units = Metres

Radar
• The assessed radar was Lowther Hill PSR (NATS) • Location and height information for preselected radar are sourced from a managed database

Development Location Data (as entered in online system)				
Coordinate (E)	**Coordinate (N)**	**Hub Height (Metres AGL)**	**Tip Height (Metres AGL)**	**Wind Turbine Reference**
405537.29	752516.24	220	277.7	A1
416644.98	753420.86	220	277.7	A2
418819.9	750750.77	220	277.7	A3
414573.7	744330.85	220	277.7	A4
410664.08	740405.88	220	277.7	A5
407815	738085.89	220	277.7	A6
403854.44	740040.99	220	277.7	A7
404864.12	747526.15	220	277.7	A8
410327.54	737910.85	220	277.7	B1
415350.59	737560.78	220	277.7	B2

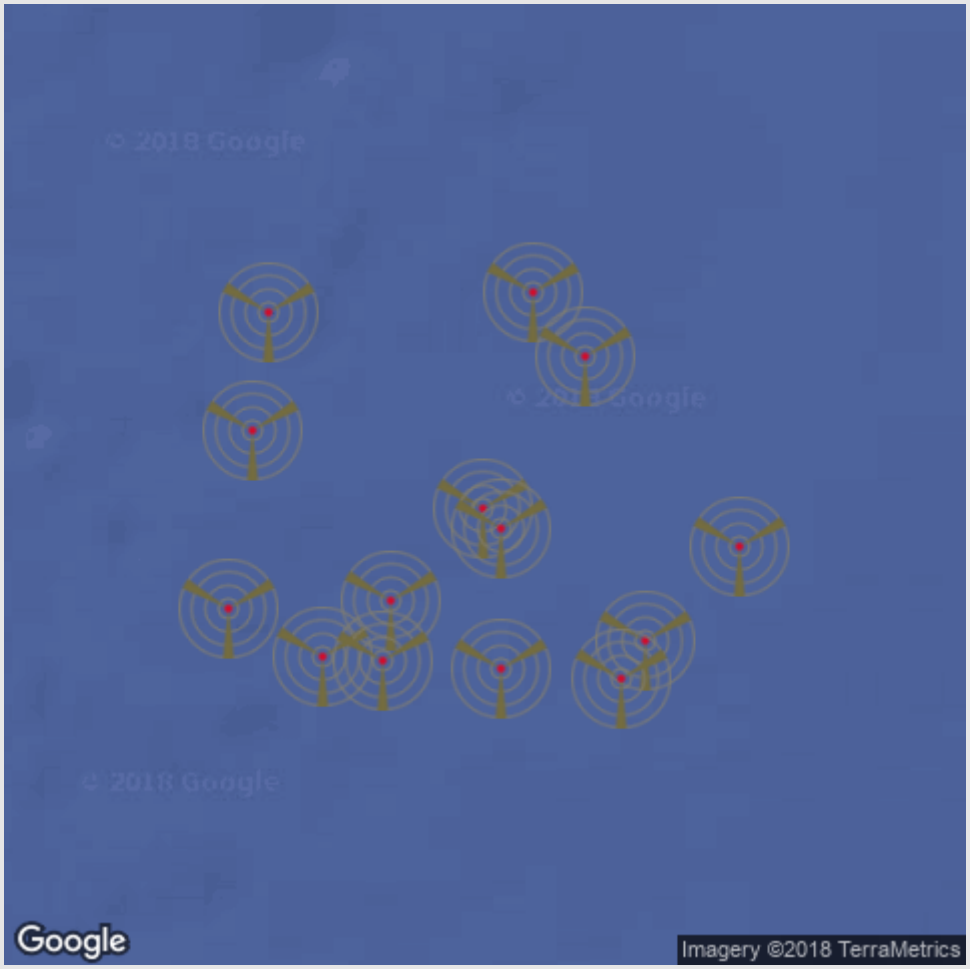
420373.6	737210.72	220	277.7	B3
425344.67	742740.62	220	277.7	B4
421435.12	738815.7	220	277.7	B5
415298.69	743440.83	220	277.7	B6

Map Showing Assessed Turbine Locations



Seagreen (Lowther)

Aerial Photograph Showing Assessed Turbine Locations



Seagreen (Lowther)

4 METHODOLOGY AND BACKGROUND

Introduction

This report indicates whether wind turbines at the Seagreen (Lowther) will be detected by the Lowther Hill PSR (NATS). This assessment shows:

- Whether wind turbines are **VISIBLE** or **HIDDEN**
- A level of certainty as to whether each wind turbine is likely to affect the radar or not
- A profile chart showing the radar, each wind turbine and intervening terrain

Scope

This assessment:

- Is new and takes no previous assessment into account
- Determines whether each assessed wind turbine at Seagreen (Lowther) will be within Radar Line of Sight of the Lowther Hill PSR (NATS)
- Does not account for diffraction effects or any other radar
- Does account for terrain, earth curvature and refraction effects
- Uses an advanced terrain data processing algorithm optimized for accurate and reliable wind farm radar calculations

Official Guidance Details

The following organisations have published documents that refer to the use of Radar Line of Sight Calculations for determining whether a wind turbine will affect a radar.

1. European Organisation for the Safety of Air Navigation (EUROCONTROL)
2. UK Civil Aviation Authority (CAA)
3. UK Royal Air Force (RAF)
4. UK Wind Energy, Defence and Civil Aviation Interests Working Group
5. UK National Air Traffic Services (NATS)
6. US Department of Defense (DoD)
7. US Department of Commerce
8. US Federal Aviation Authority (FAA)
9. South African Weather Service (SAWS)
10. Radio Advisory Board of Canada (RABC)
11. Canadian Wind Energy Association (CanWEA)

Report Preparation

This report has been created by a custom-built advanced online service which has the following features:

- Fast report delivery by email
- Responsive and knowledgeable technical support team
- Advanced terrain data processing algorithms

Radar Line of Sight Calculation – Accuracy Details

5 APPENDIX - CALCULATION NOTES

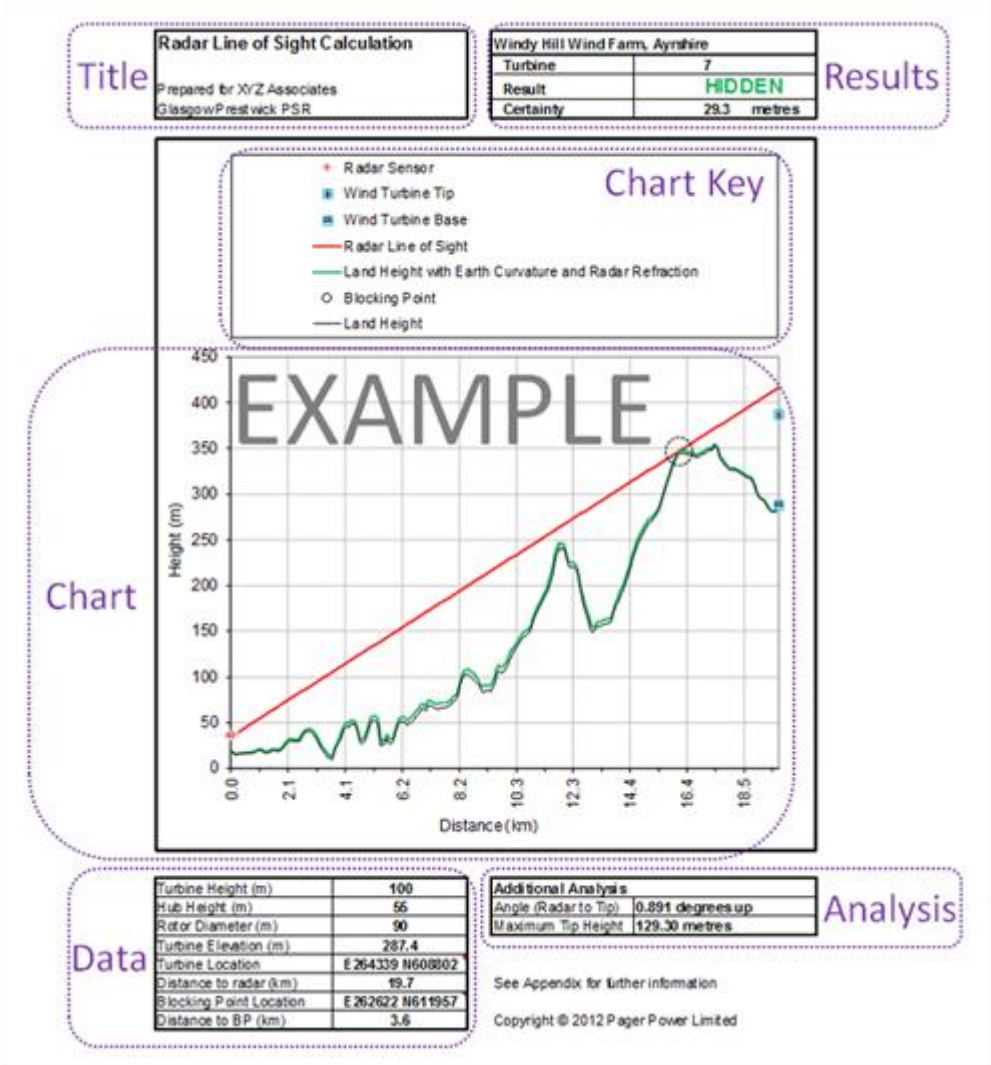


Diagram showing areas of a Radar Line of Sight Calculation

The information in the various areas of the calculation sheet is described below:

Title Details
Name of organisation that has requested the calculation (As given when setting up Pager Power Online user account)
Name of the radar (As selected or entered)

Results	
Name of the development (As entered)	
Turbine	Turbine Number as entered or uploaded
Result	**VISIBLE** turbines are likely to affect the radar whereas **HIDDEN** turbines are unlikely to affect the radar.
Certainty	This is a vertical distance in metres and is the distance from the turbine tip to the line of sight. The higher the number the greater the certainty.

Chart Key	
Radar Sensor	This is the radar antenna. It is a single point at the left of the chart.
Wind Turbine Tip	This is the highest point of the wind turbine. It is a single point at the right of the chart.
Wind Turbine Base	This is the bottom of the turbine. It is a single point at the right of the chart.
Radar Line of Sight	This is a straight line from the Radar Sensor towards the turbine which coincides with the terrain between the radar and the wind turbine.
Land Height with Earth Curvature and Radar Refraction	This is the terrain profile between the radar and the turbine. Calculation accuracy is increased by including both Earth curvature and standard radar refraction. Refraction means that the radar signal bends slightly as it passes through the atmosphere.
Blocking Point	This is a single point where the Radar Line of Sight is the same as Land Height with Earth Curvature and Refraction.
Land Height	This is calculated accurately using an advanced weighted average algorithm and height data from a terrain database.

Chart	
Vertical Axis	Height above sea level in metres
Horizontal Axis	Distance from the radar in kilometres

Data	
Turbine Height (m)	The maximum turbine tip height above ground level in metres.
Hub Height (m)	The turbine hub height above ground level in metres.
Rotor Diameter (m)	The diameter of the area swept by the turbine blades in metres. The Rotor Radius is half of the Rotor Diameter.
Turbine Elevation (m)	The height of the ground on which the turbine stands relative to sea level.
Turbine Location	The coordinates of the turbine location.
Distance to radar (km)	The horizontal distance from the radar to the turbine in kilometres.
Blocking Point Location	The coordinates of the Blocking Point. Buildings and trees at this location might mean the radar is less likely to be affected by the wind turbine.
Distance to BP (km)	The horizontal distance from the turbine to the Blocking Point in kilometres.

Analysis	
Angle (Radar to Tip)	This is the vertical angle from the radar to the wind turbine tip. Some radar are less likely to be affected by a wind turbine if this angle is down.
Maximum Height	A turbine having this tip height would be **HIDDEN**. A turbine that was any higher would be **VISIBLE**.