RWE

Proposed Solar PV Development

Byers Gill Solar
EN010139

6.4.2.2 Environmental Statement
Appendix 2.2 Solar Photovoltaic Glint and Glare Study

Planning Act 2008

APFP Regulation 5(2)(q)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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PAGERPOWER
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Solar Photovoltaic Glint and Glare Study

JBM Solar Developments Limited

Byers Gill Solar

January 2024

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from the proposed Byers Gill solar photovoltaic (PV) development. This glint and glare assessment concerns the potential impact on surrounding road safety, railway operations and infrastructure, and aviation activity associated with Teesside International Airport.

Conclusions

A moderate impact (considering the baseline scenario) is predicted on three sections of road due to the location of the reflecting panels relative to a road user's primary field of view, and the lack of sufficient mitigating factors.

A moderate impact (considering the baseline scenario) is predicted onten dwellings due to the duration of effects, and the lack of sufficient mitigating factors.

The height of proposed hedgerow/tree planting should be managed so that relevant reflecting areas are obscured from view.

Further information is provided in Section 7.

There are no impacts requiring mitigation on surrounding railway operations and infrastructure, and aviation activity associated with Teesside International Airport.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. There is no existing planning guidance for the assessment of solar reflections from solar panels towards roads and nearby dwellings. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the fourth edition published in 2022[1]. The guidance document sets out the methodology for assessing roads, dwellings, railway operations and infrastructure, and aviation activity with respect to solar reflections from solar panels.

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. The scenario in which a solar reflection can occur for all receptors is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced

[1] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[2].

Assessment Results

Roads

A moderate impact is predicted on:

- A 0.2km section (road receptors 84-86) and 0.1km section (road receptors 90-91) of Ricknall Lane/Lodge Lane;
- A 1.5km section of Unnamed Road/The Green/ High Street (road receptors 155 to 170).

Assuming that the height of proposed hedgerow/tree planting along reflecting panel boundaries for these sections will be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none, no further mitigation is recommended.

Further details are provided in Section 7 of the report.

A low impact is predicted on:

- A 0.3km section of Elstob Lane/Bishopton Lane (road receptors 126-129); and
- A 0.6km section of Elstob Lane/Bishopton Lane (road receptors 132-138).

This is because solar reflections are geometrically possible from outside of a road user's primary field of view (50 degrees either side), and/or there are significant mitigating factors such as:

- Significant clearance distance between road user and closest visible reflecting panel;
- Reflections incident with sunlight;
- Generally low traffic volume/density expected along most sections.

No impacts are predicted on the remaining assessed road sections, because solar reflections are not geometrically possible, or there is significant screening in the form of existing vegetation, buildings, and/or terrain such that reflections would not be visible in practice.

Dwellings

A moderate impact is predicted on ten dwellings (87-88, 98, 101, 104, 111-115) due to the duration of effects, and the lack of sufficient mitigating factors. Assuming that the height of proposed hedgerow/tree planting along reflecting panel boundaries for these dwellings will be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none, no further mitigation is recommended.

Further information is provided in Section 7.

A low impact is predicted on nine dwellings (84, 91, 117-118, 119, 121, 126, 200-201) due to the duration of effects and the presence of the following mitigating factors:

- Significant separation distance between observer and closest visible reflecting panel;

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[2]Source: SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

The impact may be reduced to none for some of these dwellings once proposed hedgerow/tree planting has been established.

No significant impacts are predicted on any of the remaining 240 dwellings within the assessment area, because where solar reflections are geometrically possible, there is significant existing and/or proposed screening such that reflections lasting more than 60 minutes on any given day and/or 3 months per year are not expected to be possible. Mitigation is not required.

Railway

The modelling has shown that solar reflections are geometrically possible[3] towards a 0.7km section of the railway line to the west of the Proposed Development.

For all receptors towards which solar reflections are geometrically possible, the reflections will occur from outside of a train driver's primary horizontal field of view (30° either side of the direction of travel). Based on imagery of the area, it appears that the majority of the sections of railway line within 0.5km of the Proposed Development are located where there is vegetation either side. The height and density of this vegetation is unclear.

A low impact is therefore predicted, and mitigation is not recommended.

Aviation

No impacts are not predicted on aviation activity associated with Teesside International Airport because solar reflections are not geometrically possible towards:

- The ATC Tower;
- The last two miles of the approach path towards runway 05;
- The last two miles of the approach path towards runway 23.

[3] Only considering reflections from solar panels within 0.5km of the receptor. Reflections outside of 0.5km are not considered to be significant.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 58 countries internationally.

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.

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from the proposed Byers Gill solar photovoltaic (PV) development. This glint and glare assessment concerns the potential impact on surrounding road safety, residential amenity, railway operations and infrastructure, and aviation activity associated with Teesside International Airport.

This report contains the following:

- Solar development details.
- Explanation of glint and glare.
- Overview of relevant guidance and studies.
- Overview of Sun movement.
- Assessment methodology.
- Identification of receptors.
- Glint and glare assessment for identified receptors.
- Results discussion.

Following this, a summary of findings and overall conclusions and recommendations from the desk-based analysis is presented.

1.2 Pager Power's Experience

Pager Power has undertaken over 1,200 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows[4]:

- Glint – a momentary flash of bright light typically received by moving receptors or from moving reflectors.
- Glare – a continuous source of bright light typically received by static receptors or from large reflective surfaces.

The term 'solar reflection' is used in this report to refer to both reflection types.

[4] These definitions are aligned with those presented within the Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) – published by the Department for Business, Energy & Industrial Strategy in March 2023 and the Federal Aviation Administration in the USA.

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Solar PV Areas

The latest solar PV layout for the Proposed Development is shown in Figure 1[5] below.

Figure 1 *Solar PV areas*

2.2 Solar Panel Information

The technical information used for the modelling is presented in Table 1 below.

Solar Panel Technical Information	
Azimuth angle[6]	180°
Elevation (tilt) angle[7]	18°
Assessed centre height[8]	2.15m above ground level (agl)

Table 1 *Solar panel information*

[5] Source: 2023.10.18 DCO Application Design Fix
[6] Direction relative to true north
[7] Relative to the horizontal
[8] Modelled at the midpoint of an assumed minimum height of 0.8m and stated maximum height of 3.5m

2.3 Reflector Areas

A resolution of 20m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 20m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results; increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points is determined by the size of the reflector areas and the assessment resolution. The bounding coordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

3 RAILWAYS AND GLINT AND GLARE

3.1 Overview

A railway stakeholder may request further information regarding the potential effects of glint and glare from reflective surfaces when a development is located adjacent to a railway line (typically 50-100m from its infrastructure). The request may depend on the scale, percentage of reflective surfaces and the complexity of the nearby railway, for example. The following section presents details regarding the most common concerns relating to glint and glare.

3.2 Glint and Glare Definition

As well as the glint and glare definition presented in Section 1.3, glare can also be categorised as causing visual discomfort whereby an observer would instinctively look away, or cause disability whereby objects become difficult to see. The guidance produced by the Commission Internationale de L'Eclairage (CIE)[9] describes disability glare as:

'Disability glare is glare that impairs vision. It is caused by scattering of light inside the eye…The veiling luminance of scattered light will have a significant effect on visibility when intense light sources are present in the peripheral visual field and contrast of objects is seen to be low.'

'Disability glare is most often of importance at night when contrast sensitivity is low and there may well be one or more bright light sources near to the line of sight, such as car headlights, streetlights or floodlights. But even in daylight conditions disability glare may be of practical significance: think of traffic lights when the sun is close to them, or the difficulty viewing paintings hanging next to windows.'

These types of glare are of particular importance in the context of railway operations as they may cause a distraction to a train driver (discomfort) or may cause railway signals to be difficult to see (disability).

3.3 Common Concerns and Signal Overview

Typical reasons stated by a railway stakeholder for requesting a glint and glare assessment often relate to the following:

1. The development producing solar reflections towards train drivers;
2. The development producing solar reflections, which causes a train driver to take action; and
3. The development producing solar reflections that affect railway signals.

With respect to point 1, a reflective panel could produce solar reflections towards a train driver. If this reflection occurs where a railway signal, crossing etc., is present, or where the driver's

[9] CIE 146:2002 & CIE 147:2002 Collection on glare (2002).

workload is particularly high, the solar reflection may affect operations. This is deemed to be the most concern with respect to solar reflections.

Following from point 1, point 2 identifies whether a modelled solar reflection could be significant depending on the technical and operational context. Only where a solar reflection occurs under certain conditions may it cause a reaction from a train driver and thus potentially affect safe operations. Therefore, any predicted reflections are evaluated based on technical and operational considerations to determine whether they could potentially affect the safety of operations. Points 1 and 2 are completed in a 2-step approach.

With respect to all points, railway lines use light signals to manage trains on approach towards particular sections of track. If a signal is passed when not permitted, a SPAD (Signal Passed At Danger) is issued. The concerns will relate specifically to the possibility of the reflections appearing to illuminate signals that are not switched on (known as a phantom aspect illusion) or a distraction caused by the glare itself, both of which could lead to a SPAD. The definition is presented below:

'Light emitted from a Signal lens assembly that has originated from an external source (usually the sun) and has been internally reflected within the Signal Head in such a way that the lens assembly gives the appearance of being lit.[10]*'*

This is a particular problem for filament bulbs with a reflective mirror incorporated into the bulb design. Many railway signals are, however, now LED. The benefits of an LED signal over a filament bulb signal with respect to possible phantom aspect illuminations are as follows:

- An LED railway signal produces a more intense light making them more visible to approaching trains when compared to the traditional filament bulb technology[11].
- LED signals can operate without a reflective mirror present unlike a filament bulb[12]. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated.
- LED signal manufacturers[13,14,15] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

Details regarding the identified railway receptors are presented in Section 5 of this report.

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[10] Source: Glossary of Signalling Terms, Railway Group Guidance Note GK/GN0802. Issue One. Date April 2004.

[11] Source: Wayside LED Signals – Why it's Harder than it Looks, Bill Petit.

[12] This can vary from one manufacturer to another.

[13] Source: https://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf (Last accessed 29.01.20).

[14] Source: http://www.vmstech.co.uk/scls.htm (Last accessed 29.01.20).

[15] Source: http://download.siemens.com.au/index.php?action=filemanager&doc_form_name=download&folder_id=5633&doc_id=16875. (Last accessed 29.01.20).

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 Guidance and Studies

Appendices A and B present a review of relevant guidance and independent studies with regard to glint and glare issues from solar panels. The overall conclusions from the available studies are as follows:

- Specular reflections of the Sun from solar panels are possible.
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence.
- Published guidance shows that the intensity of solar reflections from solar panels are equal to or less than those from water. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment.

4.2 Background

Details of the Sun's movements and solar reflections are presented in Appendix C.

4.3 Methodology

4.3.1 Pager Power's Methodology

The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance and studies. The methodology for this glint and glare assessment is as follows:

- Identify receptors in the area surrounding the solar development.
- Consider direct solar reflections from the solar development towards the identified receptors by undertaking geometric calculations and intensity calculations where required.
- Consider the visibility of the panels from the receptor's location. If the panels are not visible from the receptor then no reflection can occur.
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur.
- Assess the glare intensity if applicable.
- Consider both the solar reflection from the solar development and the location of the direct sunlight with respect to the receptor's position.
- Consider the solar reflection with respect to the published studies and guidance.
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

Within the Pager Power model, the solar development area is defined, as well as the relevant receptor locations. The result is a chart that states whether a reflection can occur, the duration and the panels that can produce the solar reflection towards the receptor.

4.3.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer freely available however it is now developed by Forge Solar. Pager Power uses this model where required for aviation receptors. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology is widely used by aviation stakeholders internationally.

Pager Power has undertaken many glint and glare assessments with both models (SGHAT and Pager Power's) producing similar results. In this study both models were used.

4.4 Assessment Limitations

Further technical details regarding the methodology of the geometric calculations and limitations are presented in Appendix E and Appendix F.

5 IDENTIFICATION OF RECEPTORS

5.1 Ground-Based Receptors

5.1.1 Overview

There is no formal guidance with regard to the maximum distance at which glint and glare should be assessed. From a technical perspective, there is no maximum distance for potential reflections. The significance of a reflection, however, decreases with distance because the proportion of an observer's field of vision that is taken up by the reflecting area diminishes as the separation distance increases. Terrain and shielding by vegetation are also more likely to obstruct an observer's view at longer distances.

The above parameters and extensive experience over a significant number of glint and glare assessments undertaken show that consideration of receptors within 1km of solar PV module areas is appropriate for glint and glare effects on roads and dwellings, and consideration of receptors within 500m of panel areas is appropriate for glint and glare effects on railways. Therefore, the study area has been designed accordingly as a 1km boundary from solar PV module areas for roads and dwellings, and a 500m boundary from solar PV module areas for railways (white outlined areas on the proceeding figures). The panels are fixed south facing and solar reflections at ground level towards the north at this latitude are highly unlikely. Therefore, the area to the north of the northern-most solar panels has been excluded.

Potential receptors are identified based on mapping and aerial photography of the region. The initial judgement is made based on a high-level consideration of aerial photography and mapping i.e. receptors are excluded if it is clear from the outset that no visibility would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible.

5.1.2 Road Receptors

Road types can generally be categorised as:

- Major National – Typically a road with a minimum of two carriageways with a maximum speed limit of up to 70mph. These roads typically have fast-moving vehicles with busy traffic.
- National – Typically a road with a one or more carriageways with a maximum speed limit of up to 60mph or 70mph. These roads typically have fast-moving vehicles with moderate to busy traffic density.
- Regional – Typically a single carriageway with a maximum speed limit of up to 60mph. The speed of vehicles will vary with a typical traffic density of low to moderate; and
- Local - Typically roads and lanes with the lowest traffic densities. Speed limits vary.

Technical modelling is not recommended for local roads, where traffic densities are likely to be relatively low. Any solar reflections from the Proposed Development that are experienced by a road user along a local road would be considered low impact in the worst case in accordance with the guidance presented in Appendix D.

The analysis has considered any major national, national, and regional roads that:

- are within the one-kilometre study area; and
- have a potential view of the panels.

In total, 211 road receptor locations have been identified distanced circa 100m apart across multiple road sections:

- A1(M) (road receptors 1 to 22);
- Aycliffe Interchange/A167 (road receptors 23 to 41);
- Lime Lane (road receptors 42 to 73);
- Ricknall Lane/Lodge Lane (road receptors 74 to 103);
- Elstob Lane/Bishopton Lane (road receptors 104 to 145);
- Unnamed Road/The Green/ High Street (road receptors 146 to 188);
- South Street (road receptors 189 to 207);
- Whitton Road (road receptors 208 to 211).

These receptors are shown in Figure 2 on the following page and in more detail in Figure 3 to Figure 10 on the following pages. A height of 1.5 metres above ground level has been taken as a typical eye-level for a road user[16]. This height has therefore been added to the ground height at each receptor location. Visibility and direction of travel are considered in the assessment of all receptors.

[16] This height is chosen for modelling purposes, elevated drivers are considered in the results discussion where appropriate.

Figure 2 *Overview of road receptors – aerial image*

Figure 3 *A1(M): road receptors 01 to 22 – aerial image*

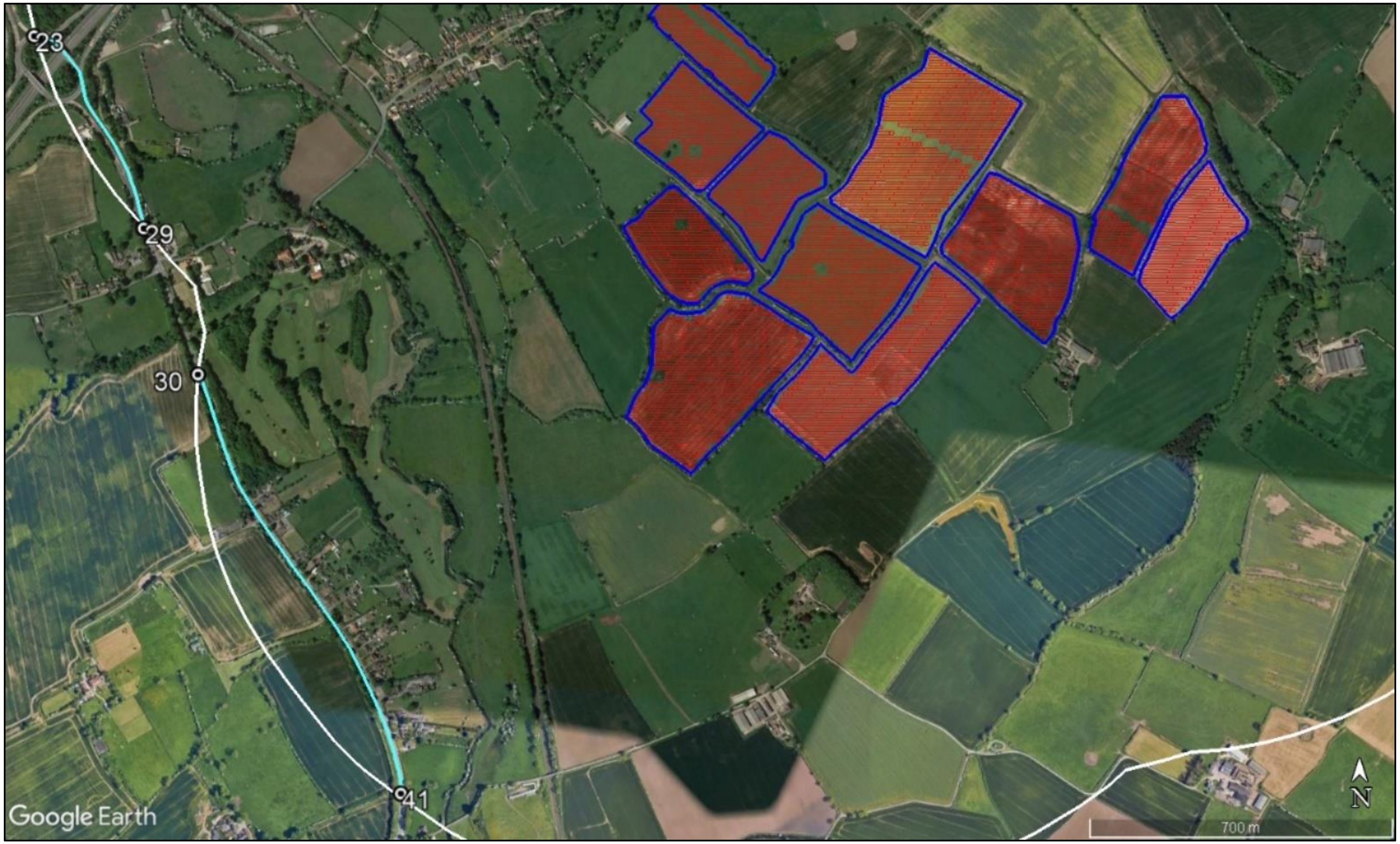

Figure 4 *Aycliffe Interchange/A167: road receptors 23 to 41 – aerial image*

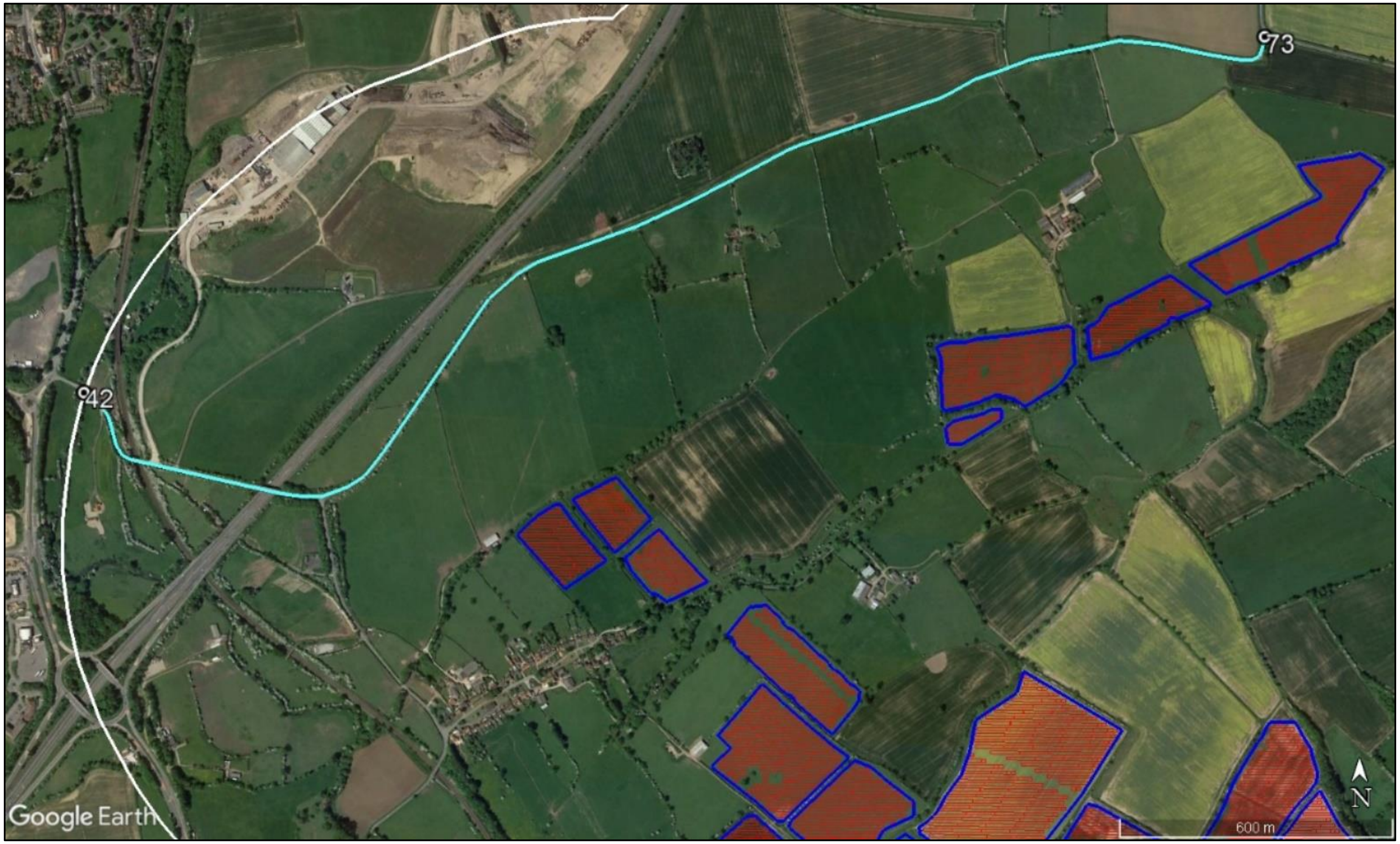

Figure 5 *Lime Lane: road receptors 42 to 73 – aerial image*

Figure 6 *Ricknall Lane/Lodge Lane: road receptors 74 to 103 – aerial image*

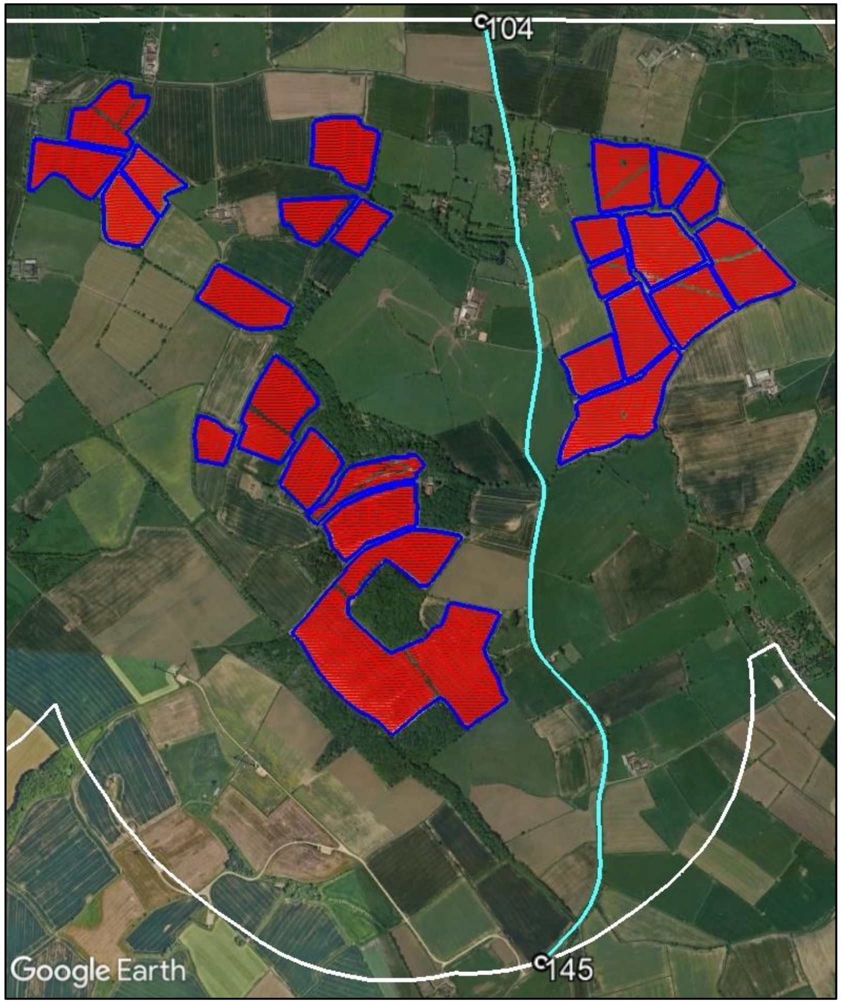

Figure 7 *Elstob Lane/Bishopton Lane: road receptors 104 to 145 – aerial image*

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Figure 8 *Unnamed Road/The Green/ High Street: road receptors 146 to 188 – aerial image*

Figure 9 *South Street: road receptors 189 to 207 – aerial image*

Figure 10 *Whitton Road: road receptors 208 to 211 – aerial image*

5.1.3 Dwelling Receptors

The analysis has considered dwellings that:

- are within the one-kilometre study area; and
- have a potential view of the panels.

In residential areas with multiple layers of dwellings, only the outer dwellings have been considered for assessment. This is because they will mostly obscure views of the solar panels to the dwellings behind them, which will therefore not be impacted by the Proposed Development because line of sight will be removed, or they will experience comparable effects to the closest assessed dwelling.

In some cases, one physical structure is split into multiple separate addresses. In such cases, the results for the assessed location will be applicable to all associated addresses. The sampling resolution is sufficiently high to capture the level of effect for all potentially affected dwellings. A height of 1.8 metres above ground level has been taken as typical eye-level for an observer on the ground floor of the dwelling since this is typically the most occupied floor of a dwelling throughout the day[17].

In total, 259 dwellings were identified for assessment, as shown in Figure 11 on the following page. These receptors are shown in more detail in Figure 12 to Figure 53 on the following pages.

[17] This fixed height for the dwelling receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views above ground floor are considered in the results discussion where necessary.

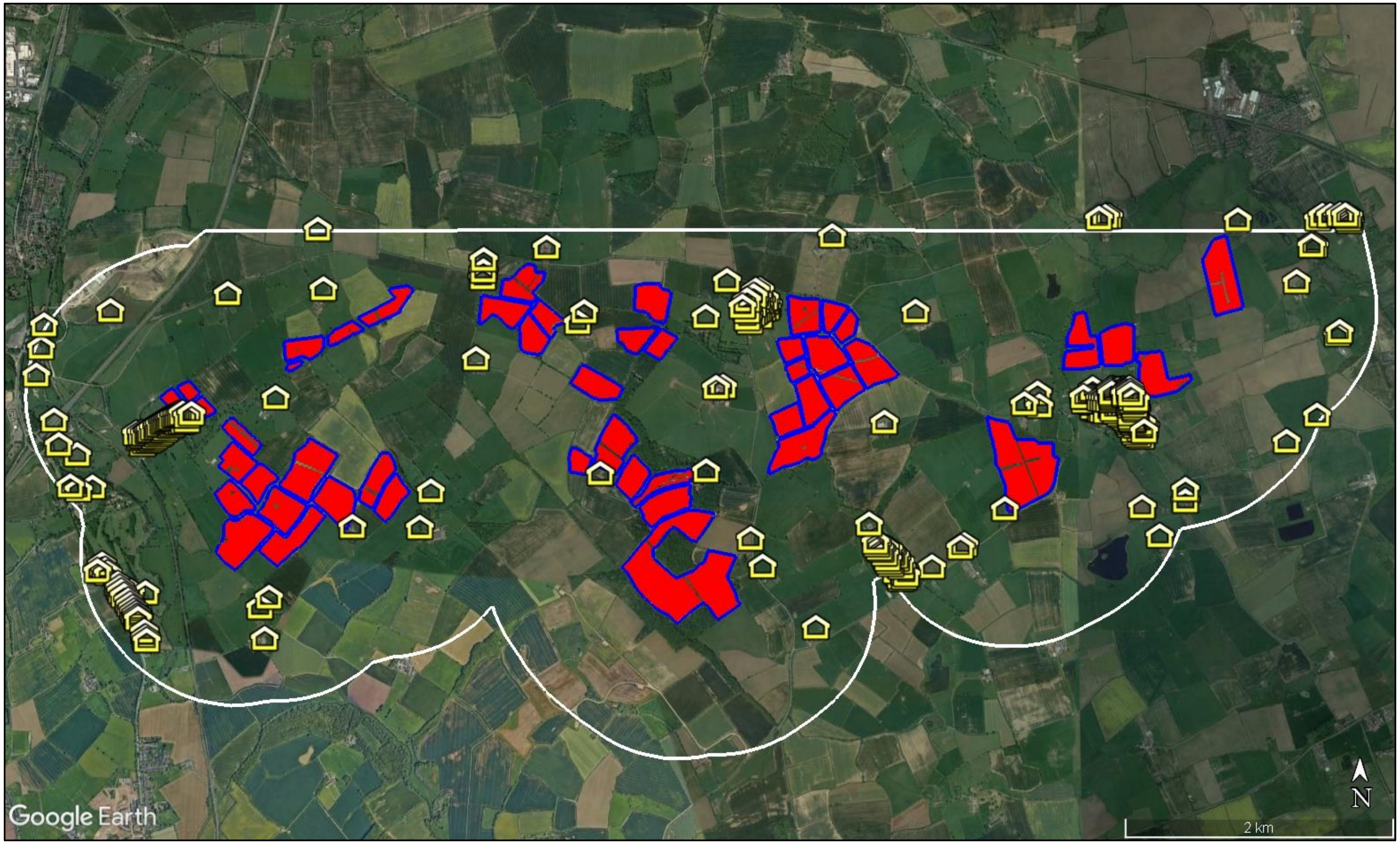

Figure 11 *Overview of dwelling receptors – aerial image*

Figure 12 *Assessed dwelling receptors 1 and 2 – aerial image*

Figure 13 *Assessed dwelling receptor 3 – aerial image*

Figure 14 *Assessed dwelling receptor 4 – aerial image*

Figure 15 *Assessed dwelling receptors 5 to 7 – aerial image*

Figure 16 *Assessed dwelling receptors 8 to 10 – aerial image*

Figure 17 *Assessed dwelling receptors 11 to 19 – aerial image*

Figure 18 *Assessed dwelling receptors 20 to 30 – aerial image*

Figure 19 *Assessed dwelling receptors 31 to 33 – aerial image*

Figure 20 *Assessed dwelling receptors 34 to 75 – aerial image*

Figure 21 *Assessed dwelling receptor 76 – aerial image*

Figure 22 *Assessed dwelling receptor 77 – aerial image*

Figure 23 *Assessed dwelling receptors 78 to 80 – aerial image*

Figure 24 *Assessed dwelling receptors 81 to 83 – aerial image*

Figure 25 *Assessed dwelling receptors 84 – aerial image*

Figure 26 *Assessed dwelling receptor 85 – aerial image*

Figure 27 *Assessed dwelling receptors 86 to 89 – aerial image*

Figure 28 *Assessed dwelling receptor 90 – aerial image*

Figure 29 *Assessed dwelling receptors 91 and 92 – aerial image*

Figure 30 *Assessed dwelling receptors 93 to 116 – aerial image*

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Figure 31 *Assessed dwelling receptors 117 and 118 – aerial image*

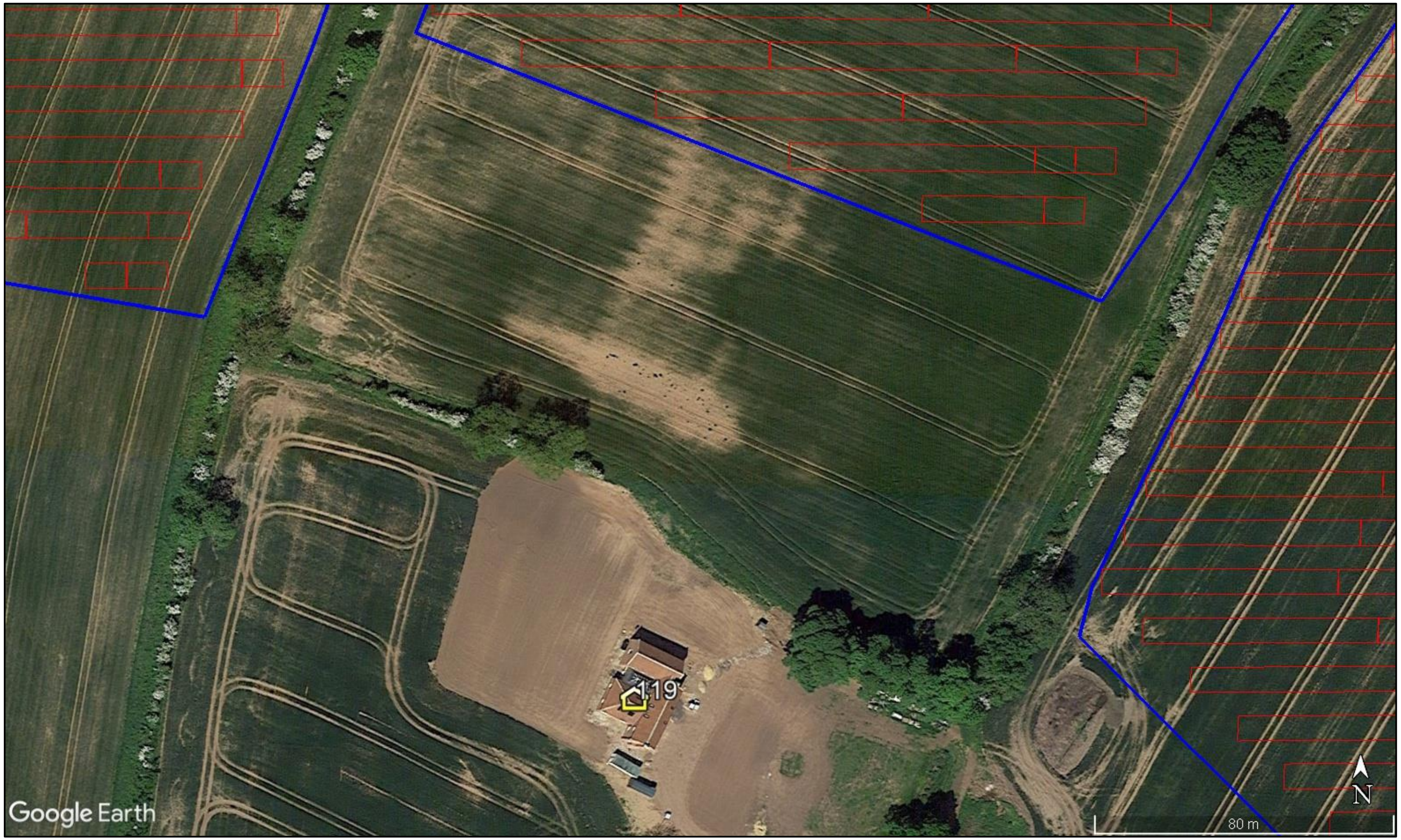

Figure 32 *Assessed dwelling receptor 119 – aerial image*

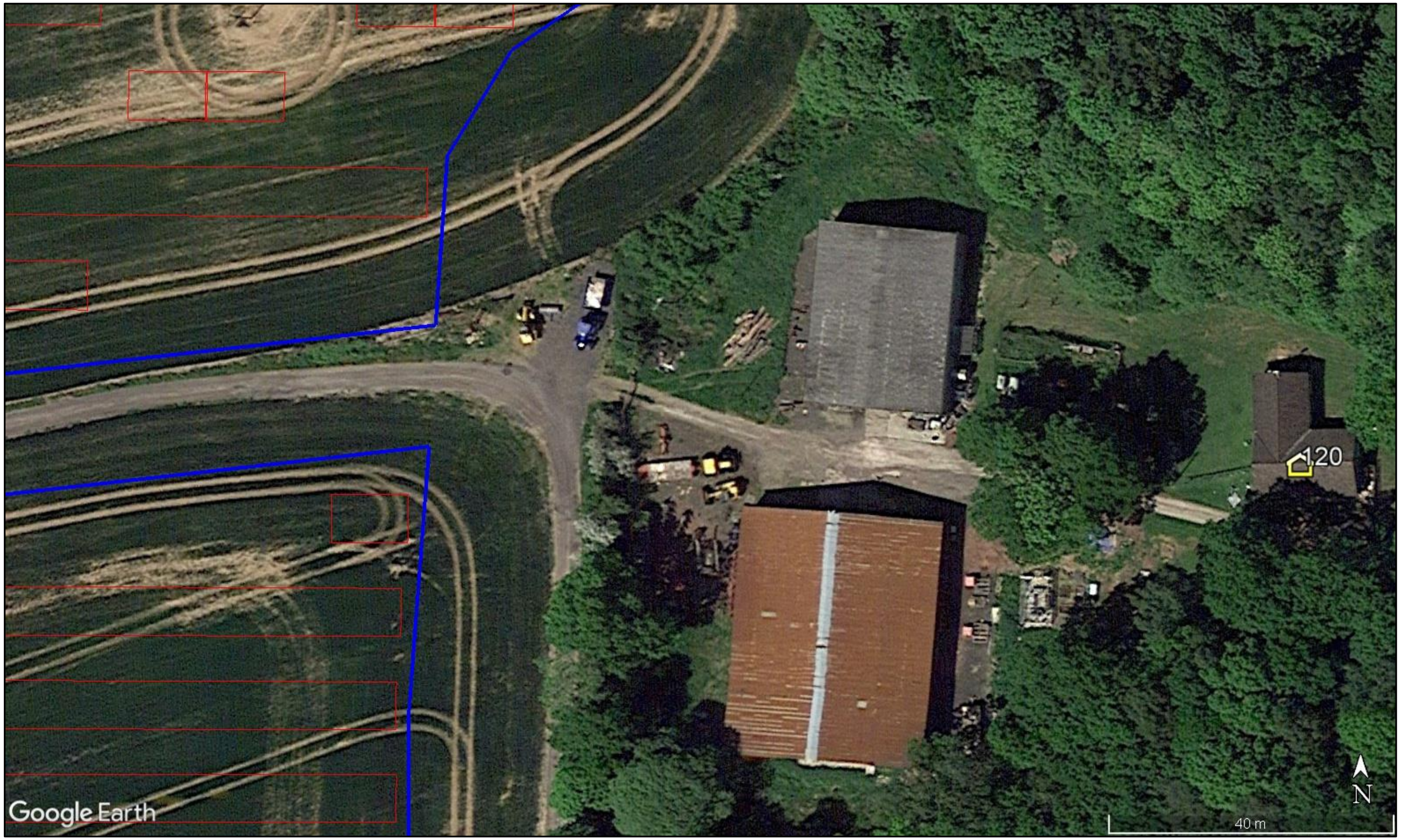

Figure 33 *Assessed dwelling receptor 120 – aerial image*

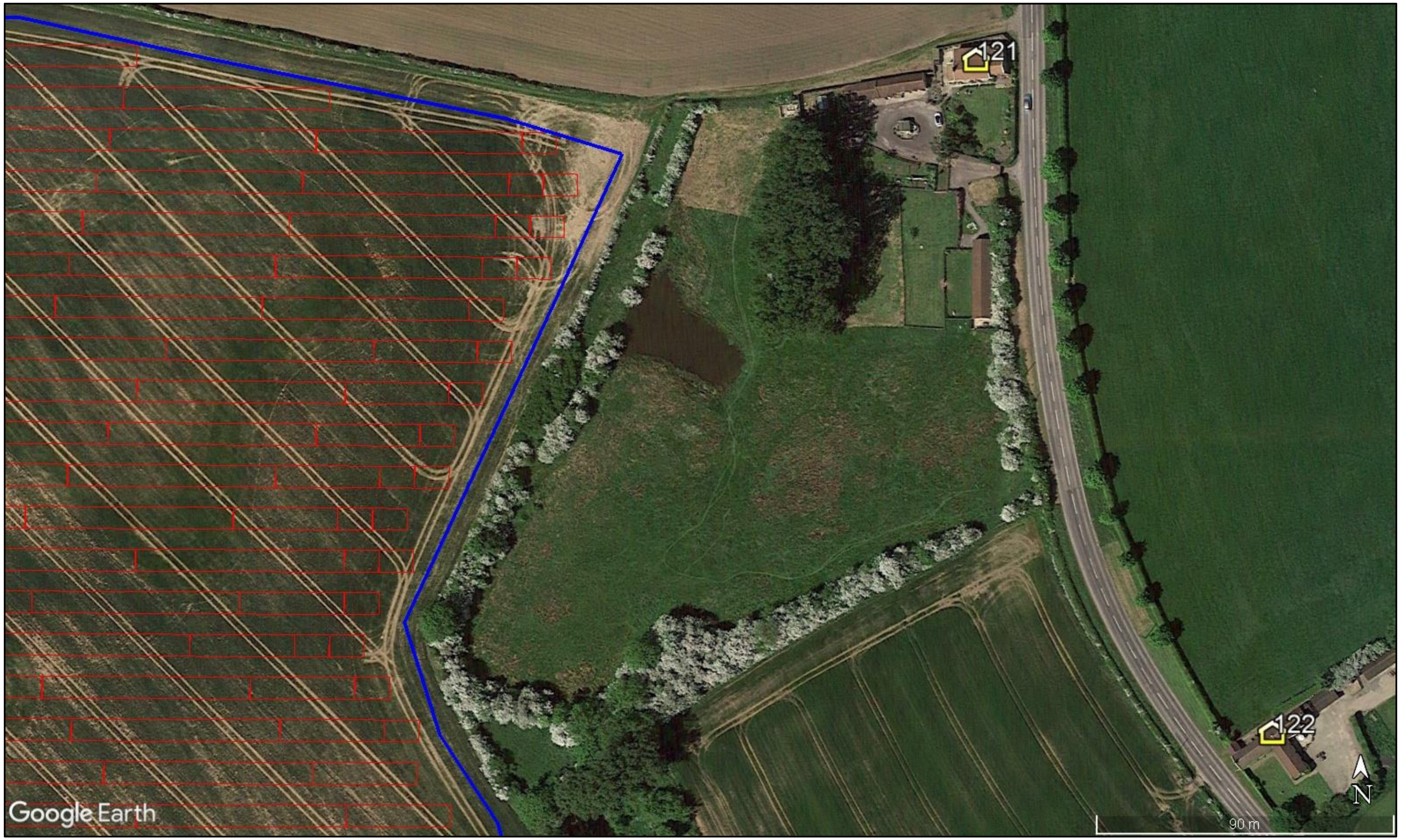

Figure 34 *Assessed dwelling receptor 121 and 122 – aerial image*

Figure 35 *Assessed dwelling receptor 123 – aerial image*

Figure 36 *Assessed dwelling receptor 124 – aerial image*

Figure 37 *Assessed dwelling receptor 125 – aerial image*

Figure 38 *Assessed dwelling receptor 126 – aerial image*

Figure 39 *Assessed dwelling receptor 127 – aerial image*

Figure 40 *Assessed dwelling receptors 128 to 153 – aerial image*

Figure 41 *Assessed dwelling receptors 154 and 155 – aerial image*

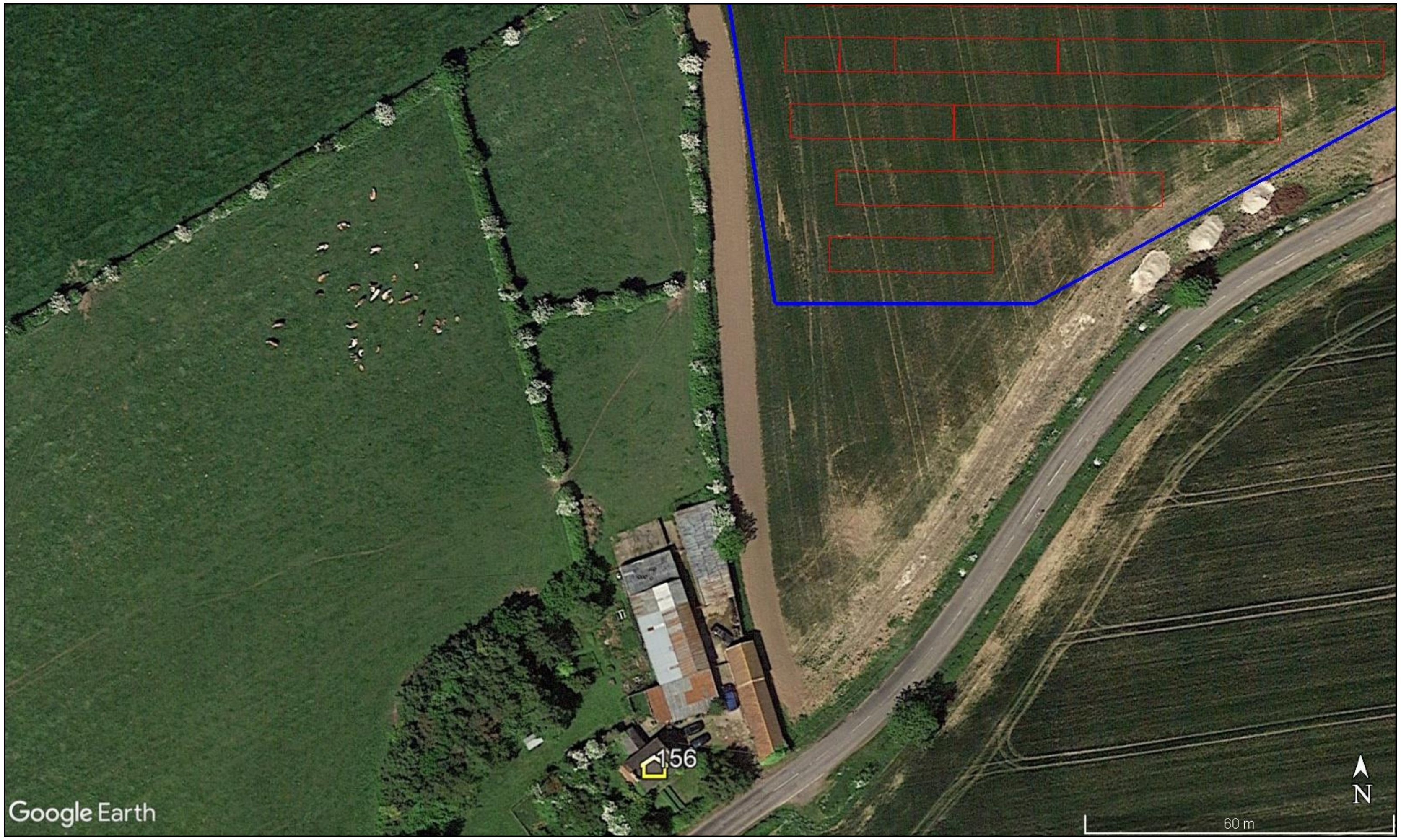

Figure 42 *Assessed dwelling receptor 156 – aerial image*

Figure 43 *Assessed dwelling receptors 157 to 159 – aerial image*

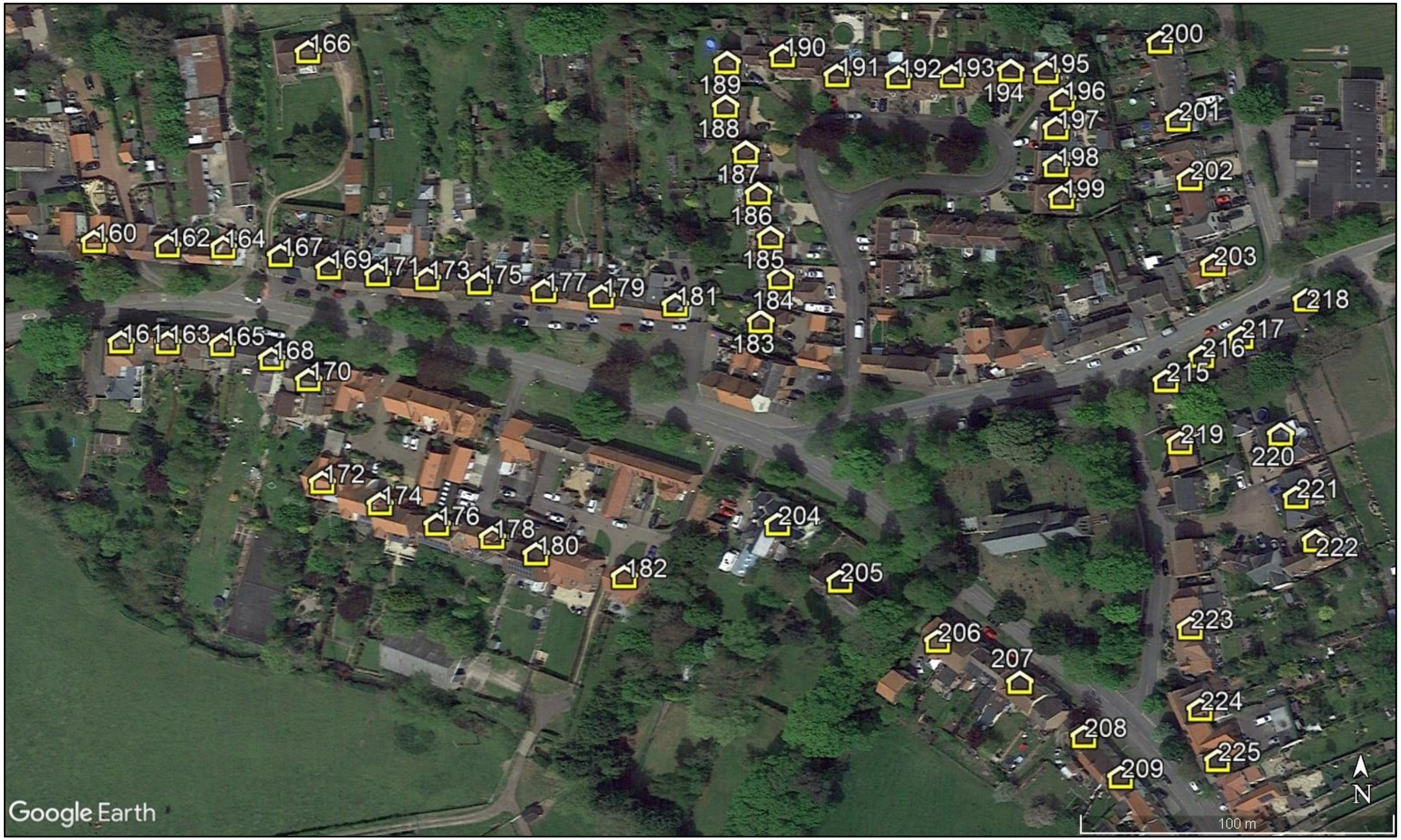

Figure 44 *Assessed dwelling receptors 160 to 209 and 215 to 225 – aerial image*

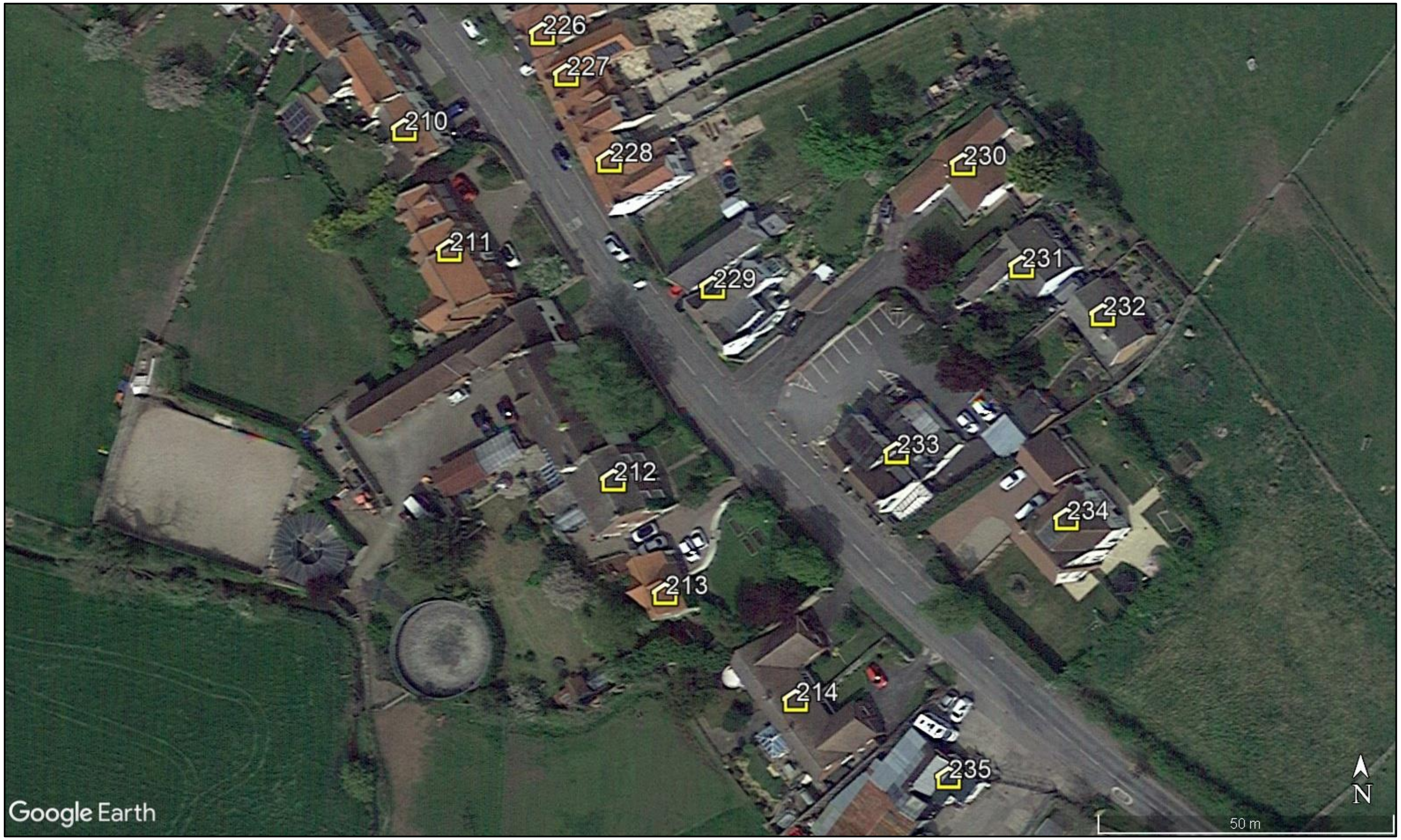

Figure 45 *Assessed dwelling receptors 210 to 214 and 226 to 235 – aerial image*

Figure 46 *Assessed dwelling receptors 236 to 237 – aerial image*

Figure 47 *Assessed dwelling receptors 238 and 239 – aerial image*

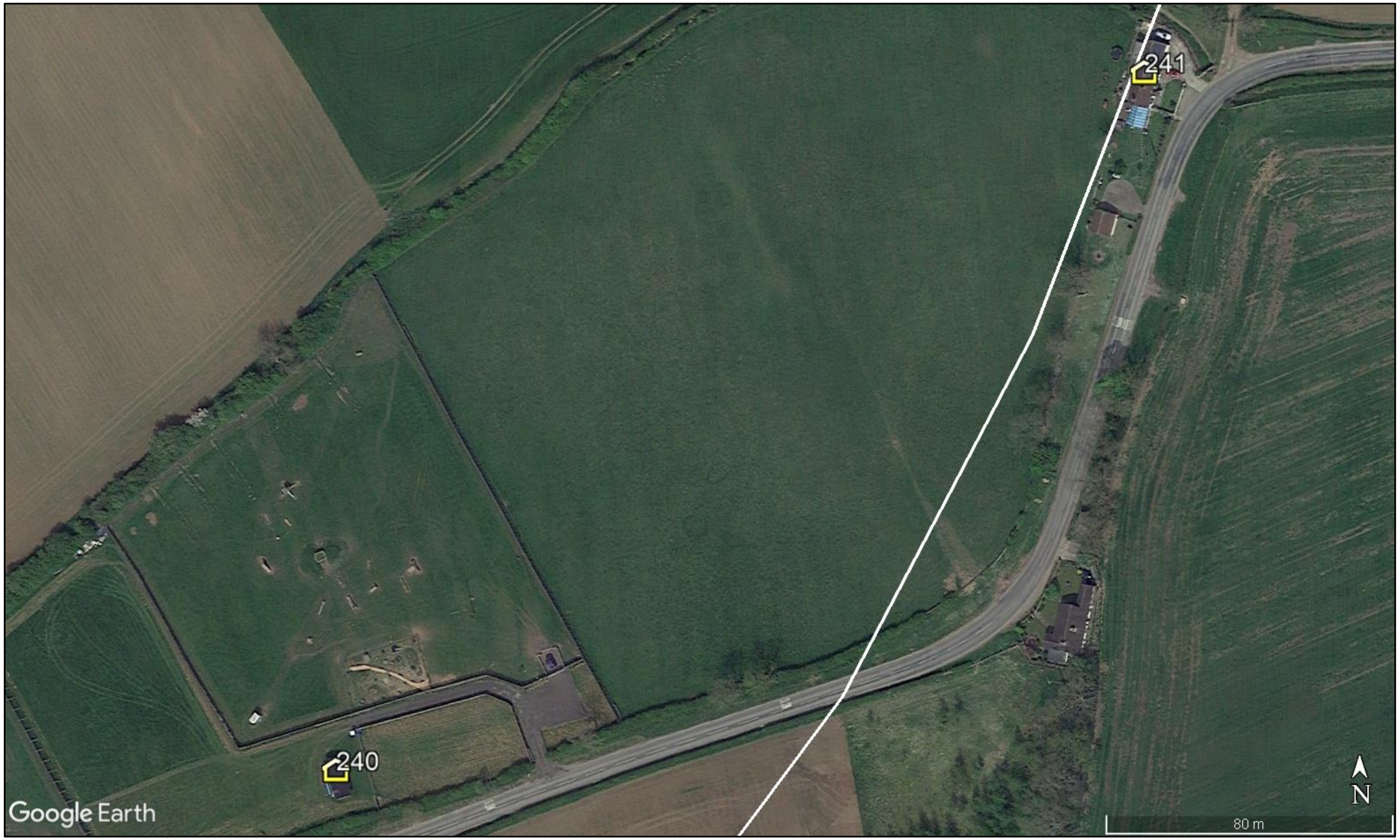

Figure 48 *Assessed dwelling receptors 240 to 241 – aerial image*

Figure 49 *Assessed dwelling receptors 242 to 244 – aerial image*

Figure 50 *Assessed dwelling receptor 245 – aerial image*

Figure 51 *Assessed dwelling receptors 246 to 256 – aerial image*

Figure 52 *Assessed dwelling receptor 257 – aerial image*

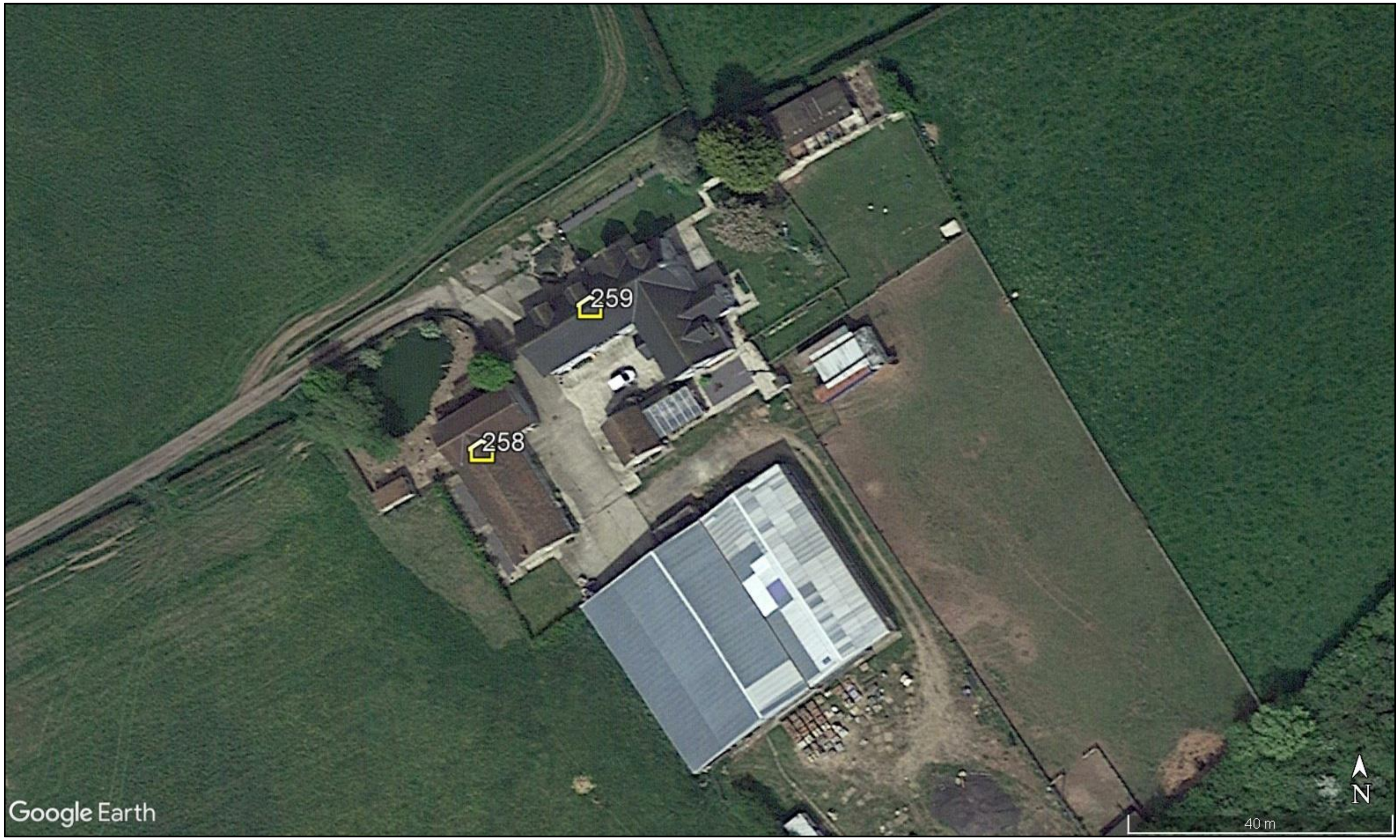

Figure 53 *Assessed dwelling receptors 258 to 259 – aerial image*

5.2 Railway Receptors

5.2.1 Train Driver Receptors

A 1.4km section of railway line has been identified for assessment, as shown by the blue line in Figure 54 below. In total, 15 train driver receptors locations are identified, distanced circa 100m apart.

Figure 54 *Overview of train driver receptors – aerial image*

5.2.2 Consideration of Railway Signals

Following a review of available imagery and consultation with Network Rail, three railway signals have been identified along the assessed section of railway line.

An overview of the approximate signal locations is shown in Figure 55 on the following page relative to the section of the railway line towards which solar reflections are geometrically possible.

Based on a review of the available imagery, all three signals are predicted to be significantly screened by intervening vegetation (shown in Figure 56 and Figure 57). For signals 1 and 2, the bulbs are already fitted with hoods. Fitting such signals with hoods is the most common mitigation for cases where reflections are of concern.

No significant impacts on the railway signals are therefore predicted, and technical modelling is not recommended.

Figure 55 *Identified railway signal locations – aerial image*

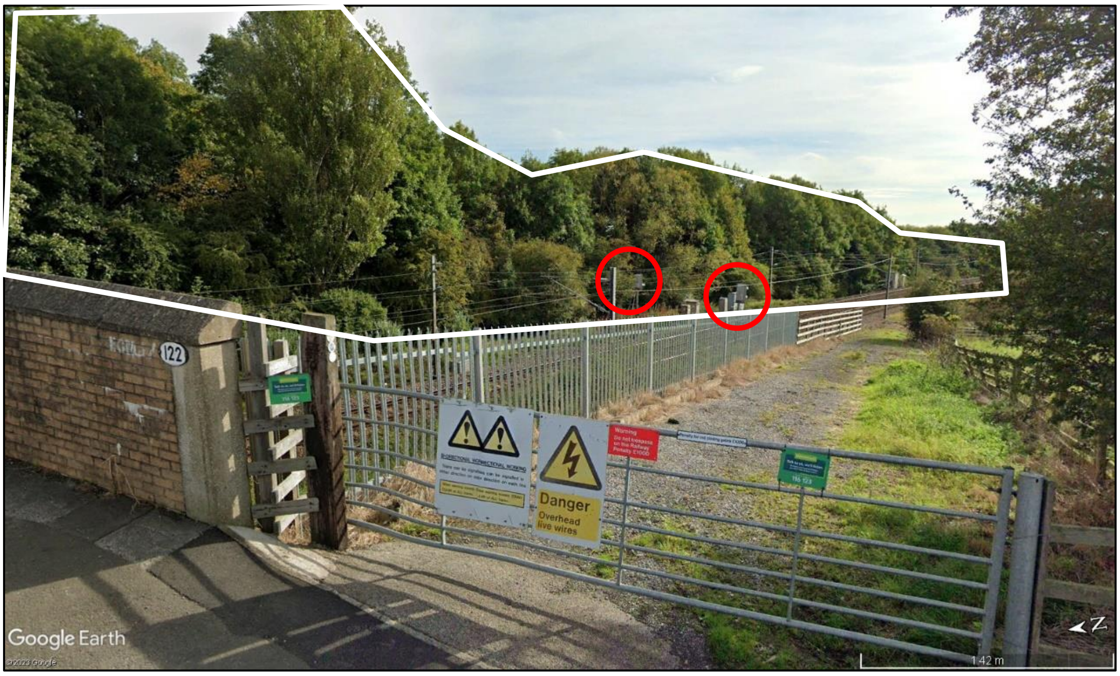

Figure 56 *Signals 1 and 2 outlined in red, significant vegetation screening outline in white*

Figure 57 *Signal 3 and significant vegetation screening outlined in white*

5.3 Aviation Receptors

5.3.1 Overview

One active airfield has been identified for the assessment; this is Teesside International Airport, a licensed aerodrome located south of the Proposed Development area, within 10km.

5.3.2 Air Traffic Control (ATC) Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within the ATC tower. The ATC tower for Teesside International Airport is located approximately 7.5km south of the Proposed Development. Figure 58 below and Figure 59 on the following page show the ATC tower. The location relative to the Proposed Development is shown in Figure 60 on page 81. The height of the visual control room has been approximated from imagery (12m agl).

Figure 58 *ATC Tower at Teesside International Airport – aerial image*

Figure 59 *ATC Tower at Teesside International Airport – street view image*

5.3.3 Approaching Aircraft

Teesside International Airport has one runway, with two associated approaches. The runway details are presented below[18]:

- 05/23 measuring 2,291m by 45m (asphalt).

It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. This is considered to be the most critical stage of the flight.

A geometric glint and glare assessment has been undertaken for both aircraft approach paths. The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from 50ft above the runway threshold out to a distance of 2 miles. The height of the aircraft is determined by using a 3-degree descent path relative to the runway threshold height.

The coordinate and altitude data defining the start and end points for each runway approach are presented in Appendix G.

Figure 60 on the following page shows the assessed aircraft approach paths (light blue lines) relative to the Proposed Development location.

[18] Source: NATS AIP last accessed November 2023

Figure 60 *Assessed runway approach paths and ATC Tower at Teesside International Airport – aerial image*

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

The following sub-sections present the modelling results as well as the significance of any predicted impact in the context of existing screening, and the relevant criteria set out in the next subsection. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.

When determining the visibility of the reflecting panels for an observer, a conservative review of the available imagery is undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

The modelling output showing the precise predicted times and the reflecting panel areas can be provided on request.

6.2 Roads

6.2.1 Impact Significance Methodology

The key considerations for road users along major national, national, and regional roads are:

- Whether a reflection is predicted to be experienced in practice; and
- The location of the reflecting panel relative to a road user's direction of travel.

Where the reflecting panels are predicted to be significantly obstructed from view, no impact is predicted, and mitigation is not required.

Where solar reflections are not experienced as a sustained source of glare, originate from outside of a road user's primary horizontal field of view (50 degrees either side of the direction of travel), or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not recommended.

Where sustained solar reflections are predicted to be experienced from inside of a road user's primary field of view, expert assessment of the following factors is required to determine the impact significance and mitigation requirement:

- Whether the solar reflection originates from directly in front of a road user – a solar reflection that is directly in front of a road user is more hazardous than a solar reflection to one side;
- Whether visibility is likely for elevated drivers (applicable to dual carriageways and motorways only) – there is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of road;
- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

If following consideration of the relevant factors, the solar reflections do not remain significant, the impact significance is low, and mitigation is not recommended.

If following consideration of the relevant factors, the solar reflections remain significant, then the impact significance is moderate, and mitigation is recommended.

Where solar reflections originate from directly in front of a road user and there are no mitigating factors, the impact significance is high, and mitigation is required.

6.2.2 Geometric Modelling Results

The modelling results[19] for road receptors are presented in Table 2 on the following page.

[19] Only considering reflections from solar panels within 1km of the receptor. Reflections outside of 1km are not considered to be significant.

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
1	Solar reflections are not geometrically possible	N/A	N/A	None	No
2 – 7	Solar reflections predicted to originate from **<u>inside</u>** of a road user's primary horizontal field of view 05:30-06:30 in March-May and August-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
8 – 23	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
24	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 05:30-06:00 in April-May and July-August	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
25 – 26	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 05:00-06:00 in May-August	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
27 – 30	Solar reflections are not geometrically possible	N/A	N/A	None	No
31 – 36	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 05:00-06:30 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
37 – 46	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
47 – 49	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 05:30-06:30 in March and September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
50 – 80	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
81 – 83	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 05:30-06:30 in March-April and August-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
84 - 86	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 05:30-06:30 in March-September	Some existing vegetation screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	N/A	Moderate	No
87 – 89	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
90 – 91	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 05:30-06:30 in March and September	Some existing vegetation and terrain screening Proposed hedgerow/tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	N/A	Moderate	No
92 – 108	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
109 – 112	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 05:00-06:30 and 18:00-19:00 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
113-117	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 05:00-06:30 and 18:00-19:00 in March-September	Some existing vegetation and terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
118 – 119	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 05:00-06:30 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
120 – 121	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 05:00-06:30 and 18:00-19:00 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
122-123	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 05:00-06:30 and 18:00-19:00 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
124 – 125	Solar reflections predicted to originate from outside of a road user's primary horizontal field of view 18:00-19:00 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

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Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
126 – 129	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 18:00-19:00 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of the majority of the reflecting panels are not expected to be possible in practice	N/A	Low	No
130 – 131	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 18:00-19:00 in March-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
132-134	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 18:00-19:00 in March-September	Some vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting w Views of the majority of the reflecting panels are not expected to be possible in practice	Closest reflecting panels are at least 0.3km away Reflections do not originate from directly in front of the road user Reflections are possible within 3 hours of sunset	Low	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
135 - 138	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 18:00-19:00 in March-September	Some vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of the majority of the reflecting panels are not expected to be possible in practice	N/A	Low	No
139 – 148	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
149 – 150	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 18:00-19:00 in March and September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
151-153	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
154	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 17:00-18:00 in April and September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
155 – 161	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 17:00 – 18:00 and 05:00- 06:00 in March-September	Some existing vegetation screening Proposed hedgerow and tree planting Significant views of reflecting panels are not expected to be possible in practice once planting has sufficiently matured	N/A	Moderate	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
162 – 170	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 17:00 – 18:00 and 05:00- 06:00 in March-September	Some existing vegetation screening Proposed hedgerow and tree planting Significant views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	N/A	Moderate	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
171 – 177	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 05:00-06:00 in April-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No
178 – 186	Solar reflections predicted to originate from **inside** of a road user's primary horizontal field of view 18:00-19:00 in March-May and July-September	Existing vegetation, buildings, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Further Mitigation Recommended/Required?
187 – 188	Solar reflections are not geometrically possible	N/A	N/A	None	No
189	Solar reflections predicted to originate from **outside** of a road user's primary horizontal field of view 18:00-19:00 in March-April and August-September	Existing vegetation screening Proposed hedgerow and tree planting Views of the reflecting panels are not expected to be possible in practice	N/A	None	No
190 - 211	Solar reflections are not geometrically possible	N/A	N/A	None	No

Table 2 *Geometric modelling results, assessment of impact significance, and mitigation recommendation/requirement – road receptors*

6.2.3 Screening Review

A review of screening is presented in Appendix H.

6.2.4 Conclusions

A moderate impact is predicted on:

- A 0.2km section (road receptors 84-86) and 0.1km section (road receptors 90-91) of Ricknall Lane/Lodge Lane;
- A 1.5km section of Unnamed Road/The Green/ High Street (road receptors 155 to 170).

Assuming that the height of proposed hedgerow/tree planting along reflecting panel boundaries for these sections will be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none, no further mitigation is recommended.

Further details are provided in Section 7 of the report.

A low impact is predicted on:

- A 0.3km section of Elstob Lane/Bishopton Lane (road receptors 126-129); and
- A 0.6km section of Elstob Lane/Bishopton Lane (road receptors 132-138).

This is because solar reflections are geometrically possible from outside of a road user's primary field of view (50 degrees either side), and/or there are significant mitigating factors such as:

- Significant clearance distance between road user and closest visible reflecting panel;
- Reflections incident with sunlight;
- Generally low traffic volume/density expected along most sections.

No impacts are predicted on the remaining assessed road sections, because solar reflections are not geometrically possible, or there is significant screening in the form of existing vegetation, buildings, and/or terrain such that reflections would not be visible in practice.

6.3 Dwellings

6.3.1 Impact Significance Methodology

The key considerations for residential dwellings are:

- Whether a reflection is predicted to be experienced in practice;
- The duration of the predicted effects, relative to thresholds of:
  - 3 months per year;
  - 60 minutes on any given day.

Where solar reflections are not geometrically possible or the reflecting panels are predicted to be significantly obstructed from view, no impact is predicted, and mitigation is not required.

Where solar reflections are experienced for less than three months per year and less than 60 minutes on any given day, or the closest reflecting panel is over 1km from the dwelling, the impact significance is low, and mitigation is not recommended.

Where reflections are predicted to be experienced for more than three months per year **and/or** for more than 60 minutes on any given day, expert assessment of the following mitigating factors is required to determine the impact significance and mitigation requirement:

- Whether visibility is likely from all storeys – the ground floor is typically considered the main living space and has a greater significance with respect to residential amenity;
- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- Whether the dwelling appears to have windows facing the reflecting area – factors that restrict potential views of a reflecting area reduce the level of impact;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

If following consideration of the relevant factors, the solar reflections do not remain significant, the impact significance is low, and mitigation is not recommended. If following consideration of the relevant factors, the solar reflections remain significant, then the impact significance is moderate, and mitigation is recommended.

If effects last for more than three months per year and for more than 60 minutes on any given day, and there are no mitigating factors, the impact significance is high, and mitigation is required.

6.3.2 Geometric Modelling Results

The modelling results[20] for dwelling locations are presented in Table 3 on the following page.

[20] Only considering reflections from solar panels within 1km of the receptor. Reflections outside of 1km are not considered to be significant.

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
01 – 04	Solar reflections are not geometrically possible	N/A	N/A	None	No
05 – 07	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00-06:00 in April-August	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
08 – 09	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
10	Solar reflections predicted for **<u>less</u>** than 60 minutes on any given day and for **<u>less</u>** than 3 months of the year 05:30-06:30 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
11 – 12	Solar reflections predicted for **<u>less</u>** than 60 minutes on any given day and for **<u>more</u>** than 3 months of the year 05:30-06:30 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
13	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:30-06:00 in April-May and July-August	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
14 – 20	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00-06:30 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
21 – 25	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00-06:00 in May-August	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
26 – 33	Solar reflections are not geometrically possible	N/A	N/A	None	No
34 – 37	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00-06:00 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
38 – 47	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00-06:30 in March-May and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
48 – 56	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00-06:30 in March-April and June-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
57 – 60	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00-06:30 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
61 – 75	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00-06:30 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
76	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
77	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 18:00-19:00 in March-May and 17:30-19:00 in July-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
78 – 80	Solar reflections are not geometrically possible	N/A	N/A	None	No
81 – 83	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 17:30-19:00 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
84	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:30-06:30 in March-April and August-September	Some existing vegetation and terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	N/A	Low	No
85	Solar reflections are not geometrically possible	N/A	N/A	None	No
86	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:30-06:30 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
87 – 88	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 06:00 in March-September and 17:30 – 18:30 in March and September	Some existing vegetation screening Proposed hedgerow/tree planting expected to provide significant screening Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	N/A	Moderate	No
89	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
90	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in April-August	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
91	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Existing and proposed vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Visible reflecting panels are at least 0.4km away Reflections incident with sunlight	Low	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
92	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Existing and proposed vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
93 – 97	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
98	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.17km away Reflections incident with sunlight	Moderate	No
99 – 100	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
101	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-May and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.17km away Reflections incident with sunlight	Moderate	No
102 – 103	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
104	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Existing and proposed vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.15km away Reflections incident with sunlight	Moderate	No
105 - 110	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
111 – 115	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Existing and proposed vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.2km away Reflections incident with sunlight	Moderate	No
116	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-September	Vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
117 – 118	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.5km away Reflections incident with sunlight	Low	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
119	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September	Existing vegetation, building, and/or terrain screening Majority of the reflecting panels are expected to be screened Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflections incident with sunlight	Low	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
120	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-September and 18:00 – 19:00 in April-August	Vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
121	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 18:00 – 19:00 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.28km away Reflections incident with sunlight	Low	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
122 – 123	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 18:00 – 19:00 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
124	Solar reflections are not geometrically possible	N/A	N/A	None	No
125	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 18:00 – 19:00 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
126	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in March-April and August-September and 17:00 – 19:00 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.75km away Reflections incident with sunlight	Low	No
127 – 131	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
132 – 133	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00 – 06:00 in May-July	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
134	Solar reflections are not geometrically possible	N/A	N/A	None	No
135 – 136	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00 – 06:00 in June-July	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
137 – 156	Solar reflections are not geometrically possible	N/A	N/A	None	No
157 – 158	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 06:00 in April-August and 18:00 – 19:00 in March-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
159 – 181	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in April-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
182	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 18:00 – 19:00 in March and September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
183 – 199	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 07:00 in April-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
200 – 201	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 05:00 – 06:00 in April-August	Existing vegetation and terrain screening Views of the reflecting panels may be possible	Reflecting panels are at least 0.2km away Reflections possible within approximately 2 hours of sunrise when Sun is low in the sky	Low	No
202 – 203	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 05:00 – 06:00 in May-July	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
204 – 214	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 18:00 – 19:00 in March-April and August-September	Existing vegetation, building, and/or terrain screening Views of the reflecting panels are not predicted	N/A	None	No
215 – 222	Solar reflections are not geometrically possible	N/A	N/A	None	No
223 – 235	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 18:00 – 19:00 in March-April and August-September	Existing vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
236	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 18:00 – 19:00 in March-September	No significant existing screening identified Proposed hedgerow and tree planting Views of the reflecting panels may be possible	Reflecting panels are at least 0.7km away Reflections possible within approximately 2 hours of sunset when Sun is low in the sky	Low	No
237	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 18:00 – 19:00 in May-July	Vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
238	Solar reflections are not geometrically possible	N/A	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
239	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 18:00 – 19:00 in April-May and August	Vegetation, building, and/or terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No
240 – 253	Solar reflections are not geometrically possible	N/A	N/A	None	No
254 – 256	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year 18:00 – 19:00 in March-April and August-September	Vegetation and terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted	N/A	None	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
257	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 18:00 – 19:00 in March-September	Existing vegetation and terrain screening Proposed hedgerow and tree planting Views of the reflecting panels are not predicted for observers on the ground floor Views of reflecting panels from upper floors may be possible	Reflecting panels are at least 0.4km away Windows are not directly facing reflecting areas Reflections possible within approximately 2 hours of sunset when Sun is low in the sky	Low	No

Receptor	Geometric modelling results from panel areas within 1km (without consideration of screening) All times in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
258 – 259	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year 18:00 – 19:00 in April-August	No significant existing screening identified Proposed hedgerow and tree planting Views of reflecting panels are not expected to be possible in practice once proposed planting has sufficiently matured	Reflecting panels are at least 0.75km away Reflections possible within approximately 2 hours of sunset when Sun is low in the sky	Low	No

Table 3 *Geometric modelling results, assessment of impact significance, and mitigation recommendation/requirement – dwelling receptors*

6.3.3 Screening Review

A review of screening is presented in Appendix H.

6.3.4 Conclusions

A moderate impact is predicted on ten dwellings (87-88, 98, 101, 104, 111-115) due to the duration of effects, and the lack of sufficient mitigating factors. Assuming that the height of proposed hedgerow/tree planting along reflecting panel boundaries for these dwellings will be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none, no further mitigation is recommended.

Further information is provided in Section 7.

A low impact is predicted on nine dwellings (84, 91, 117-118, 119, 121, 126, 200-201) due to the duration of effects and the presence of the following mitigating factors:

- Significant separation distance between observer and closest visible reflecting panel;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

The impact may be reduced to none for some of these dwellings once proposed hedgerow/tree planting has been established.

No significant impacts are predicted on any of the remaining 240 dwellings within the assessment area, because where solar reflections are geometrically possible, there is significant existing and/or proposed screening such that reflections lasting more than 60 minutes on any given day and/or 3 months per year are not expected to be possible. Mitigation is not required.

6.4 Railways

6.4.1 Impact Significance Methodology

The key considerations for quantifying impact significance for train driver receptors are:

- Whether a reflection is predicted to be experienced in practice; and
- The location of the reflecting panel relative to a train driver's direction of travel.

Where reflections are not predicted to be experienced by a train driver in practice, no impacts are predicted, and mitigation is not required.

Where reflections originate from outside of a train driver's primary field of view (30 degrees either side of the direction of travel), or the closest reflecting area is over 500m from the train driver, the impact significance is low, and mitigation is not recommended.

Where reflections originate from inside of a train driver's field of view but there are mitigating circumstances, assessment of the following factors is required to determine the impact significance (low or moderate) and mitigation requirement:

- Whether the solar reflection originates from directly in front of a train driver – a solar reflection that is directly in front of a road user is more hazardous than a solar reflection to one side;
- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not; and

- Whether a signal, station, level crossing, or switching point is located within the reflection zone – a train driver with a higher workload will be more impacted than a train driver with a lower workload.

Where reflections originate from directly in front of a train driver and there are no mitigating circumstances, the impact significance is high, and mitigation is required.

6.4.2 Geometric Modelling Results

The modelling has shown that solar reflections are geometrically possible[21] towards a 0.7km section (train driver receptors 06 to 13) of the railway line to the west. This section of railway line is shown in orange in Figure 61 below.

Figure 61 *Section of railway towards which solar reflections are geometrically possible (orange) – aerial image*

The results and analysis are presented in Table 4 on the following page.

[21] Only considering reflections from solar panels within 0.5km of the receptor. Reflections outside of 0.5km are not considered to be significant.

Receptor	Geometric modelling results from panel areas within 500m (without consideration of screening) All times are in GMT	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Baseline Impact Classification	Mitigation Recommended/Required?
01 – 05	Solar reflections are not geometrically possible from panel areas within 500m	N/A	N/A	None	No
06	Solar reflections are predicted to originate from **outside** of a train driver's primary horizontal field of view (from panel area A) 05:00-06:00 in March-April and August-September	Significant vegetation screening Views of the reflecting panels are not predicted	N/A	None	No
07 – 13	Solar reflections are predicted to originate from **outside** of a train driver's primary horizontal field of view (from panel area A) 05:00-06:15 in March-September	Vegetation screening but height and density is unclear Views of the reflecting panels may be possible	Reflecting panels are at least 0.4km away Reflections possible within approximately 2 hours of sunrise when Sun is low in the sky	Low	No

Table 4 *Geometric modelling results, assessment of impact significance, and mitigation recommendation/requirement – train driver receptors*

6.4.3 Screening Review

A review of screening is presented in Appendix I.

6.4.4 Conclusions

No significant impacts are predicted on any of the modelled railway sections, because where solar reflections are geometrically possible, the reflecting panels are significantly screened, or they are outside of the typical field of view (30 degrees either side) with significant mitigating factors such as:

- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.
- Significant clearance distance between train driver and closest reflecting panel.

Mitigation is not recommended.

6.5 Aviation

6.5.1 Glare Intensity Designation

The Forge model has been used to determine whether reflections are possible. Intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for aviation receptors. These calculations are routinely required for solar photovoltaic developments on or near aerodromes. The intensity model calculates the expected intensity of a reflection with respect to the potential for an after-image (or worse) occurring. The designation used by the model is presented in Table 5 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	Glare beyond 50 deg from pilot line-of-sight
Low potential	Low potential for temporary after-image
Potential	Potential for temporary after-image
Potential for permanent eye damage	Potential for permanent eye damage

Table 5 *Glare intensity designation*

This coding has been used in the table where a reflection has been calculated and is in accordance with Sandia National Laboratories' methodology.

In addition, the intensity model allows for assessment of a variety of solar panel surface materials. In the first instance, a surface material of 'smooth glass without an anti-reflective coating' is assessed. This is the most reflective surface and allows for a 'worst case' assessment. Other surfaces that could be modelled include:

- Smooth glass with an anti-reflective coating;
- Light textured glass without an anti-reflective coating;
- Light textured glass with an anti-reflective coating; or
- Deeply textured glass.

If significant glare is predicted, modelling of less reflective surfaces could be undertaken.

6.5.2 Key Considerations for ATC Tower

The process for quantifying impact significance is defined in the report appendices. For an ATC Tower, the key considerations are:

- Whether a reflection is predicted to be experienced in practice.
- The intensity of glare for the solar reflections:
  - Glare with 'low potential for temporary after-image' (green glare).
  - Glare with 'potential for temporary after-image' (yellow glare).
  - Glare with 'potential for permanent eye damage' (red glare).
- Whether a reflection is predicted to be operationally significant in practice or not.

Where no solar reflections are geometrically possible or where solar reflections are predicted to be significantly screened, no impact is predicted, and mitigation is not required.

Glare of any kind towards an ATC tower was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[22] for on-airfield solar. Whilst this guidance was never formally applicable outside of the USA, it has been a common point of reference internationally. Pager Power recommends a pragmatic approach to consider glare towards the ATC Tower in an operational context. As per Pager Power's glint and glare guidance document[23], where solar reflections are of an intensity no greater than 'low potential for temporary after-image' (green glare) expert assessment of the following relevant factors is required to determine the impact significance[24]:

- The likely traffic volumes and level of safeguarding at the aerodrome. Licensed aerodromes typically have higher traffic volumes and are formally safeguarded. Unlicensed aerodromes have greater capacity for operational acceptance.
- The time of day at which glare is predicted. Will the ATC Tower be operational at the time of day at which glare is predicted?
- The duration of any predicted glare. Glare that is experienced for low durations throughout the year is less significant than longer durations.
- Glare location relative to key operational areas. A solar reflection originating near sensitive areas such as the runway threshold will have a higher impact upon ATC personnel.
- The relative size of the reflecting panel area. Does the reflecting area make up a large percentage of an ATC observer's field of view?[25]

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[22] This FAA guidance from 2013 has since been superseded by the FAA guidance in 2021 whereby airports are tasked with determining safety requirements themselves.
[23] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.
[24] This approach taken is reflective of the changes made in the 2021 FAA guidance; however, it should be noted that this guidance states that it is up to the airport to determine the safety requirements themselves. Therefore, an airport may not accept any glare towards an ATC Tower.
[25] 210 degrees azimuth field of view.

- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible. Effects that coincide with direct sunlight appear less prominent than those that do not.
- The intensity of the predicted glare. Is the intensity of glare close to the green/yellow glare threshold on the intensity chart?
- The level of predicted effect relative to existing sources of glare. A solar reflection is less noticeable by ATC personnel when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating factors, where the solar reflection does not remain significant, a low impact is predicted, and mitigation is not recommended; however, consultation with the aerodrome is recommended to understand their position along with any feedback or comments regarding the Proposed Development. Where the solar reflection remains significant or where glare with no greater than 'potential for temporary after-image' (yellow glare) is predicted, the impact significance is moderate, and mitigation is recommended.

Where solar reflections are of an intensity greater than 'potential for temporary after-image', the impact significance is high, and mitigation is required.

6.5.3 Key Considerations for Runway Approaches

The process for determining impact significance is defined in Appendix D. For the runway approach paths, the key considerations are:

- Whether a reflection is predicted to be experienced in practice;
- The location of glare relative to a pilot's primary field of view (50 degrees either side of the approach bearing).
- The intensity of glare for the solar reflections:
  - Glare with 'low potential for temporary after-image' (green glare).
  - Glare with 'potential for temporary after-image' (yellow glare).
  - Glare with 'potential for permanent eye damage' (red glare).
- Whether a reflection is predicted to be operationally significant in practice or not.

Where no solar reflections are geometrically possible or where solar reflections are predicted to be significantly screened, no impact is predicted, and mitigation is not required.

Where solar reflections are of an intensity no greater than 'low potential for temporary after-image' (green glare) or occur outside of a pilot's primary field-of-view (50 degrees either side of the runway approach relative to the runway threshold), the impact significance is low, and mitigation is not required.

Glare with 'potential for a temporary after-image' (yellow glare) was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[26] for on-airfield solar. Pager Power recommends a pragmatic approach whereby instances of 'yellow' glare are evaluated in a technical and operational context. Where solar reflections are of an intensity no greater than 'low potential for temporary after-image' expert assessment of the following mitigating factors is required to determine the impact significance[27]:

- The likely traffic volumes and level of safeguarding at the aerodrome – licensed aerodromes typically have higher traffic volumes and are formally safeguarded;
- The time of day at which glare is predicted and whether the aerodrome will be operational such that pilots can be on the approach at these times;
- The duration of any predicted glare – glare that occurs for low durations throughout the year is less likely to be experienced than glare that occurs for longer durations throughout the year;
- The location and size of the reflecting panel area relative to a pilot's primary field-of-view;
- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible – effects that coincide with direct sunlight appear less prominent than those that do not;
- The level of predicted effect relative to existing sources of glare – a solar reflection is less noticeable by pilots when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating factors, where the solar reflection does not remain significant, a low impact is predicted, and mitigation is not recommended.

Where the solar reflection remains significant, the impact significance is moderate, and mitigation is recommended. Where solar reflections are of an intensity greater than 'potential for temporary after-image', the impact significance is high, and mitigation is required.

6.5.4 Summary of Results

The following sections summarise the results of the assessment:

- The key considerations for each receptor type. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.
- Geometric results of the assessment based solely on bare-earth terrain i.e., without consideration of screening in the form of buildings, dwellings, (existing or proposed) vegetation, and/or terrain.

[26] This FAA guidance from 2013 has since been superseded by the FAA guidance in 2021 whereby airports are tasked with determining safety requirements themselves.

[27] This approach taken is reflective of the changes made in the 2021 FAA guidance; however, it should be noted that this guidance states that it is up to the airport to determine the safety requirements themselves. Therefore, an airport may not accept any yellow glare towards approach paths.

- Whether a reflection will be experienced in practice. When determining the visibility of the reflecting panels for an observer, a conservative review of the available imagery, landscape strategy plan, google earth viewshed (high-level terrain analysis), and/or site photography (if available) is undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing and/or proposed screening will remove effects. Detailed screening analysis may be undertaken to determine visibility, where appropriate.
- The impact significance and any mitigation recommendations/requirements.
- The desk-based review of the available imagery, where appropriate.

6.5.5 Geometric Modelling Results

Table 6 below presents the following:

- Geometric modelling results (without consideration of screening);
- Consideration of relevant factors (where appropriate);
- Predicted impact significance;
- Mitigation recommendation/requirement.

Receptors	Geometric modelling results (without consideration of screening)	Glare Type (Forge)	Relevant Factors	Predicted Impact Classification	Mitigation Recommended/Required?
ATC Tower Runway 05 Approach Runway 23 Approach	Solar reflections are not geometrically possible	N/A	N/A	None	No

Table 6 *Geometric modelling results –aviation receptors (Teesside Airport)*

6.5.6 Conclusions

No impacts are not predicted on aviation activity associated with Teesside International Airport because solar reflections are not geometrically possible towards:

- The ATC Tower;
- The last two miles of the approach path towards runway 05;
- The last two miles of the approach path towards runway 23.

7 HIGH-LEVEL MITIGATION OVERVIEW

7.1 Overview

It is possible that a site survey or other detailed screening analysis would reveal that the reflecting areas are already significantly obscured from view relative to the identified receptors. Ordinarily, mitigation for ground-based receptors is achieved where necessary via screening in the form of planting to obstruct views. The optimal strategy may therefore include:

- Provision of screening (planting or opaque fence) within the site boundary – this is the preferred solution by stakeholders as the screening is under the developer's control;
- Provision of screening (planting or opaque fence) outside of the site boundary – less favoured by stakeholders but is still a suitable solution if it can be maintained.

The relevant reflecting areas that should be obscured from view and potential screening locations have therefore been defined in this section. The required height will depend on the relative elevation of the receptors, the base of the planting itself, and the reflecting panels.

Where implementing screening is not a viable option, changes to the panel configuration could be explored. This is likely to involve altering the azimuth and tilt angles of the panels, or changes to the site footprint.

7.2 Roads

A moderate impact is predicted on:

- A 0.2km section (road receptors 84-86) and 0.1km section (road receptors 90-91) of Ricknall Lane/Lodge Lane;
- A 1.5km section of Unnamed Road/The Green/ High Street (road receptors 155 to 170).

The height of proposed hedgerow/tree planting along panel boundaries should be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none.

The critical screening locations for these road sections are shown in the figures on the following pages.

Figure 62 *Critical proposed hedgerow/tree planting (green line) relative to reflecting area for road section 84-86 (yellow area)*

Figure 63 *Critical proposed hedgerow/tree planting (pink line) relative to reflecting area for road section 90-91 (pink line)*

Figure 64 *Critical proposed hedgerow/tree planting (green line) relative to reflectors (yellow icons) for road section 155-161 (yellow area)*

Figure 65 *Critical proposed hedgerow/tree planting (pink line) relative to reflectors (yellow icons for road section 162-170*

7.3 Dwellings

A moderate impact is predicted on ten dwellings (87-88, 98, 101, 104, 111-115) due to the duration of effects, and the lack of sufficient mitigating factors.

The height of proposed hedgerow/tree planting along panel boundaries should be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none.

The critical screening locations for these dwellings are shown in the figures below and on the following page.

Figure 66 *Critical proposed hedgerow/tree planting (green lines) relative to reflecting points (yellow icons) for dwellings 87 and 88*

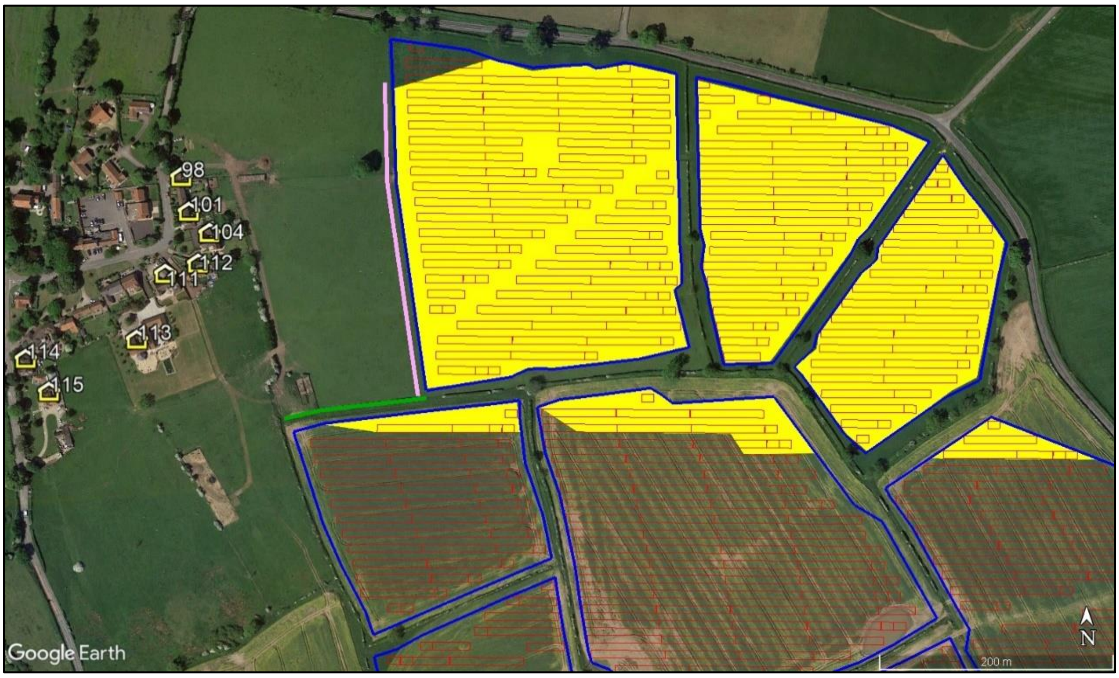

Figure 67 *Critical screening locations for dwellings 98, 101, 104, 111-115 (pink and green lines)*

8 CONCLUSIONS

8.1 Roads

A moderate impact is predicted on:

- A 0.2km section (road receptors 84-86) and 0.1km section (road receptors 90-91) of Ricknall Lane/Lodge Lane;
- A 1.5km section of Unnamed Road/The Green/ High Street (road receptors 155 to 170).

Assuming that the height of proposed hedgerow/tree planting along reflecting panel boundaries for these sections will be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none, no further mitigation is recommended.

Further details are provided in Section 7 of the report.

A low impact is predicted on:

- A 0.3km section of Elstob Lane/Bishopton Lane (road receptors 126-129); and
- A 0.6km section of Elstob Lane/Bishopton Lane (road receptors 132-138).

This is because solar reflections are geometrically possible from outside of a road user's primary field of view (50 degrees either side), and/or there are significant mitigating factors such as:

- Significant clearance distance between road user and closest visible reflecting panel;
- Reflections incident with sunlight;
- Generally low traffic volume/density expected along most sections.

No impacts are predicted on the remaining assessed road sections, because solar reflections are not geometrically possible, or there is significant screening in the form of existing vegetation, buildings, and/or terrain such that reflections would not be visible in practice.

8.2 Dwellings

A moderate impact is predicted on ten dwellings (87-88, 98, 101, 104, 111-115) due to the duration of effects, and the lack of sufficient mitigating factors. Assuming that the height of proposed hedgerow/tree planting along reflecting panel boundaries for these dwellings will be managed so that relevant reflecting areas are obscured from view, so that the impact would be reduced to low/none, no further mitigation is recommended.

Further information is provided in Section 7.

A low impact is predicted on nine dwellings (84, 91, 117-118, 119, 121, 126, 200-201) due to the duration of effects and the presence of the following mitigating factors:

- Significant separation distance between observer and closest visible reflecting panel;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

The impact may be reduced to none for some of these dwellings once proposed hedgerow/tree planting has been established.

No significant impacts are predicted on any of the remaining 240 dwellings within the assessment area, because where solar reflections are geometrically possible, there is significant existing and/or proposed screening such that reflections lasting more than 60 minutes on any given day and/or 3 months per year are not expected to be possible. Mitigation is not required.

8.3 Railway

The modelling has shown that solar reflections are geometrically possible[28] towards a 0.7km section (train driver receptors 06 to 13) of the railway line to the west of the Proposed Development.

For all receptors towards which solar reflections are geometrically possible, the reflections will occur from outside of a train driver's primary horizontal field of view (30° either side of the direction of travel). Based on imagery of the area, it appears that the majority of the sections of railway line within 0.5km of the Proposed Development are located where there is vegetation either side. The height and density of this vegetation is unclear.

A low impact is therefore predicted, and mitigation is not recommended.

8.4 Aviation

No impacts are not predicted on aviation activity associated with Teesside International Airport because solar reflections are not geometrically possible towards:

- The ATC Tower;
- The last two miles of the approach path towards runway 05;
- The last two miles of the approach path towards runway 23.

8.5 Overall

A moderate impact (considering the baseline scenario) is predicted on three sections of road due to the location of the reflecting panels relative to a road user's primary field of view, and the lack of sufficient mitigating factors.

A moderate impact (considering the baseline scenario) is predicted onten dwellings due to the duration of effects, and the lack of sufficient mitigating factors.

The height of proposed hedgerow/tree planting should be managed so that relevant reflecting areas are obscured from view.

Further information is provided in Section 7.

There are no impacts requiring mitigation on surrounding railway operations and infrastructure, and aviation activity associated with Teesside International Airport.

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[28] Only considering reflections from solar panels within 0.5km of the receptor. Reflections outside of 0.5km are not considered to be significant.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

This section presents details regarding the relevant guidance and studies with respect to the considerations and effects of solar reflections from solar panels, known as 'Glint and Glare'.

This is not a comprehensive review of the data sources, rather it is intended to give an overview of the important parameters and considerations that have informed this assessment.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[29] (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.

Particular factors a local planning authority will need to consider include:

…

- *the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on **neighbouring uses and aircraft safety**;*
- *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;*

…

The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground-mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero.'

[29] Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, published: 18 June 2015, last updated: 14 August 2023, last accessed on: 20 November 2023

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[30] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

'3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation.[31] However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

3.10.94 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

3.10.95 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

3.10.96 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.

3.10.97 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels.'

The EN-3 does not state which receptors should be considered as part of a quantitative glint and glare assessment. Based on Pager Power's extensive project experience, typical receptors include residential dwellings, road users, aviation infrastructure, and railway infrastructure.

Sections 3.10.125-127 state:

3.10.125 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.

3.10.126 Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.

3.10.127 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence. In practice

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[30] Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: March 2023, accessed on: 20/11/2023.

[31] *Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.*

this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.

The mitigation strategies listed within the EN-3 are relevant strategies that are frequently utilised to eliminate or reduce glint and glare effects towards surrounding observers. The most common form of mitigation is the implementation of screening along the site boundary.

Sections 3.10.149-150 state:

3.10.149 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

3.10.150 Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms.

The latest version of the draft EN-3 goes some way in referencing that the issue is more complex than presented in the previous issue; though, this is still unlikely to be welcomed by aviation stakeholders, who will still request a glint and glare assessment on the basis that glare may lead to impact upon aviation safety. It is possible that the final issue of the policy will change in light of further consultation responses from aviation stakeholders.

Finally, the EN-3 relates solely to nationally significant renewable energy infrastructure and therefore does not apply to all planning applications for solar farms.

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare has been determined when assessing the impact of solar reflections upon surrounding roads and dwellings. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[32] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The

[32] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

formal policy was cancelled on September 7th, 2012[33] however the advice is still applicable[34] until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

CAA Interim Guidance

This interim guidance makes the following recommendations (p.2-3):

'8. It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.

9. Guidance on safeguarding procedures at CAA licensed aerodromes is published within CAP 738 Safeguarding of Aerodromes and advice for unlicensed aerodromes is contained within CAP 793 Safe Operating Practices at Unlicensed Aerodromes.

10. Where Proposed Developments in the vicinity of aerodromes require an application for planning permission the relevant LPA normally consults aerodrome operators or NATS when aeronautical interests might be affected. This consultation procedure is a statutory obligation in the case of certain major airports, and may include military establishments and certain air traffic surveillance technical sites. These arrangements are explained in Department for Transport Circular 1/2003 and for Scotland, Scottish Government Circular 2/2003.

11. In the event of SPV developments proposed under the Electricity Act, the relevant government department should routinely consult with the CAA. There is therefore no requirement for the CAA to be separately consulted for such proposed SPV installations or developments.

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the responsibility of the ALH[35], as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

13. During the installation and associated construction of SPV systems there may also be a need to liaise with nearby aerodromes if cranes are to be used; CAA notification and permission is not required.

14. The CAA aims to replace this informal guidance with formal policy in due course and reserves the right to cancel, amend or alter the guidance provided in this document at its discretion upon receipt of new information.

15. Further guidance may be obtained from CAA's Aerodrome Standards Department via aerodromes@caa.co.uk.'

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[33] Archived at Pager Power
[34] Reference email from the CAA dated 19/05/2014.
[35] Aerodrome Licence Holder.

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes has been produced by the United States Federal Aviation Administration (FAA). The first guidelines were produced initially in November 2010 and updated in 2013. A final policy was released in 2021, which superseded the interim guidance.

The 2010 document is entitled '*Technical Guidance for Evaluating Selected Solar Technologies on Airports*'[36], the 2013 update is entitled '*Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*'[37], and the 2021 final policy is entitled '*Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports*'[38].

Key excerpts from the final policy are presented below:

Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The policy in this document updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs prior to submittal of a Notice of Proposed Construction or Alteration Form 7460-1 (hereinafter Form 7460-1). Airport sponsors are no longer required to submit the results of an ocular analysis to FAA. Instead, to demonstrate compliance with 14 CFR 77.5(c), FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined there is no potential for ocular impact to the airport's ATCT cab. This process will enable FAA to evaluate the solar energy system project, with assurance that the system will not impact the ATCT cab.

FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts. There are several tools available on the open market to airport sponsors that can analyze potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g., on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts.

The excerpt above states where a solar PV development is to be located on a federally obligated aerodrome with an ATC Tower, it will require a glint and glare assessment to accompany its

[36] Archived at Pager Power

[37] Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, Department of Transportation, Federal Aviation Administration (FAA), date: 10/2013, accessed on: 08/12/2021.

[38] Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, Federal Aviation Administration, date: May 2021, accessed on: 08/12/2021.

application. It states that pilots on approach are no longer a specific assessment requirement due to effects from solar energy systems being similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Ultimately it comes down to the specific aerodrome to ensure it is adequately safeguarded, and it is on this basis that glint and glare assessments are routinely still requested.

The policy also states that several different tools and methodologies can be used to assess the impacts of glint and glare, which was previously required to be undertaken by the Solar Glare Hazard Analysis Tool (SGHAT) using the Sandia National Laboratories methodology.

In 2018, the FAA released the latest version (Version 1.1) of the '*Technical Guidance for Evaluating Selected Solar Technologies on Airports'*[39]. Whilst the 2021 final policy also supersedes this guidance, many of the points are still relevant because aerodromes are still safeguarding against glint and glare irrespective of the FAA guidance. The key points are presented below for reference:

- *Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as "glare," which can cause a brief loss of vision, also known as flash blindness*[40].
- *The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.*
- *As illustrated on Figure 16*[41]*, flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.*
- *Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:*
    - *A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;*
    - *A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;*
    - *A geometric analysis to determine days and times when an impact is predicted.*

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[39] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.
[40] Flash Blindness, as described in the FAA guidelines, can be described as a temporary visual interference effect that persists after the source of illumination has ceased. This occurs from many reflective materials in the ambient environment.
[41] First figure in Appendix B.

- *The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.*
- ***1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.*
- ***2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.*
- ***3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.*
- *Facilities placed in remote locations, like the desert, will be far from receptors and therefore potential impacts are limited to passing aircraft. Because the intensity of the light reflected from the solar panel decreases with increasing distance, an appropriate question is how far you need to be from a solar reflected surface to avoid flash blindness. It is known that this distance is directly proportional to the size of the array in question[42] but still requires further research to definitively answer.*
- ***Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower*

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[42] Ho, Clifford, Cheryl Ghanbari, and Richard Diver. 2009. Hazard Analysis of Glint and Glare From Concentrating Solar Power Plants. SolarPACES 2009, Berlin Germany. Sandia National Laboratories.

and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016[43] with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (1) A person must not exhibit in the United Kingdom any light which—

(a) by reason of its glare is liable to endanger aircraft taking off from or landing at an aerodrome; or

(b) by reason of its liability to be mistaken for an aeronautical ground light is liable to endanger aircraft.

(2) If any light which appears to the CAA to be a light described in paragraph (1) is exhibited, the CAA may direct the person who is the occupier of the place where the light is exhibited or who has charge of the light, to take such steps within a reasonable time as are specified in the direction—

(a) to extinguish or screen the light; and

(b) to prevent in the future the exhibition of any other light which may similarly endanger aircraft.

(3) The direction may be served either personally or by post, or by affixing it in some conspicuous place near to the light to which it relates.

(4) In the case of a light which is or may be visible from any waters within the area of a general lighthouse authority, the power of the CAA under this article must not be exercised except with the consent of that authority.

Lights which dazzle or distract

225. A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft.'

The document states that no 'light', 'dazzle' or 'glare' should be produced which will create a detrimental impact upon aircraft safety.

Endangering safety of an aircraft

240. A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft.

Assessment Process – Railways

Railway operations is not mentioned specifically within this guidance however it is stated that a developer will need to consider *'the proposal's visual impact, the effect on landscape of glint and glare and on neighbouring uses…'*. In the UK, Network Rail is a statutory consultee when a development is located in close proximity to its infrastructure.

[43] The Air Navigation Order 2016. [online] Available at: <https://www.legislation.gov.uk/uksi/2016/765/contents/made> [Accessed 4 February 2022].

No process for determining and contextualising the effects of glint and glare are, however, provided. Therefore, the Pager Power approach is to determine whether a reflection from a development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

Railway Assessment Guidelines

The following section provides an overview of the relevant railway guidance with respect to the siting of signals on railway lines. Network Rail is the stakeholder of the UK's railway infrastructure. Whilst the guidance is not strictly applicable in other countries, the general principles within the guidance is expected to apply.

A railway operator's concerns would likely to relate to the following:

1. The development producing solar glare that affects train drivers; and
2. The development producing solar reflections that affect railway signals and create a risk of a phantom aspect signal.

Railway guidelines are presented on the following pages. These relate specifically to the sighting distance for railway signals.

Reflections and Glare

The extract below and on the following page is taken from Section A5 – Reflections and glare (pages 64-65) of the 'Signal Sighting Assessment Requirements'[44] which details the requirement for assessing glare towards railway signals.

Reflections and glare

Rationale

Reflections can alter the appearance of a display so that it appears to be something else.

Guidance

A5 is present if direct glare or reflected light is directed into the eyes or into the lineside signalling asset that could make the asset appear to show a different aspect or indication to the one presented.

A5 is relevant to any lineside signalling asset that is capable of presenting a lit signal aspect or indication.

The extent to which excessive illumination could make an asset appear to show a different signal aspect or indication to the one being presented can be influenced by the product being used. Requirements for assessing the phantom display performance of signalling products are set out in GKRT0057 section 4.1.

Problems arising from reflection and glare occur when there is a very large range of luminance, that is, where there are some objects that are far brighter than others. The following types of glare are relevant:

a) Disability glare, caused by scattering of light in the eye, can make it difficult to read a lit display.

b) Discomfort glare, which is often associated with disability glare. While being unpleasant, it does not affect the signal reading time directly, but may lead to distraction and fatigue.

[44] Source: Signal Sighting Assessment Requirements, June 2016. Railway Group Guidance Note. Last accessed 18.10.2016.

Examples of the adverse effect of disability glare include:

a) *When a colour light signal presenting a lit yellow aspect is viewed at night but the driver is unable to determine whether the aspect is a single yellow or a double yellow.*
b) *Where a colour light signal is positioned beneath a platform roof painted white and the light reflecting off the roof can make the signal difficult to read.*

Options for militating against A5 include:

a) *Using a product that is specified to achieve high light source: phantom ratio values.*
b) *Alteration to the features causing the glare or reflection.*
c) *Provision of screening.*

Glare is possible and should be assessed when the luminance is much brighter than other light sources. Glare may be unpleasant and therefore cause distraction and fatigue, or may make the signal difficult to read and increase the reading time.

Determining the Field of Focus

The extract on the following pages is taken from Appendix F - Guidance on Field of Vision (pages 98-101) of the 'Signal Sighting Assessment Requirements'[45] which details the visibility of signals, train drivers' field of vision and the implications with regard to signal positioning.

Asset visibility

The effectiveness of an observer's visual system in detecting the existence of a target asset will depend upon its:

a) *Position in the observer's visual field.*
b) *Contrast with its background.*
c) *Luminance properties.*
d) *The observer's adaptation to the illumination level of the environment.*

It is also influenced by the processes relating to colour vision, visual accommodation, and visual acuity. Each of these issues is described in the following sections.

Field of vision

The field of vision, or visual field, is the area of the visual environment that is registered by the eyes when both eyes and head are held still. The normal extent of the visual field is approximately 135o in the vertical plane and 200o in the horizontal plane.

The visual field is usually described in terms of central and peripheral regions: the central field being the area that provides detailed information. This extends from the central point (0°) to approximately 30° at each eye. The peripheral field extends from 30o out to the edge of the visual field.

[45] Source: Signal Sighting Assessment Requirements, June 2016. Railway Group Guidance Note. Last accessed 28.08.2020.

F.6.3 Objects positioned towards the centre of the observer's field of vision are seen more quickly and identified more accurately because this is where our sensitivity to contrast is the highest. Peripheral vision is particularly sensitive to movement and light.

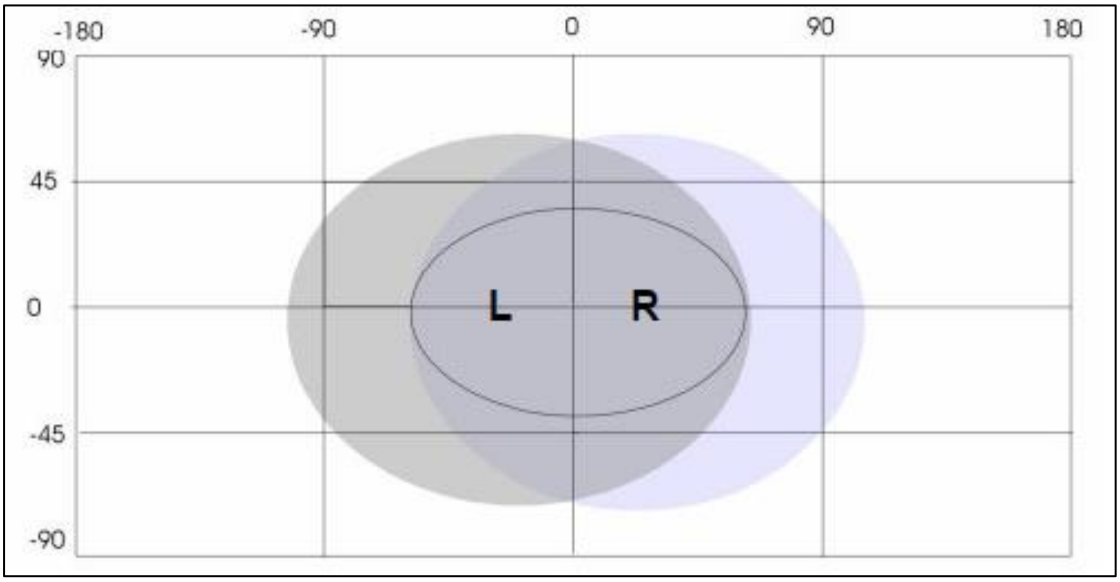


Figure G 21 - Field of view

In Figure G 21, the two shaded regions represent the view from the left eye (L) and the right eye (R) respectively. The darker shaded region represents the region of binocular overlap. The oval in the centre represents the central field of vision.

Research has shown that drivers search for signs or signals towards the centre of the field of vision.

Signals, indicators and signs should be positioned at a height and distance from the running line that permits them to be viewed towards the centre of the field of vision. This is because:

a) As train speed increases, drivers become increasingly dependent on central vision for asset detection. At high speeds, drivers demonstrate a tunnel vision effect and focus only on objects in a field of + 8^o from the direction of travel.

b) Sensitivity to movement in the peripheral field, even minor distractions can reduce the visibility of the asset if it is viewed towards the peripheral field of vision. The presence of clutter to the sides of the running line can be highly distracting (for example, fence posts, lamp-posts, traffic, or non-signal lights, such as house, compatibility factors or security lights).

Figure G 22 and Table G 5 identify the radius of an 8o cone at a range of close-up viewing distances from the driver's eye. This shows that, depending on the lateral position of a stop signal, the optimal (normal) train stopping point could be as far as 25 m back from the signal to ensure that it is sufficiently prominent.

The dimensions quoted in Table G 5 assume that the driver is looking straight ahead. Where driver-only operation (DOO) applies, the drivers' line of sight at the time of starting the train is influenced by the location of DOO monitors and mirrors. In this case it may be appropriate to provide supplementary information alongside the monitors or mirrors using one of the following:

a) A co-acting signal.

b) A miniature banner repeater indicator.

c) *A right away indicator.*

d) *A sign to remind the driver to check the signal aspect.*

In order to prevent misreading by trains on adjacent lines, the co-acting signal or miniature banner repeater may be configured so that the aspect or indication is presented only when a train is at the platform to which it applies.

'Car stop' signs should be positioned so that the relevant platform starting signals and / or indicators can be seen in the driver's central field of vision.

If possible, clutter and non-signal lights in a driver's field of view should be screened off or removed so that they do not cause distraction.

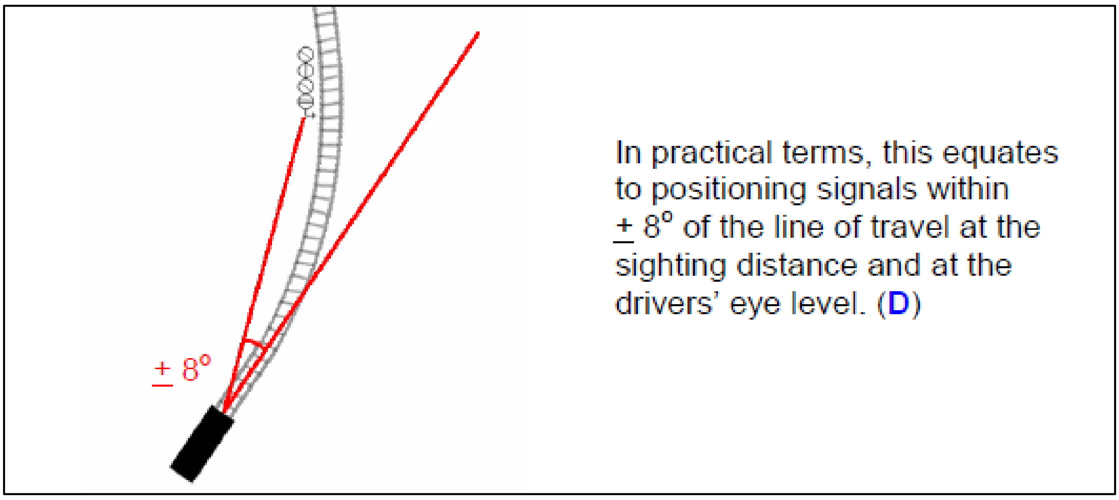


Figure G 22 - Signal positioning

'A' (m)	'B' (m)	Typical display positions
5	*0.70*	-
6	*0.84*	-
7	*0.98*	-
8	*1.12*	-
9	*1.26*	-
10	*1.41*	-
11	*1.55*	-
12	*1.69*	-
13	*1.83*	-
14	*1.97*	-
15	*2.11*	*A stop aspect positioned 3.3 m above rail level and 2.1 m from the left hand rail is within the 8° cone at 15.44 m in front of the driver*
16	*2.25*	-
17	*2.39*	-
18	*2.53*	*A stop aspect positioned 5.1 m above rail level and 0.9 m from the left hand rail is within the 8° cone at 17.93 m in front of the driver*
19	*2.67*	-
20	*2.81*	-
21	*2.95*	-
22	*3.09*	-
23	*3.23*	-
24	*3.37*	-
25	*3.51*	*A stop aspect positioned 3.3 m above rail level and 2.1 m from the right hand rail is within the 8° cone at 25.46 m in front of the driver*

Table G 5 – 8° cone angle co-ordinates for close-up viewing

The distance at which the 8° cone along the track is initiated is dependent on the minimum reading time and distance which is associated to the speed of trains along the track. This is discussed below.

Determining the Assessed Minimum Reading Time

The extract below is taken from section B5 (pages 8-9) of the 'Guidance on Signal Positioning and Visibility' which details the required minimum reading time for a train driver when approaching a signal.

'B5.2.2 Determining the assessed minimum reading time

GE/RT8037

The assessed minimum reading time shall be no less than eight seconds travelling time before the signal.

The assessed minimum reading time shall be greater than eight seconds where there is an increased likelihood of misread or failure to observe. Circumstances where this applies include, but are not necessarily limited to, the following:

a) *the time taken to identify the signal is longer (for example, because the signal being viewed is one of a number of signals on a gantry, or because the signal is viewed against a complex background)*
b) *the time taken to interpret the information presented by the signal is longer (for example, because the signal is capable of presenting route information for a complex layout ahead)*
c) *there is a risk that the need to perform other duties could cause distraction from viewing the signal correctly (for example, the observance of lineside signs, a station stop between the caution and stop signals, or DOO (P) duties)*
d) *the control of the train speed is influenced by other factors (for example, anticipation of the signal aspect changing).*

The assessed minimum reading time shall be determined using a structured format approved by the infrastructure controller.'

The distance at which a signal should be clearly viewable is determined by the maximum speed of the trains along the track. If there are multiple signals present at a location then an additional 0.2 seconds reading time is added to the overall viewing time.

Signal Design and Lighting System

Many railway signals are now LED lights and not filament (incandescent) bulbs. The benefits of an LED signal over a filament bulb signal with respect to possible phantom aspect illuminations are as follows:

- An LED railway signal produces a more intense light making them more visible to approaching trains when compared to the traditional filament bulb technology[46];

[46] Source: Wayside LED Signals – Why it's Harder than it Looks, Bill Petit.

- No reflective mirror is present within the LED signal itself unlike a filament bulb. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated.

Many LED signal manufacturers[47,48,49] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

[47] Source: http://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf. (Last accessed 21.02.18).
[48] Source: http://www.vmstech.co.uk/downloads/Rail.pdf. (Last accessed 21.02.18).
[49] Source: Siemens, Sigmaguard LED Tri-Colour L Signal – LED Signal Technology at Incandescent Prices. Datasheet 1A-23. (Last accessed 22.02.18).

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

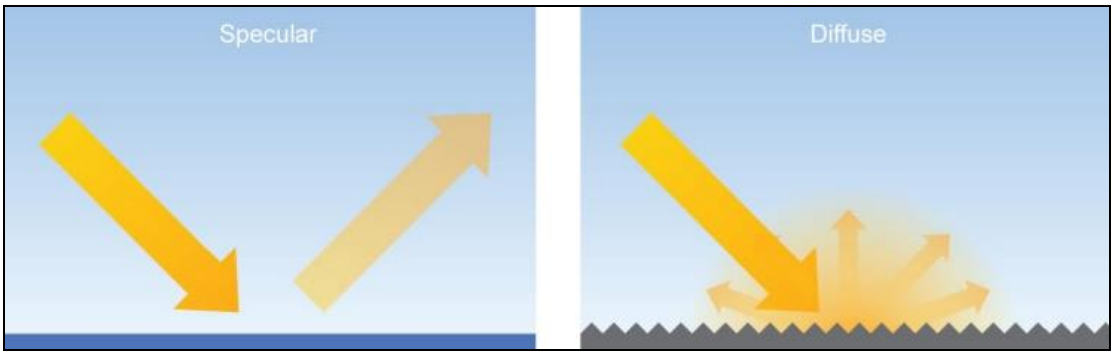
Overview

Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels and glass. An overview of these studies is presented below.

The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[50], illustrates the difference between the two types of reflections. Because solar panels are flat and have a smooth surface most of the light reflected is specular, which means that incident light from a specific direction is reradiated in a specific direction.



Specular and diffuse reflections

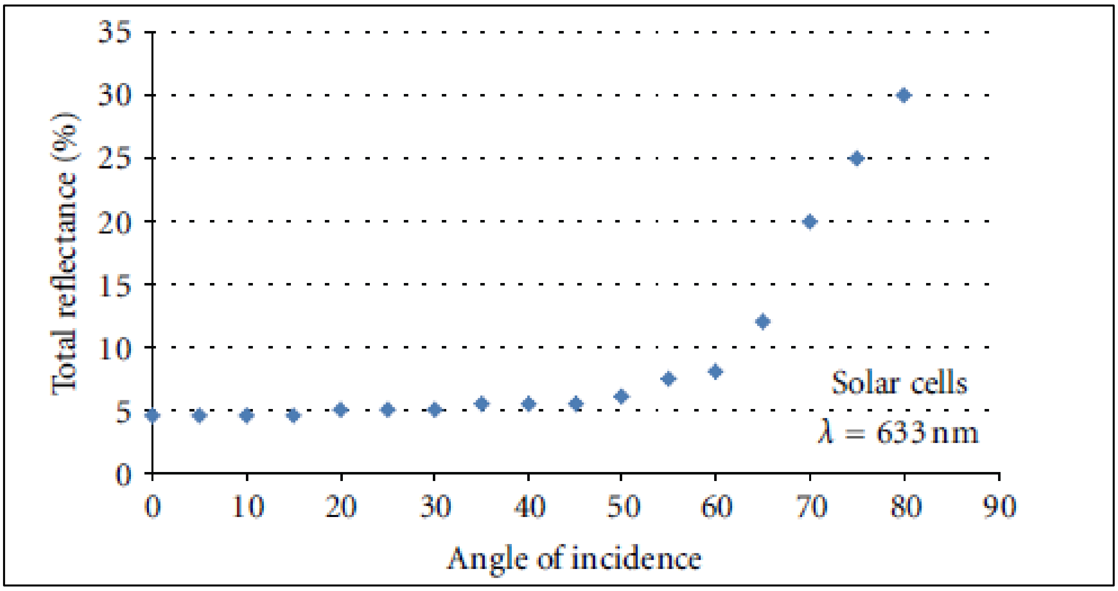
[50] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

Solar Reflection Studies

An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"

Evan Riley and Scott Olson published in 2011 their study titled: *A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems*[51]". They researched the potential glare that a pilot could experience from a 25-degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water;
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have a reflectivity greater than water and flat plate PV modules.

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[51] Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems," ISRN Renewable Energy, vol. 2011, Article ID 651857, 6 pages, 2011. doi:10.5402/2011/651857

FAA Guidance – "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[52]

The 2018 FAA Guidance included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected[53]
Snow	80
White Concrete	77
Bare Aluminium	74
Vegetation	50
Bare Soil	30
Wood Shingle	17
Water	5
Solar Panels	5
Black Asphalt	2

Relative reflectivity of various surfaces

Note that the data above does not appear to consider the reflection type (specular or diffuse).

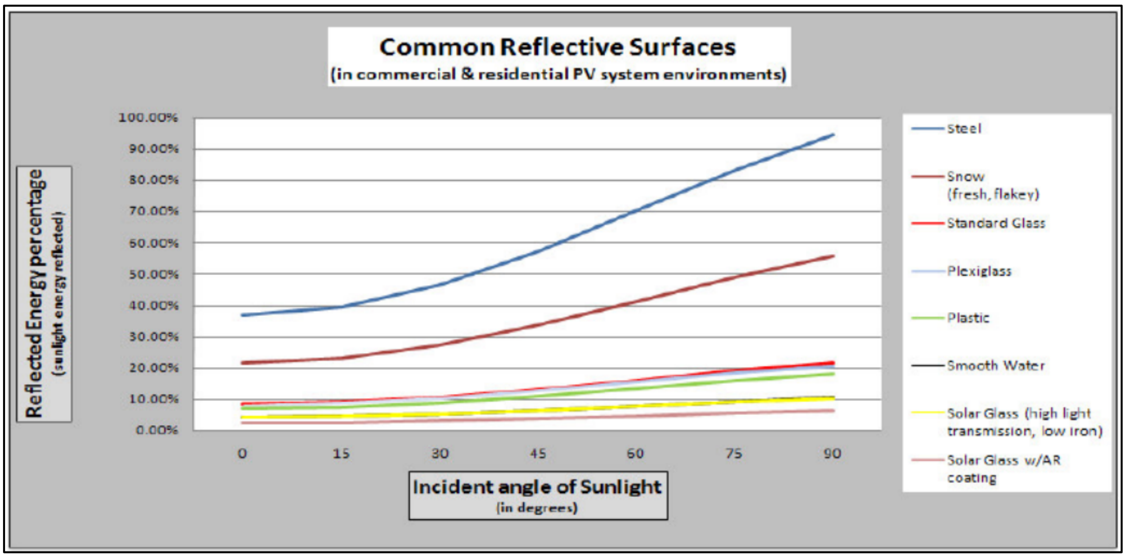
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

[52] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.
[53] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[54] to '*increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment*'.

The figure presented below shows the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel.



Common reflective surfaces

The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those of '*standard glass and other common reflective surfaces*'.

With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered "No Hazard to Air Navigation". The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

[54] Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

The Sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (horizontal angle i.e. from left to right) and elevation describes the Sun's angle relative to the horizon (vertical angle i.e. up and down).

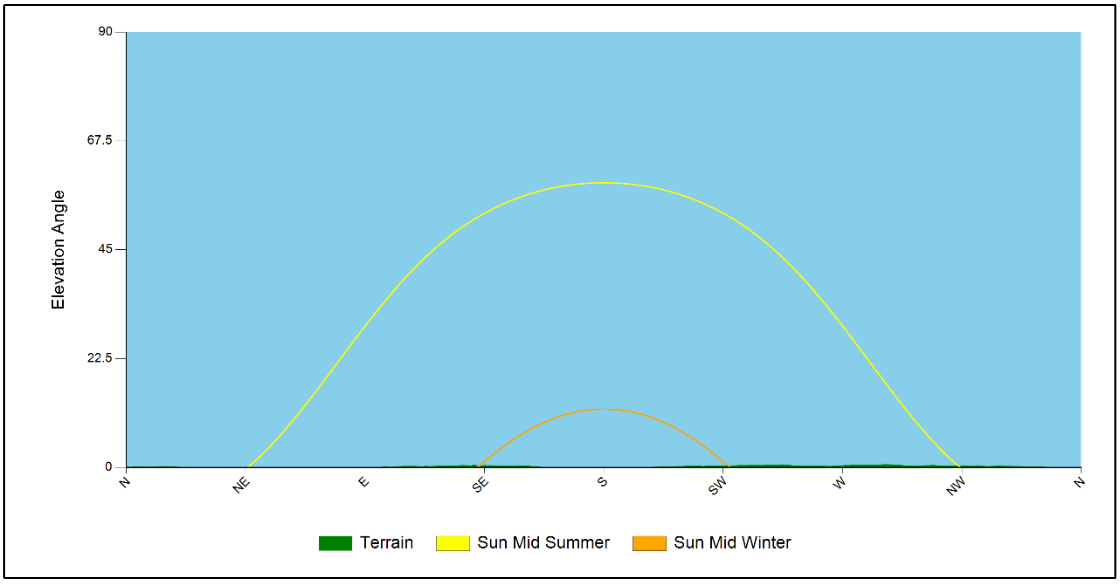
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- Time.
- Date.
- Latitude.
- Longitude.

The following is true at the location of the solar development:

- The Sun is at its highest around midday and is to the south at this time.
- The Sun rises highest on 21 June (longest day).
- On 21 December, the maximum elevation reached by the Sun is at its lowest (shortest day).

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year from lon:-1.498444 lat:54.585538.



Terrain elevation at the horizon

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

The significance of glint and glare will vary for different receptors. The following section presents a general overview of the significance criteria with respect to experiencing a solar reflection.

Impact Significance Definition

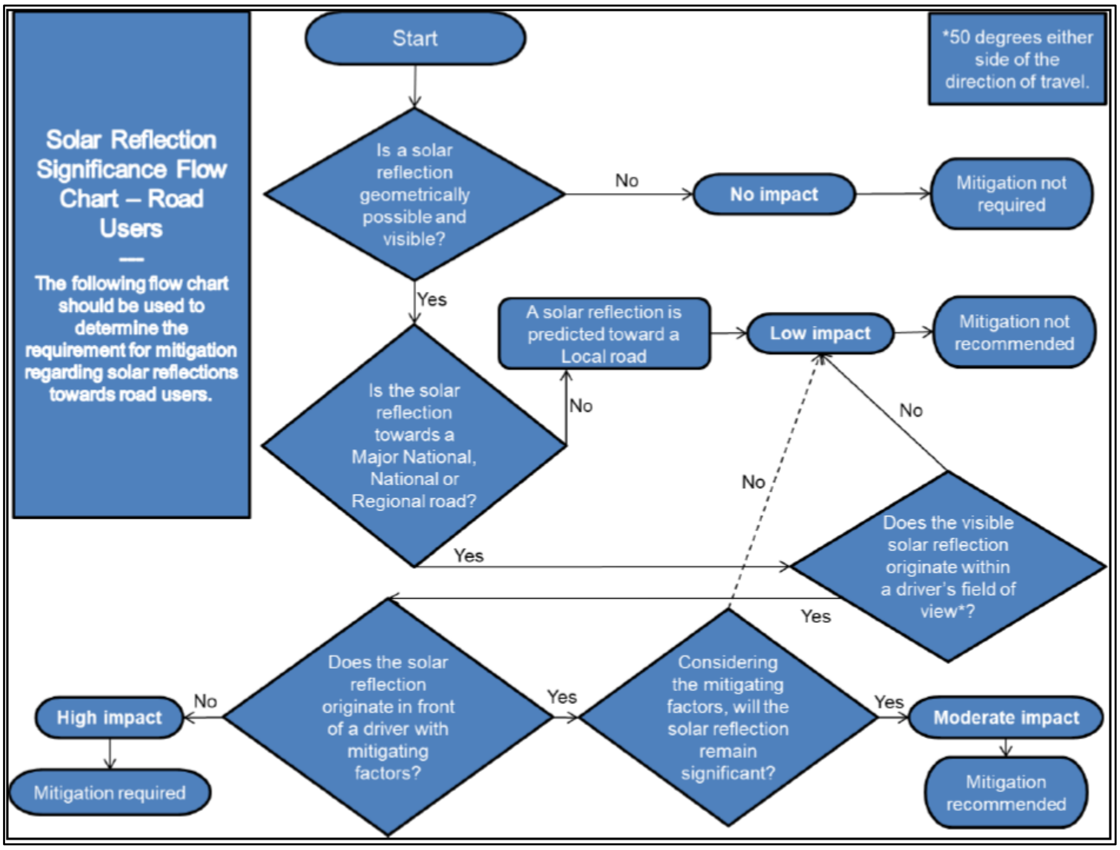
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels.	No mitigation required.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.	Whilst the impact may be acceptable, consultation and/or further analysis should be undertaken to determine the requirement for mitigation.
Major	A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.	Mitigation will be required if the proposed solar development is to proceed.

Impact significance definition

Assessment Process for Road Receptors

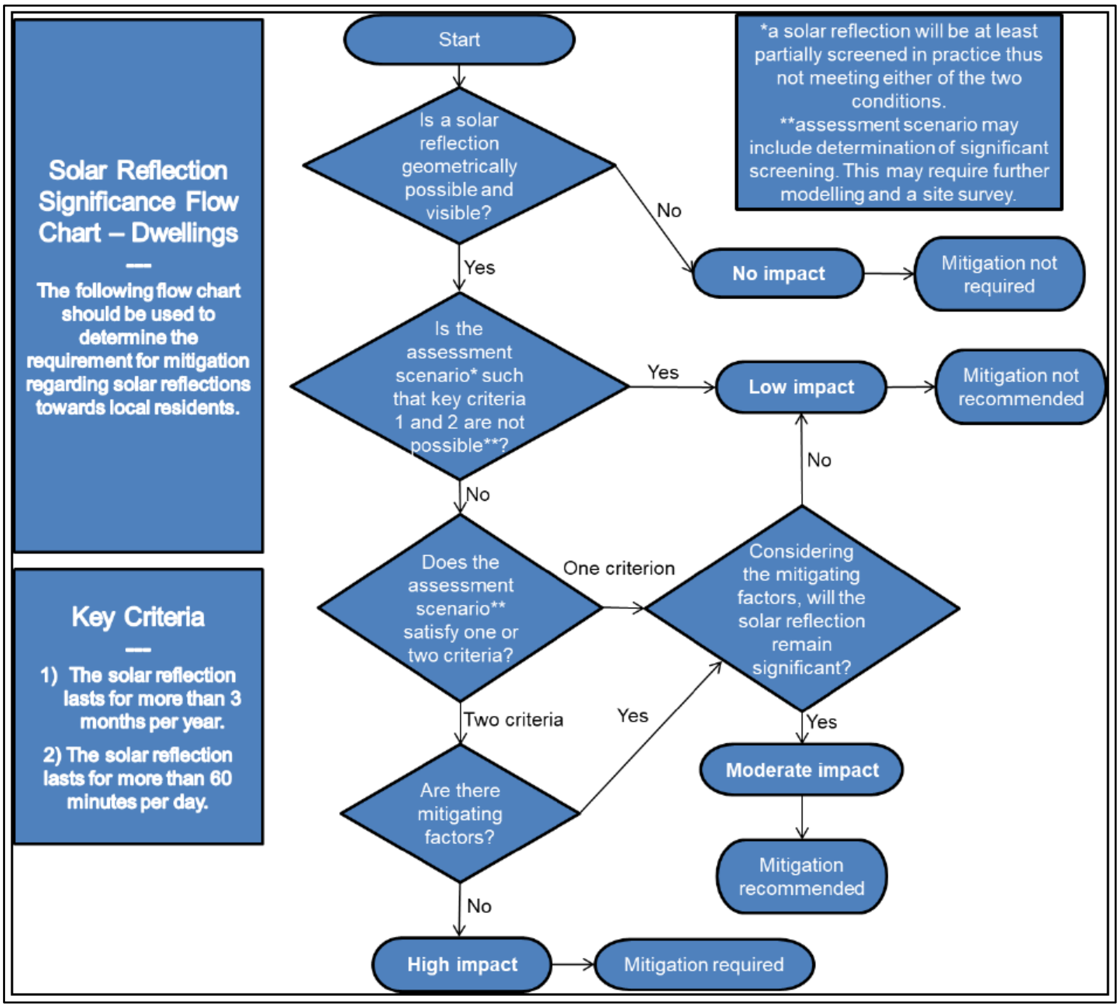
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

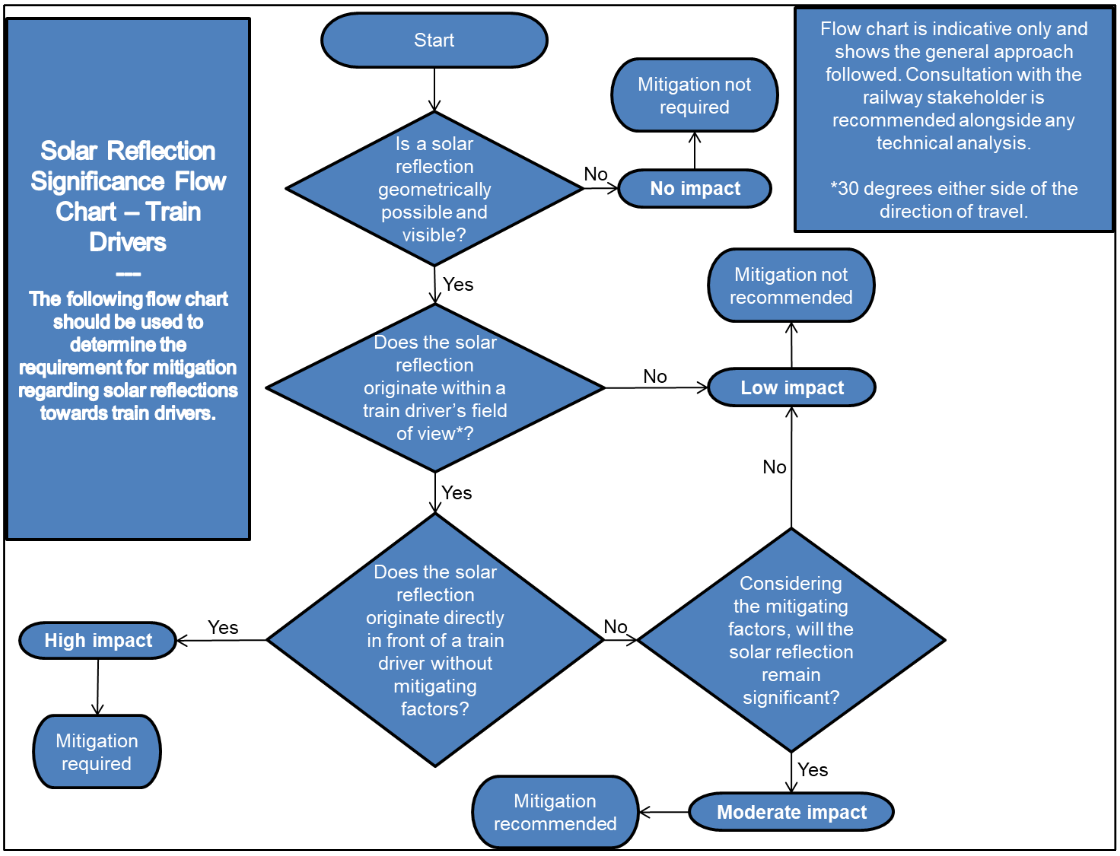
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling receptor mitigation requirement flow chart

Assessment Process for Railway Receptors

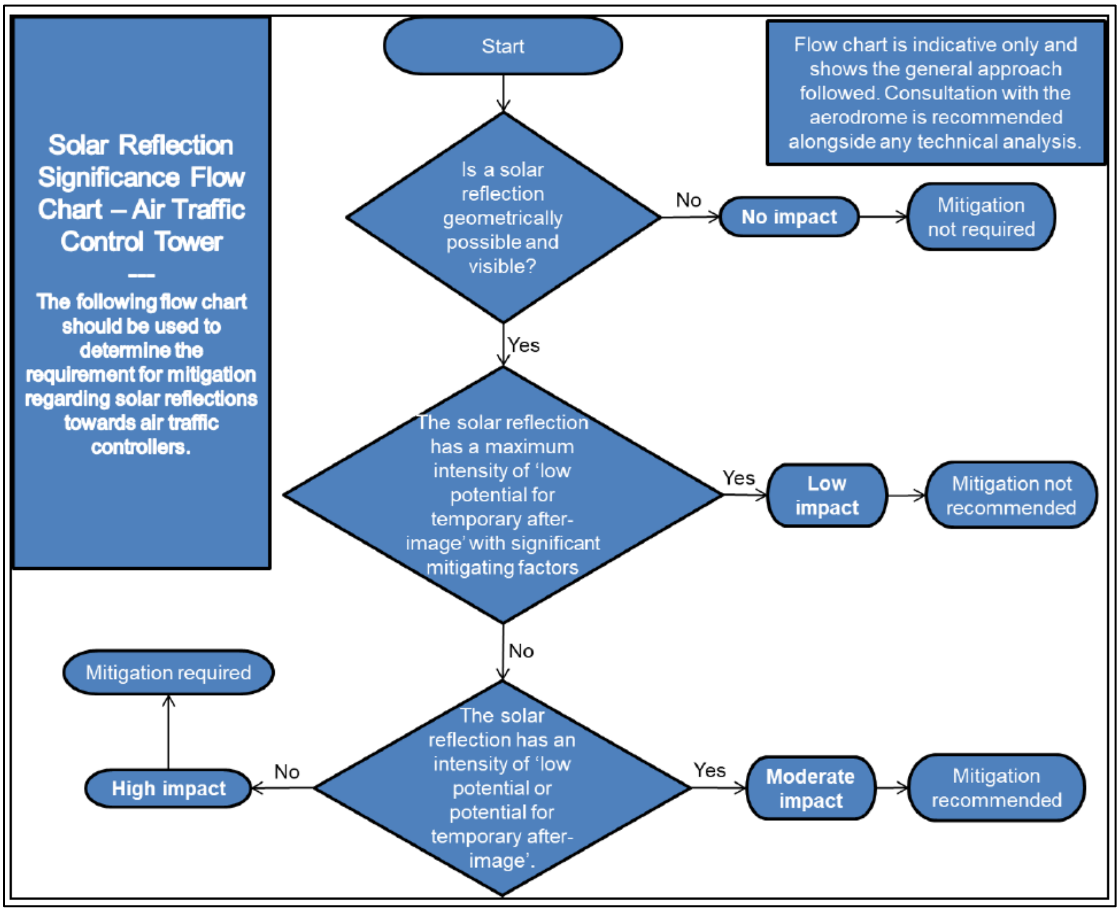
The flow chart presented below has been followed when determining the mitigation requirement for railway receptors.



Train driver impact significance flow chart

Assessment Process – ATC Tower

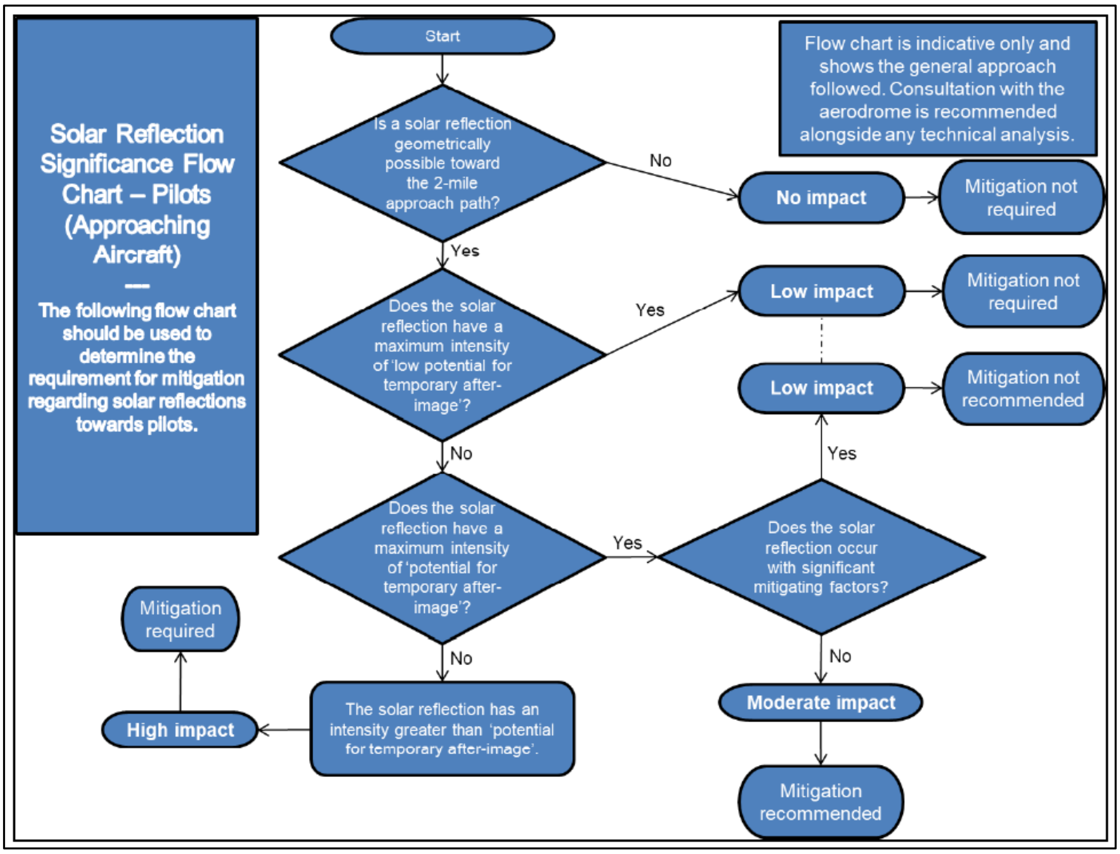
The flow chart presented below has been followed when determining the mitigation requirement for the ATC Tower.



ATC Tower mitigation requirement flow chart

Assessment Process – Approaching Aircraft

The flow chart presented below has been followed when determining the mitigation requirement for approaching aircraft.



Approaching aircraft receptor mitigation requirement flow chart

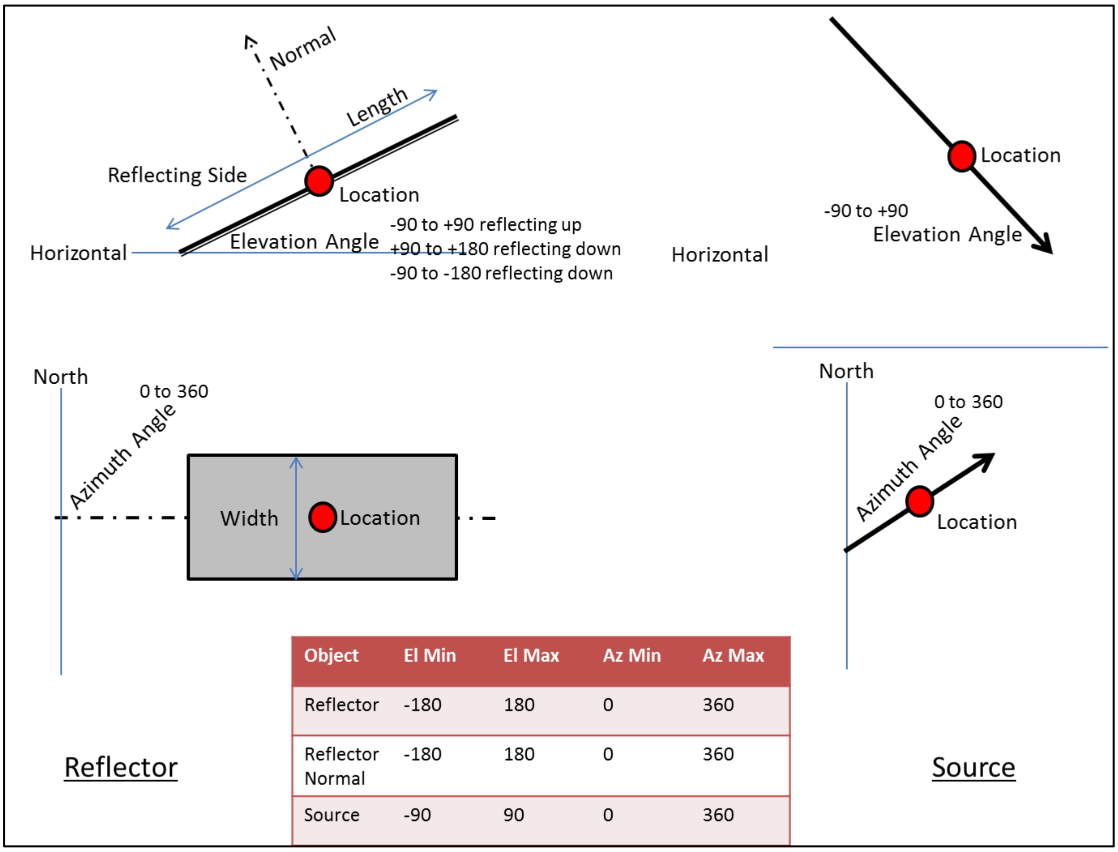
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power's Reflection Calculations Methodology

The calculations are three dimensional and complex, accounting for:

- The Earth's orbit around the Sun;
- The Earth's rotation;
- The Earth's orientation;
- The reflector's location;
- The reflector's 3D Orientation.

Reflections from a flat reflector are calculated by considering the normal which is an imaginary line that is perpendicular to the reflective surface and originates from it. The diagram below may be used to aid understanding of the reflection calculation process.



Object	El Min	El Max	Az Min	Az Max
Reflector	-180	180	0	360
Reflector Normal	-180	180	0	360
Source	-90	90	0	360

The following process is used to determine the 3D Azimuth and Elevation of a reflection:

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;

- If this angle is less than 90 degrees a reflection will occur. If it is greater than 90 degrees no reflection will occur because the source is behind the reflector;
- Calculate the Azimuth and Elevation of the reflection in accordance with the following:
    - The angle between source and normal is equal to angle between normal and reflection;
    - Source, Normal and Reflection are in the same plane.

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

The model considers 100% sunlight during daylight hours which is highly conservative.

The model does not account for terrain between the reflecting solar panels and the assessed receptor where a solar reflection is geometrically possible.

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)[55].

It is assumed that the panel elevation angle assessed represents the elevation angle for all of the panels within each solar panel area defined.

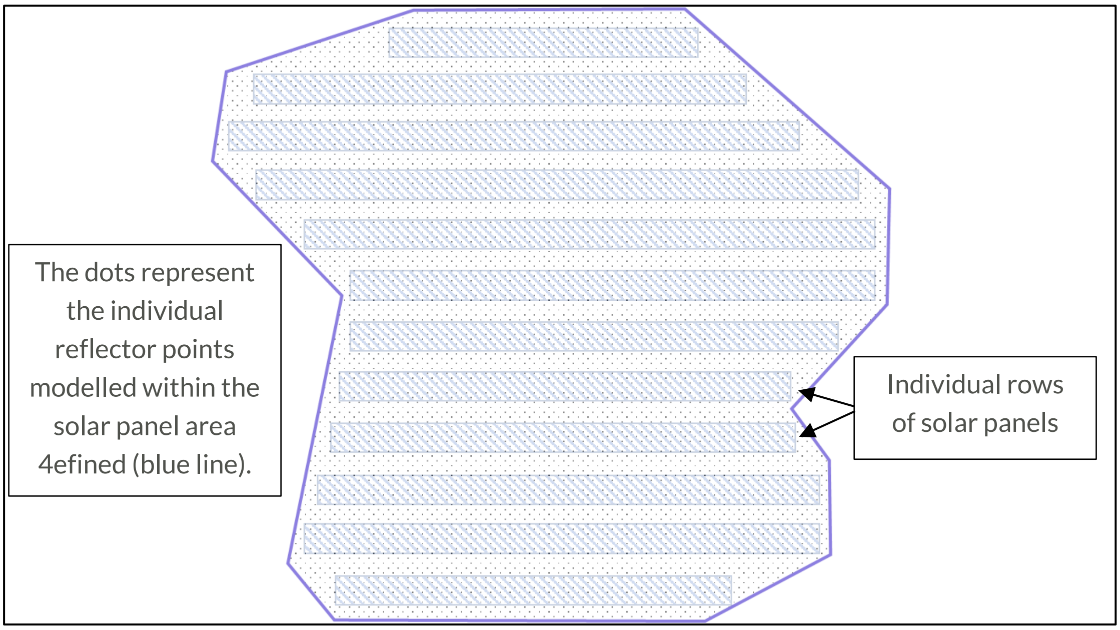
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

Only a reflection from the face of the panel has been considered. The frame or the reverse of the frame of the solar panel has not been considered.

The model assumes that a receptor can view the face of every panel (point, defined in the following paragraph) within the development area whilst in reality this, in the majority of cases, will not occur. Therefore any predicted solar reflection from the face of a solar panel that is not visible to a receptor will not occur in practice.

A finite number of points within each solar panel area defined is chosen based on an assessment resolution so that a comprehensive understanding of the entire development can be formed. This determines whether a solar reflection could ever occur at a chosen receptor. The model does not consider the specific panel rows or the entire face of the solar panel within the development outline, rather a single point is defined every 'x' metres (based on the assessment resolution) with the geometric characteristics of the panel. A panel area is however defined to encapsulate all possible panel locations. See the figure on the following page which illustrates this process.

[55] UK only.



Solar panel area modelling overview

A single reflection point is chosen for the geometric calculations. This suitably determines whether a solar reflection can be experienced at a receptor location and the time of year and duration of the solar reflection. Increased accuracy could be achieved by increasing the number of heights assessed however this would only marginally change the results and is not considered significant.

The available street view imagery, satellite mapping, terrain and any site imagery provided by the developer has been used to assess line of sight from the assessed receptors to the modelled solar panel area, unless stated otherwise. In some cases, this imagery may not be up to date and may not give the full perspective of the installation from the location of the assessed receptor.

Any screening in the form of trees, buildings etc. that may obstruct the Sun from view of the solar panels is not within the modelling unless stated otherwise. The terrain profile at the horizon is considered if stated.

Forge's Sandia National Laboratories' (SGHAT) Model[56]

Summary of assumptions and abstractions required by the SGHAT/ForgeSolar analysis methodology

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are now retained for two years after analysis completion. Files should be downloaded and saved if additional persistence is required.
3. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
4. Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects analyses of path receptors.
5. Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
6. The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the total heights of the coordinates outlined in the Google map. For more accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
9. The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
10. The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
11. The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
12. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
14. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
15. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

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[56] https://www.forgesolar.com/help/#assumptions

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Terrain Height

Terrain Height was calculated from Pager Power's database (established on OS Panorama 50m DTM) based on the coordinates of the point of interest.

Road Receptor Data

The table below presents the coordinates for the assessed road receptors.

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
1	-1.561414	54.583596	107	-1.479520	54.589580
2	-1.560395	54.584292	108	-1.479020	54.588630
3	-1.559414	54.584955	109	-1.478840	54.587780
4	-1.558313	54.585661	110	-1.478590	54.586760
5	-1.557293	54.586304	111	-1.478380	54.585950
6	-1.556218	54.586971	112	-1.478540	54.585050
7	-1.555258	54.587593	113	-1.478780	54.584250
8	-1.554188	54.588262	114	-1.479070	54.583310
9	-1.553140	54.588917	115	-1.479240	54.582420
10	-1.552097	54.589574	116	-1.478750	54.581670
11	-1.551008	54.590260	117	-1.478150	54.580730
12	-1.550016	54.590892	118	-1.478400	54.579880
13	-1.548980	54.591553	119	-1.478680	54.578990
14	-1.547806	54.592299	120	-1.478930	54.578100
15	-1.546699	54.593001	121	-1.478990	54.577240
16	-1.545836	54.593543	122	-1.478990	54.576420
17	-1.544648	54.594307	123	-1.478870	54.575560
18	-1.543739	54.594955	124	-1.478150	54.574640
19	-1.542809	54.595715	125	-1.477060	54.573940

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
20	-1.542047	54.596401	126	-1.476250	54.573430
21	-1.541281	54.597197	127	-1.475130	54.572690
22	-1.540591	54.598039	128	-1.474400	54.571850
23	-1.540225	54.598498	129	-1.474250	54.570990
24	-1.561761	54.584455	130	-1.474470	54.570100
25	-1.560518	54.584025	131	-1.474700	54.569170
26	-1.559897	54.583221	132	-1.474650	54.568260
27	-1.559124	54.582449	133	-1.474610	54.567320
28	-1.558373	54.581673	134	-1.474710	54.566500
29	-1.557896	54.580823	135	-1.475220	54.565650
30	-1.557660	54.580389	136	-1.476090	54.564900
31	-1.555798	54.577448	137	-1.477142	54.564244
32	-1.555279	54.576599	138	-1.477707	54.563898
33	-1.554784	54.575735	139	-1.480640	54.594590
34	-1.554151	54.574937	140	-1.479110	54.594410
35	-1.553282	54.574168	141	-1.477720	54.594090
36	-1.552448	54.573456	142	-1.476210	54.593840
37	-1.551539	54.572714	143	-1.474670	54.593690
38	-1.550677	54.571977	144	-1.473040	54.593630
39	-1.549913	54.571183	145	-1.471610	54.593530
40	-1.549261	54.570366	146	-1.470090	54.593320
41	-1.548778	54.569512	147	-1.468500	54.593090
42	-1.548515	54.568516	148	-1.467320	54.592590
43	-1.561516	54.589644	149	-1.466640	54.591790
44	-1.560542	54.588973	150	-1.466090	54.590990

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
45	-1.559707	54.588264	151	-1.465080	54.590340
46	-1.558282	54.588088	152	-1.463960	54.589650
47	-1.556722	54.587888	153	-1.462930	54.589010
48	-1.555253	54.587699	154	-1.461840	54.588410
49	-1.553676	54.587569	155	-1.460520	54.587920
50	-1.552184	54.587857	156	-1.459140	54.587420
51	-1.551170	54.588489	157	-1.457770	54.586970
52	-1.550279	54.589227	158	-1.456320	54.586750
53	-1.549369	54.589989	159	-1.454880	54.586510
54	-1.548490	54.590732	160	-1.453560	54.586110
55	-1.547661	54.591427	161	-1.452170	54.585790
56	-1.546374	54.592018	162	-1.450380	54.585580
57	-1.545034	54.592343	163	-1.448750	54.585650
58	-1.543530	54.592657	164	-1.447590	54.585750
59	-1.542009	54.593018	165	-1.445920	54.585920
60	-1.540694	54.593382	166	-1.444360	54.585910
61	-1.539316	54.593796	167	-1.442780	54.585680
62	-1.537948	54.594221	168	-1.441430	54.585750
63	-1.536556	54.594546	169	-1.439810	54.585730
64	-1.535083	54.594828	170	-1.438170	54.585470
65	-1.533567	54.595122	171	-1.435810	54.584540
66	-1.532125	54.595450	172	-1.436920	54.585080
67	-1.530762	54.595811	173	-1.434950	54.583830
68	-1.529298	54.596104	174	-1.433680	54.583180
69	-1.527777	54.596281	175	-1.432510	54.582590

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
70	-1.526395	54.596422	176	-1.431760	54.581830
71	-1.524718	54.596299	177	-1.430790	54.581170
72	-1.523198	54.596122	178	-1.430190	54.580370
73	-1.521687	54.596500	179	-1.429550	54.579630
74	-1.529939	54.600805	180	-1.428750	54.578930
75	-1.528642	54.600278	181	-1.427690	54.578070
76	-1.527314	54.599779	182	-1.467900	54.592970
77	-1.525871	54.599514	183	-1.466740	54.593620
78	-1.524368	54.599356	184	-1.465650	54.594210
79	-1.522952	54.599119	185	-1.464120	54.594360
80	-1.521787	54.598506	186	-1.462530	54.594530
81	-1.521796	54.597656	187	-1.461100	54.594640
82	-1.521764	54.596740	188	-1.459600	54.594850
83	-1.520445	54.596366	189	-1.458130	54.595160
84	-1.518961	54.596156	190	-1.456550	54.595470
85	-1.517475	54.595947	191	-1.455180	54.595730
86	-1.515986	54.595747	192	-1.453650	54.596030
87	-1.514391	54.595532	193	-1.452150	54.596270
88	-1.512902	54.595331	194	-1.450680	54.596450
89	-1.511416	54.595124	195	-1.449150	54.596610
90	-1.509710	54.594915	196	-1.447610	54.596770
91	-1.508346	54.594923	197	-1.446140	54.596910
92	-1.506727	54.595004	198	-1.444750	54.597320
93	-1.505604	54.595552	199	-1.443550	54.597900
94	-1.504249	54.595823	200	-1.442270	54.598410

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
95	-1.502682	54.595694	201	-1.440740	54.598460
96	-1.501215	54.595620	202	-1.439230	54.598250
97	-1.499634	54.595573	203	-1.437750	54.598460
98	-1.498004	54.595608	204	-1.436470	54.598770
99	-1.496592	54.595833	205	-1.434970	54.599330
100	-1.494930	54.596130	206	-1.434880	54.600080
101	-1.493676	54.596110	207	-1.433710	54.600730
102	-1.492039	54.596084	208	-1.432520	54.601260
103	-1.490408	54.596021	209	-1.430950	54.601410
104	-1.488883	54.595990	210	-1.429820	54.601910
105	-1.487259	54.595869	211	-1.428620	54.602540
106	-1.485893	54.595652			

Road Receptor Data

Dwelling Receptor Data

The table below presents the coordinates for the assessed dwelling receptors.

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
1	54.590672	-1.560106	131	54.575767	-1.464313
2	54.589171	-1.560449	132	54.575901	-1.463876
3	54.587344	-1.560999	133	54.575814	-1.46344
4	54.591618	-1.552465	134	54.575503	-1.463893
5	54.584361	-1.55898	135	54.575664	-1.463283
6	54.582739	-1.558433	136	54.575554	-1.463093
7	54.582074	-1.55634	137	54.57529	-1.463702
8	54.579991	-1.557128	138	54.57516	-1.46356
9	54.579737	-1.556185	139	54.575366	-1.462708
10	54.579918	-1.554587	140	54.574967	-1.463389

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
11	54.574971	-1.553651	141	54.575158	-1.462551
12	54.574803	-1.553469	142	54.574792	-1.463181
13	54.574351	-1.553997	143	54.574335	-1.462594
14	54.57443	-1.553107	144	54.574971	-1.462113
15	54.574204	-1.55281	145	54.574617	-1.461975
16	54.57361	-1.552005	146	54.574185	-1.462308
17	54.573509	-1.551648	147	54.574445	-1.461687
18	54.573401	-1.551476	148	54.574254	-1.461634
19	54.57325	-1.55143	149	54.57397	-1.462101
20	54.573001	-1.551258	150	54.573811	-1.461997
21	54.572727	-1.550933	151	54.574129	-1.461413
22	54.572975	-1.55017	152	54.573941	-1.461624
23	54.572402	-1.550471	153	54.574639	-1.458454
24	54.572133	-1.550234	154	54.575927	-1.455191
25	54.572906	-1.548504	155	54.576122	-1.454749
26	54.571898	-1.549943	156	54.578492	-1.450115
27	54.571666	-1.549777	157	54.585476	-1.447868
28	54.571518	-1.549529	158	54.58532	-1.446139
29	54.571331	-1.549441	159	54.586183	-1.446351
30	54.571208	-1.54934	160	54.585928	-1.441047
31	54.570344	-1.548615	161	54.585638	-1.44091
32	54.569956	-1.548485	162	54.585914	-1.440677
33	54.569748	-1.548344	163	54.585636	-1.440677
34	54.583486	-1.549553	164	54.58591	-1.440399
35	54.583166	-1.549131	165	54.58563	-1.440405

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
36	54.583256	-1.548942	166	54.586469	-1.439978
37	54.583325	-1.548782	167	54.585885	-1.440114
38	54.583506	-1.54896	168	54.585589	-1.440159
39	54.583483	-1.548576	169	54.585848	-1.439873
40	54.583597	-1.548187	170	54.585529	-1.439976
41	54.583655	-1.548027	171	54.585829	-1.439629
42	54.58371	-1.547867	172	54.585234	-1.439914
43	54.583841	-1.547566	173	54.585817	-1.439384
44	54.583884	-1.547156	174	54.585172	-1.439628
45	54.584011	-1.547045	175	54.585803	-1.439126
46	54.584092	-1.546829	176	54.585113	-1.439345
47	54.58423	-1.546477	177	54.585781	-1.438806
48	54.584299	-1.546267	178	54.585076	-1.439069
49	54.584378	-1.54606	179	54.585764	-1.438523
50	54.584428	-1.54584	180	54.585029	-1.438852
51	54.584484	-1.545667	181	54.585739	-1.438162
52	54.584548	-1.54547	182	54.584966	-1.438415
53	54.584458	-1.545255	183	54.585691	-1.437745
54	54.584663	-1.545135	184	54.585814	-1.437647
55	54.584696	-1.544903	185	54.58593	-1.437696
56	54.584747	-1.544711	186	54.586055	-1.437754
57	54.584772	-1.544465	187	54.586172	-1.437816
58	54.584834	-1.544226	188	54.586303	-1.437914
59	54.584801	-1.543204	189	54.586428	-1.437907
60	54.584649	-1.543702	190	54.586448	-1.437633

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
61	54.584335	-1.543727	191	54.586391	-1.437367
62	54.584275	-1.544095	192	54.586386	-1.437066
63	54.584242	-1.544385	193	54.58639	-1.436803
64	54.584232	-1.544771	194	54.586406	-1.436513
65	54.584078	-1.54542	195	54.586401	-1.436337
66	54.583973	-1.545602	196	54.586323	-1.43626
67	54.583811	-1.546166	197	54.586241	-1.436291
68	54.583674	-1.546393	198	54.586135	-1.436293
69	54.583519	-1.546774	199	54.586044	-1.436265
70	54.583401	-1.547082	200	54.586485	-1.435783
71	54.583254	-1.54742	201	54.586262	-1.435696
72	54.583127	-1.547752	202	54.586095	-1.435639
73	54.583011	-1.548091	203	54.585851	-1.435524
74	54.582957	-1.548502	204	54.585116	-1.437661
75	54.582771	-1.548819	205	54.584954	-1.437356
76	54.592733	-1.538941	206	54.584783	-1.436877
77	54.585858	-1.53353	207	54.584664	-1.436473
78	54.569869	-1.53488	208	54.584508	-1.436154
79	54.571949	-1.535383	209	54.584391	-1.435971
80	54.57262	-1.534354	210	54.584238	-1.435782
81	54.57732	-1.524773	211	54.584059	-1.43567
82	54.577277	-1.517064	212	54.583715	-1.435249
83	54.57968	-1.515822	213	54.583544	-1.435116
84	54.593069	-1.528067	214	54.583383	-1.434777
85	54.597015	-1.528722	215	54.585522	-1.435757

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
86	54.594991	-1.509713	216	54.585591	-1.435582
87	54.594238	-1.509745	217	54.585645	-1.43539
88	54.59378	-1.509808	218	54.58575	-1.435072
89	54.595797	-1.502531	219	54.585346	-1.435689
90	54.588442	-1.510585	220	54.585369	-1.435197
91	54.591551	-1.498256	221	54.585191	-1.435121
92	54.590834	-1.498978	222	54.585067	-1.435028
93	54.593611	-1.481972	223	54.584819	-1.435638
94	54.592977	-1.478686	224	54.584586	-1.435585
95	54.593018	-1.478209	225	54.584439	-1.435496
96	54.592607	-1.478932	226	54.584377	-1.435426
97	54.592536	-1.4785	227	54.584317	-1.435365
98	54.592452	-1.47765	228	54.584189	-1.435256
99	54.592331	-1.479664	229	54.584003	-1.434992
100	54.592268	-1.478137	230	54.584185	-1.434348
101	54.592197	-1.477561	231	54.584034	-1.434196
102	54.591904	-1.480203	232	54.583962	-1.433986
103	54.592014	-1.478967	233	54.583756	-1.434517
104	54.592042	-1.477308	234	54.583656	-1.434075
105	54.591602	-1.479676	235	54.583265	-1.434379
106	54.591322	-1.479477	236	54.578617	-1.434311
107	54.59143	-1.479093	237	54.57668	-1.432291
108	54.591543	-1.478819	238	54.579003	-1.429347
109	54.591681	-1.478547	239	54.579772	-1.429339
110	54.591739	-1.478316	240	54.582965	-1.417771

No.	Latitude (°)	Longitude (°)	No.	Latitude (°)	Longitude (°)
111	54.59174	-1.477868	241	54.584707	-1.414273
112	54.591817	-1.477455	242	54.597807	-1.439248
113	54.591255	-1.478241	243	54.597921	-1.438551
114	54.591114	-1.479644	244	54.597927	-1.438144
115	54.590871	-1.479358	245	54.5977	-1.423329
116	54.591239	-1.484392	246	54.597776	-1.414051
117	54.58655	-1.483209	247	54.597998	-1.413572
118	54.586607	-1.48241	248	54.59798	-1.412678
119	54.580844	-1.496436	249	54.598041	-1.411561
120	54.581025	-1.484337	250	54.598016	-1.410967
121	54.576517	-1.479246	251	54.597953	-1.410613
122	54.57469	-1.477875	252	54.597751	-1.410612
123	54.570621	-1.471766	253	54.597603	-1.410455
124	54.596609	-1.469922	254	54.596146	-1.414628
125	54.591609	-1.46036	255	54.595984	-1.41443
126	54.584248	-1.463933	256	54.595987	-1.414766
127	54.57748	-1.46567	257	54.59359	-1.416555
128	54.576295	-1.464942	258	54.590072	-1.411898
129	54.576109	-1.464794	259	54.590264	-1.411648
130	54.57587	-1.464504			

Dwelling Receptor Data

Train Driver Receptor Data

The table below presents the coordinates for the assessed train driver receptors.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.552127	54.583498	9	-1.545637	54.577601
2	-1.550877	54.582951	10	-1.545372	54.576717

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
3	-1.549767	54.582345	11	-1.545120	54.575831
4	-1.548760	54.581665	12	-1.544871	54.574958
5	-1.547896	54.580922	13	-1.544614	54.574060
6	-1.547160	54.580176	14	-1.544358	54.573162
7	-1.546527	54.579345	15	-1.544091	54.572227
8	-1.546010	54.578472			

Train driver receptor locations

Railway Signal Locations

The table below presents the coordinates for the assessed railway signals.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.549183	54.581913	3	-1.546955	54.580054
2	-1.549001	54.581960			

Railway Signal locations

ATC Tower Location – Teesside International Airport

The table below presents the ATC Tower coordinates.

Type	Longitude (°)	Latitude (°)
ATC Tower	-1.427587	54.513247

ATC Tower coordinates

The Approach Surface for Aircraft Landing on Runway 05 at Teesside International Airport

The table below presents the coordinate and altitude data defining the start and end points for the assessed approach to runway 05 at Teesside International Airport. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.24m) above the runway threshold.

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-1.442428	54.502231	50.29
2-mile point	-1.479146	54.482676	218.98

Coordinate and altitude data defining the start and end points for the assessed approach towards runway 05

The Approach Surface for Aircraft Landing on Runway 23 at Teesside International Airport

The table below presents the coordinate and altitude data defining the start and end points for the assessed approach to runway 23 at Teesside International Airport. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.24m) above the runway threshold.

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-1.416392	54.516139	50.60
2-mile point	-1.379650	54.535687	219.28

Coordinate and altitude data defining the start and end points for the assessed approach towards runway 23

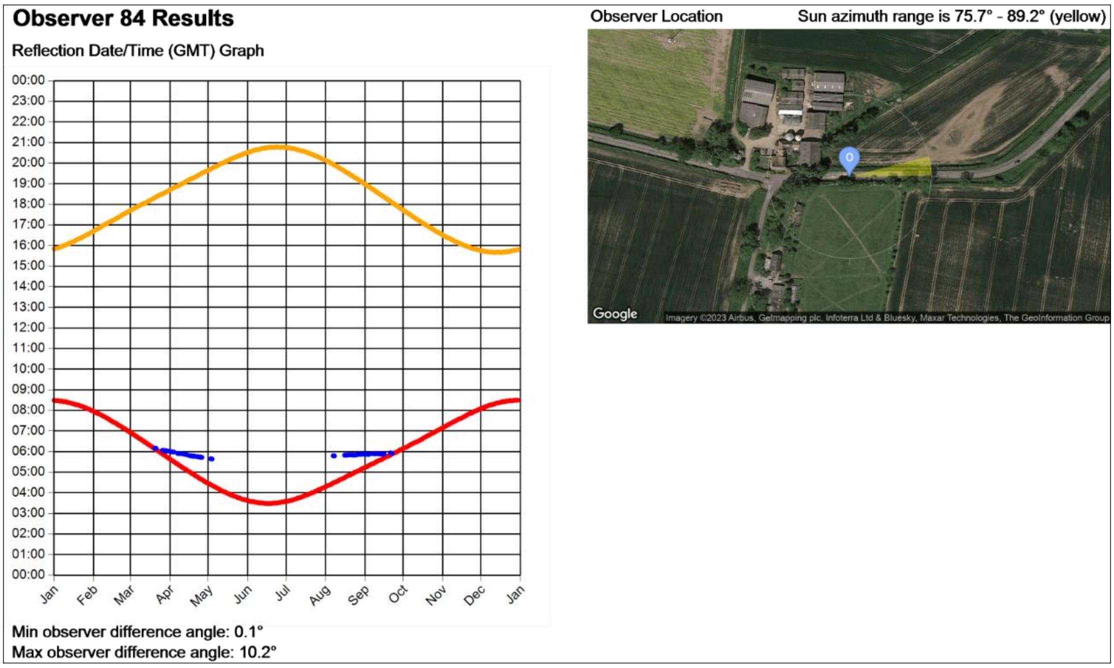
APPENDIX H – MODELLING RESULTS

Overview

The charts for the receptors where an impact is predicted are shown in the following sections. Each chart shows:

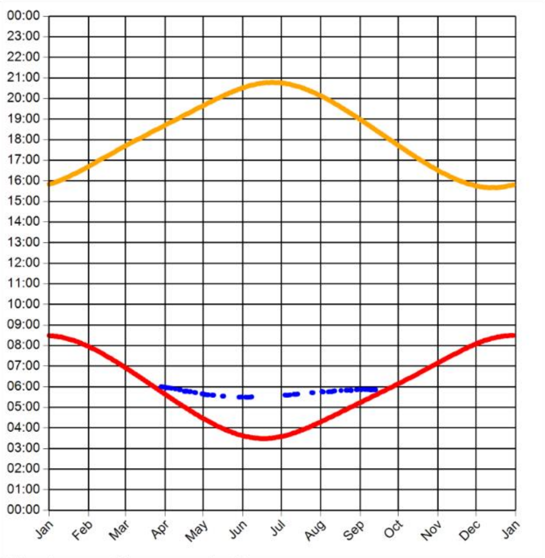
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflection date/time graph – left hand side of the page. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas;
- The sunrise and sunset curves throughout the year (red and yellow lines).

Road Receptors



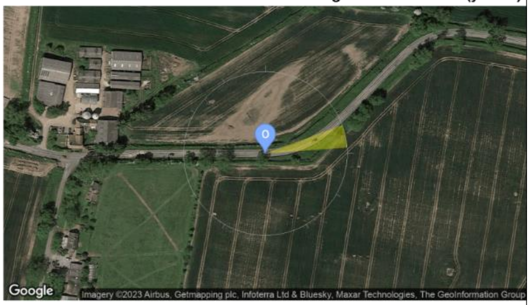
Observer 85 Results

Reflection Date/Time (GMT) Graph



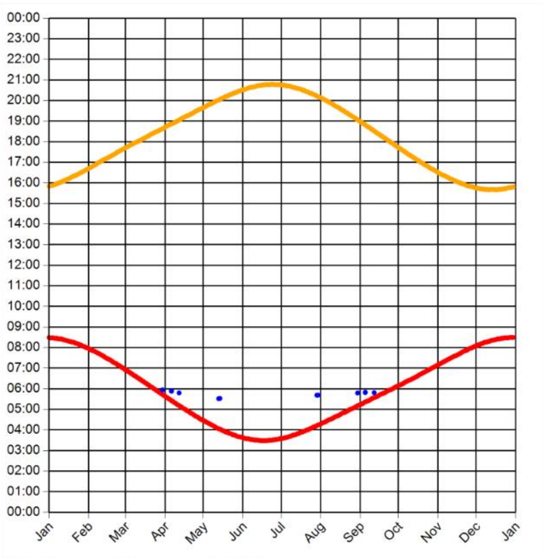
Min observer difference angle: 1°
Max observer difference angle: 14°

Observer Location — Sun azimuth range is 69.6° - 85.8° (yellow)



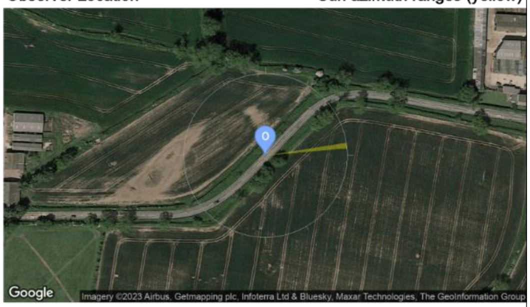
Observer 86 Results

Reflection Date/Time (GMT) Graph



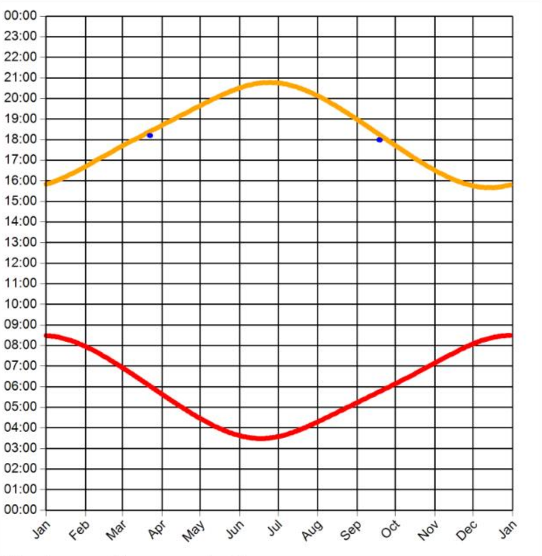
Min observer difference angle: 0.2°
Max observer difference angle: 10.6°

Observer Location — Sun azimuth ranges (yellow)



Observer 90 Results

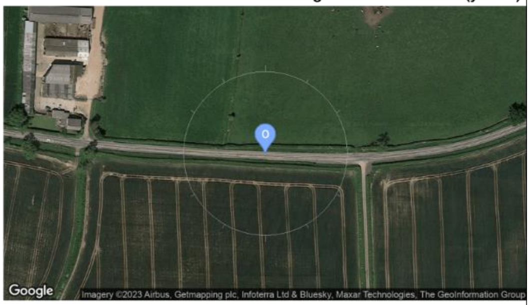
Reflection Date/Time (GMT) Graph



Min observer difference angle: 2°
Max observer difference angle: 2.1°

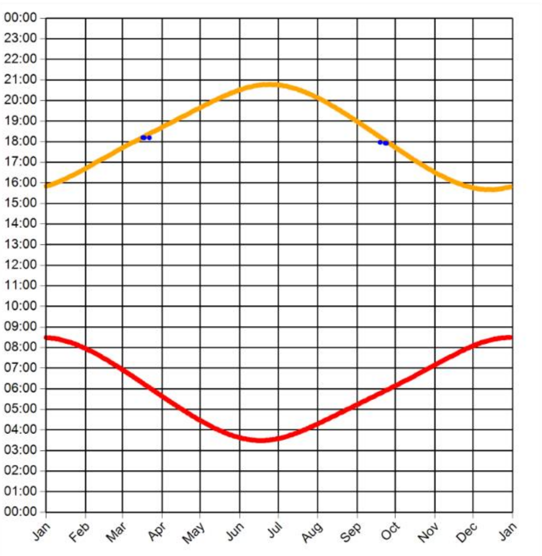
Observer Location

Sun azimuth range is 270.6° - 270.9° (yellow)



Observer 91 Results

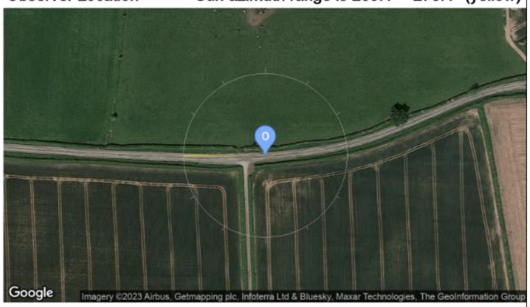
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.7°
Max observer difference angle: 2.2°

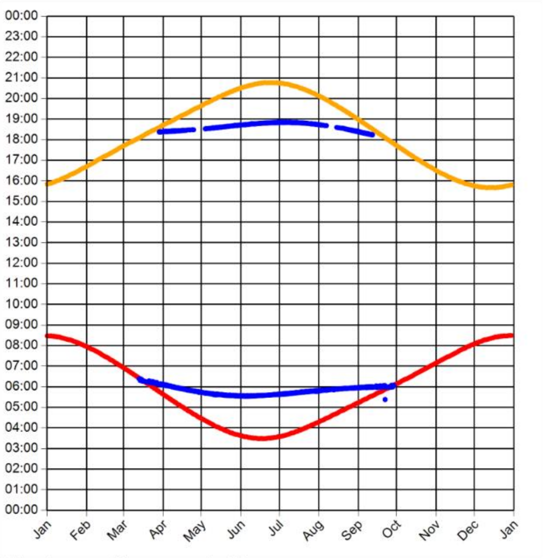
Observer Location

Sun azimuth range is 269.1° - 270.4° (yellow)



Observer 113 Results

Reflection Date/Time (GMT) Graph

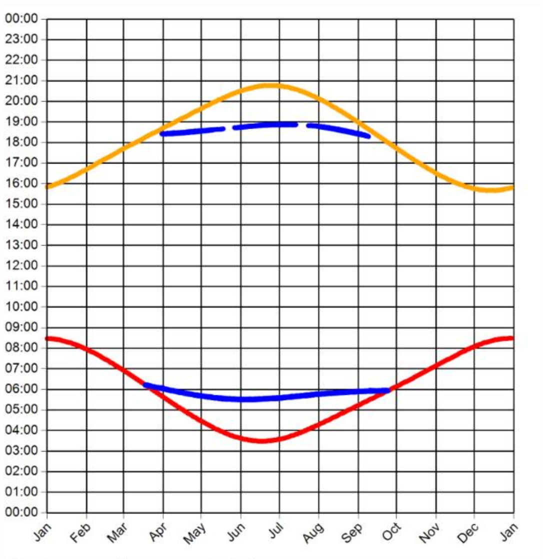


Min observer difference angle: 0°
Max observer difference angle: 16°

Observer Location | Sun azimuth ranges (yellow)

Observer 114 Results

Reflection Date/Time (GMT) Graph

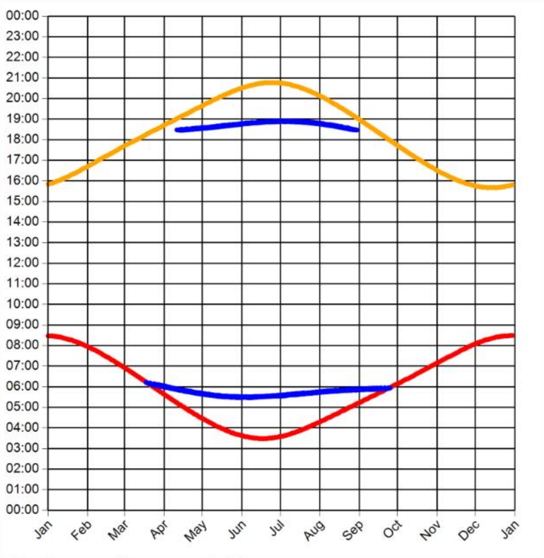


Min observer difference angle: 0.1°
Max observer difference angle: 15.1°

Observer Location | Sun azimuth ranges (yellow)

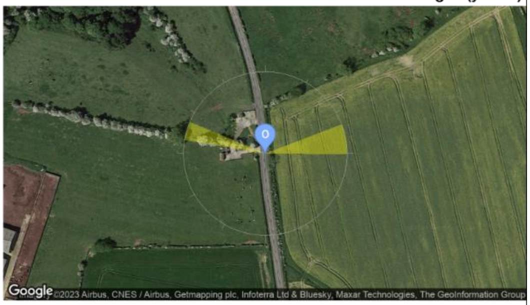
Observer 115 Results

Reflection Date/Time (GMT) Graph



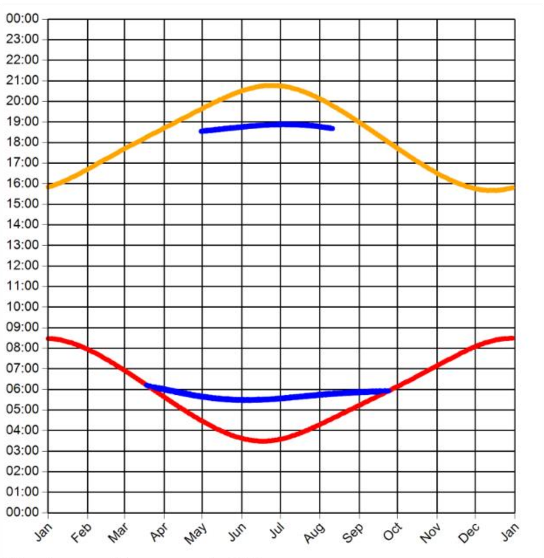
Min observer difference angle: 0°
Max observer difference angle: 14.8°

Observer Location — Sun azimuth ranges (yellow)



Observer 116 Results

Reflection Date/Time (GMT) Graph

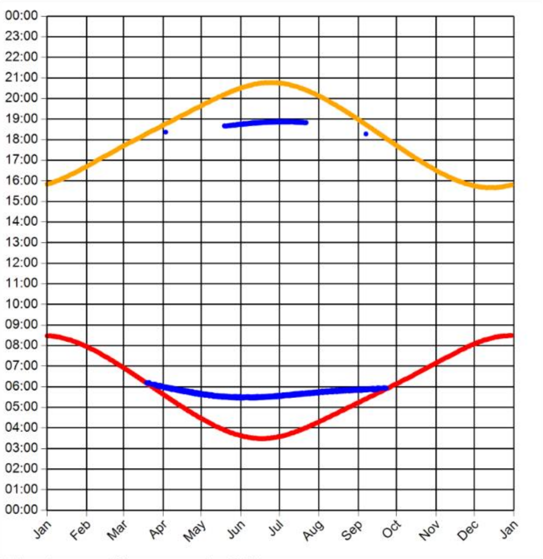


Min observer difference angle: 0.1°
Max observer difference angle: 14.5°

Observer Location — Sun azimuth ranges (yellow)

Observer 117 Results

Reflection Date/Time (GMT) Graph



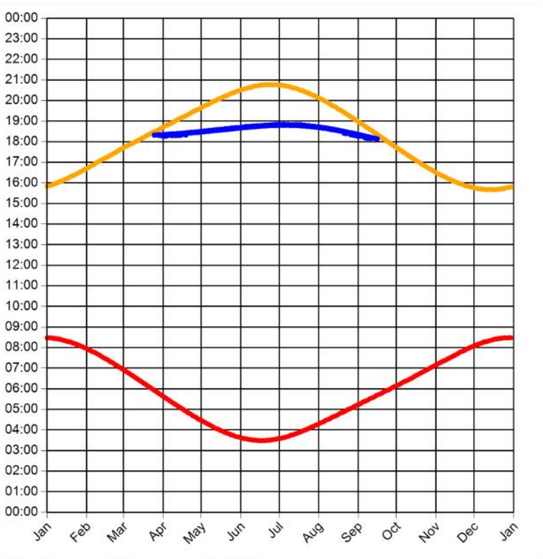
Min observer difference angle: 0.1°
Max observer difference angle: 14.6°

Observer Location

Sun azimuth ranges (yellow)

Observer 126 Results

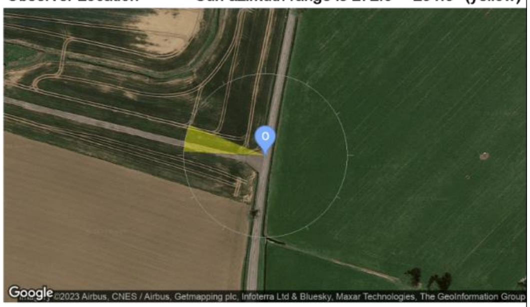
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 13.1°

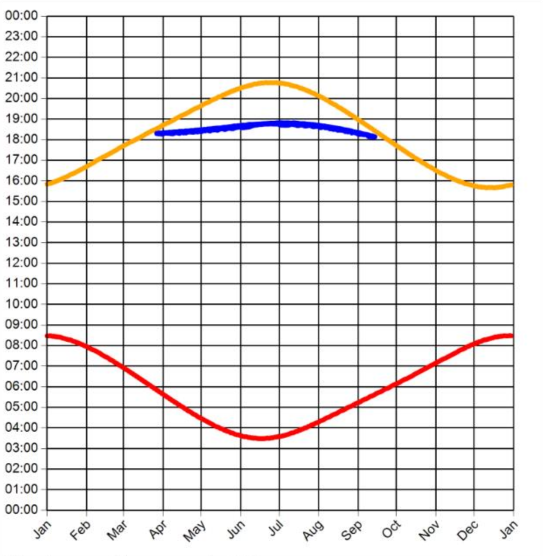
Observer Location

Sun azimuth range is 272.8° - 291.8° (yellow)

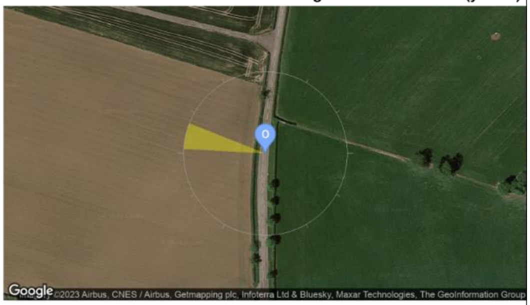


Observer 127 Results

Reflection Date/Time (GMT) Graph



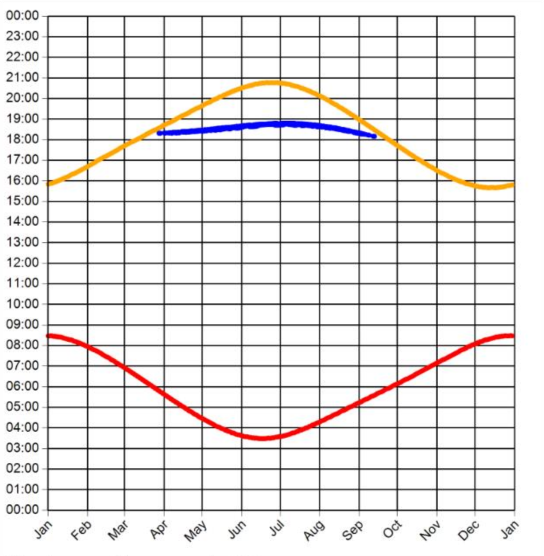
Observer Location — Sun azimuth range is 273.2° - 291.7° (yellow)



Min observer difference angle: 1.1°
Max observer difference angle: 14.6°

Observer 128 Results

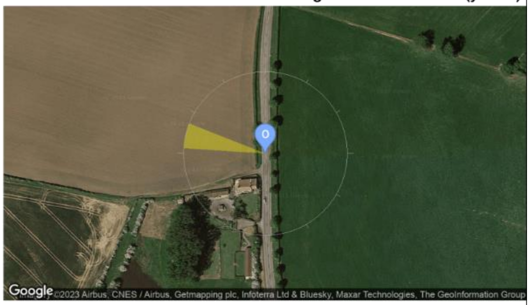
Reflection Date/Time (GMT) Graph



Min observer difference angle: 1.2°
Max observer difference angle: 14.8°

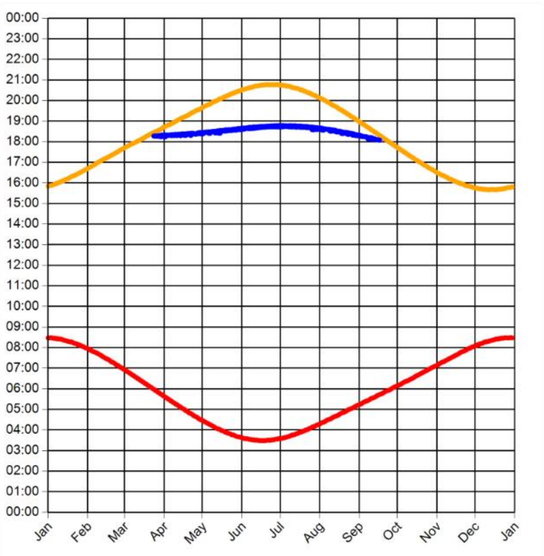
Observer Location

Sun azimuth range is 273.7° - 291.5° (yellow)



Observer 129 Results

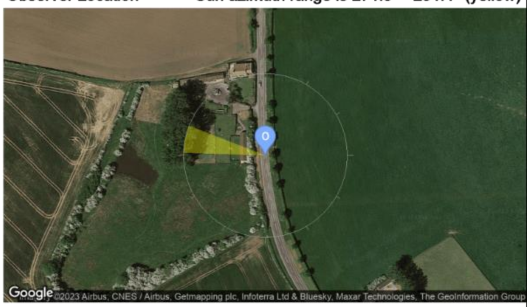
Reflection Date/Time (GMT) Graph



Min observer difference angle: 1°
Max observer difference angle: 14.5°

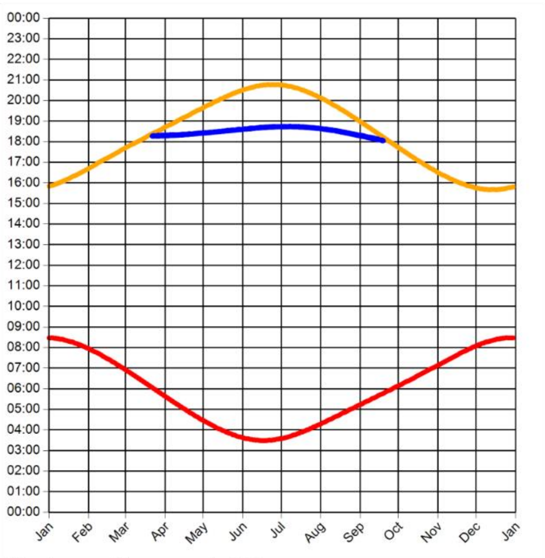
Observer Location

Sun azimuth range is 271.9° - 291.4° (yellow)



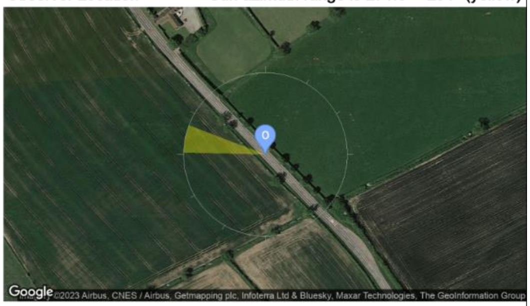
Observer 132 Results

Reflection Date/Time (GMT) Graph



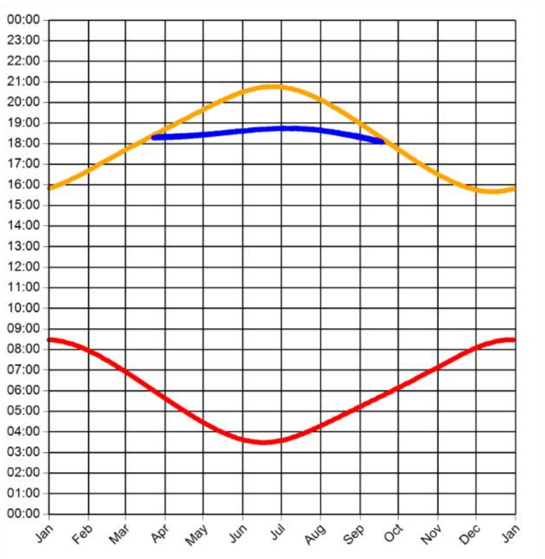
Min observer difference angle: 0.3°
Max observer difference angle: 14.7°

Observer Location — Sun azimuth range is 271.3° - 291° (yellow)



Observer 133 Results

Reflection Date/Time (GMT) Graph

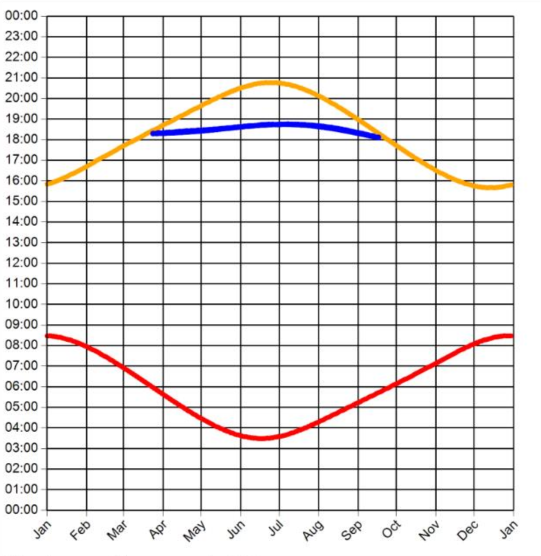


Min observer difference angle: 0.3°
Max observer difference angle: 14.4°

Observer Location — Sun azimuth range is 271.8° - 290.9° (yellow)

Observer 134 Results

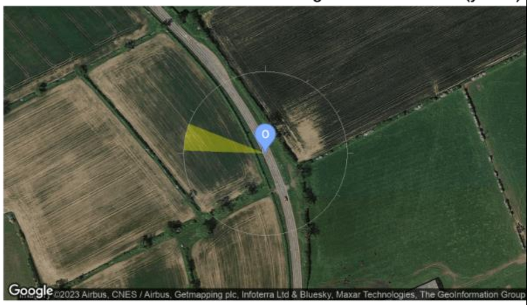
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 14.4°

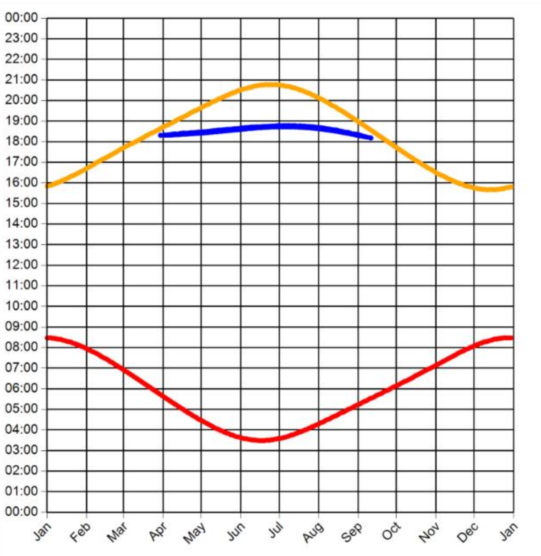
Observer Location

Sun azimuth range is 272.2° - 291.3° (yellow)



Observer 135 Results

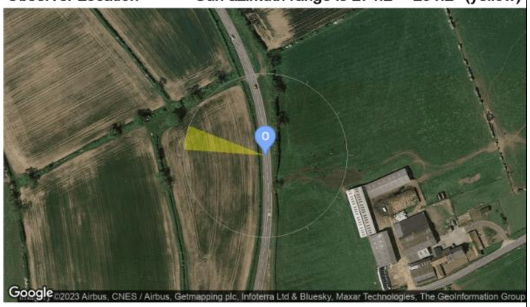
Reflection Date/Time (GMT) Graph



Min observer difference angle: 1.8°
Max observer difference angle: 14.4°

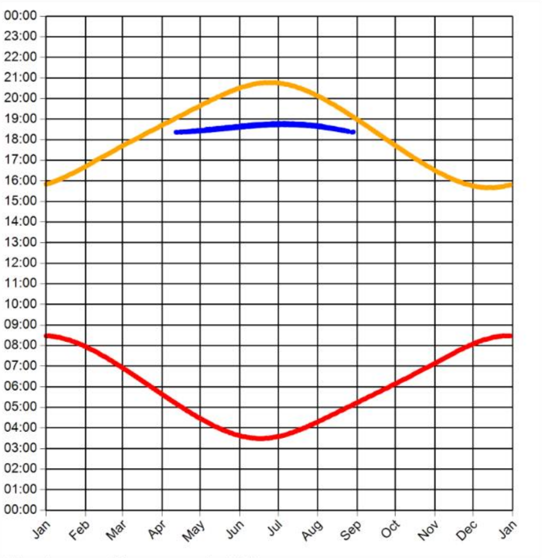
Observer Location

Sun azimuth range is 274.2° - 291.2° (yellow)



Observer 136 Results

Reflection Date/Time (GMT) Graph



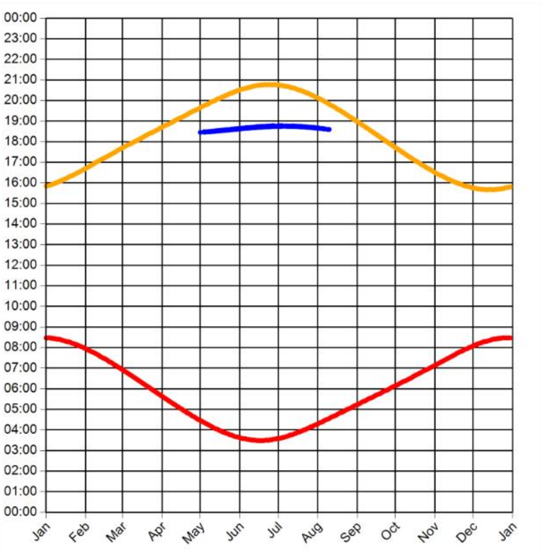
Min observer difference angle: 4.7°
Max observer difference angle: 14.5°

Observer Location

Sun azimuth range is 278.4° - 291.4° (yellow)

Observer 137 Results

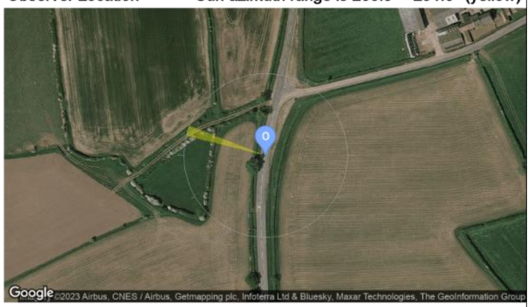
Reflection Date/Time (GMT) Graph



Min observer difference angle: 8.5°
Max observer difference angle: 14.1°

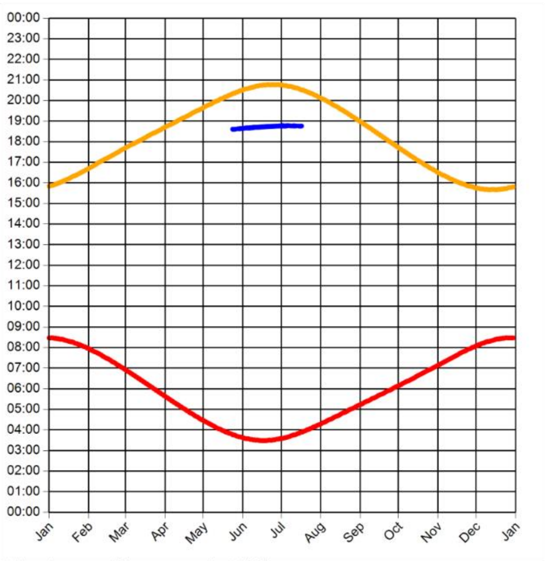
Observer Location

Sun azimuth range is 283.9° - 291.3° (yellow)



Observer 138 Results

Reflection Date/Time (GMT) Graph

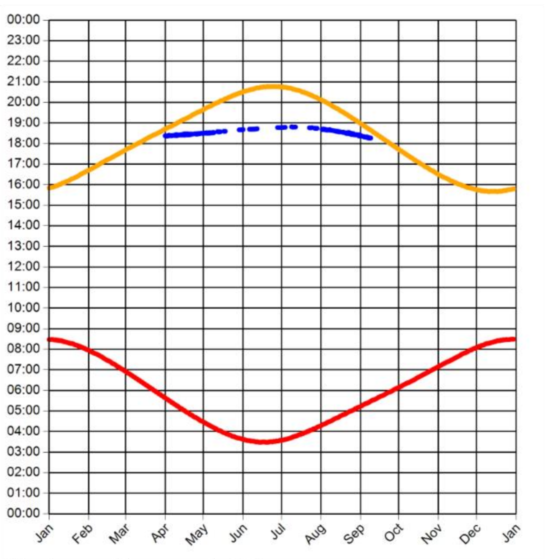


Min observer difference angle: 11.9°
Max observer difference angle: 13.7°

Observer Location — Sun azimuth range is 289.1° - 291.2° (yellow)

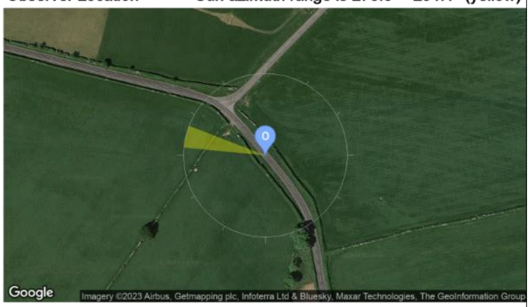
Observer 155 Results

Reflection Date/Time (GMT) Graph



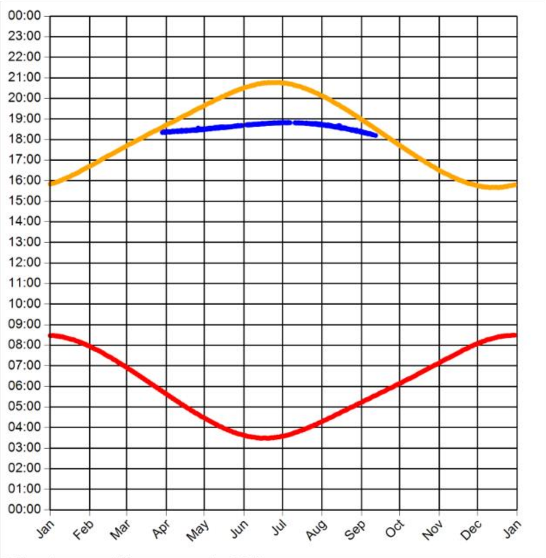
Min observer difference angle: 0.9°
Max observer difference angle: 13.2°

Observer Location — Sun azimuth range is 275.5° - 291.1° (yellow)



Observer 156 Results

Reflection Date/Time (GMT) Graph



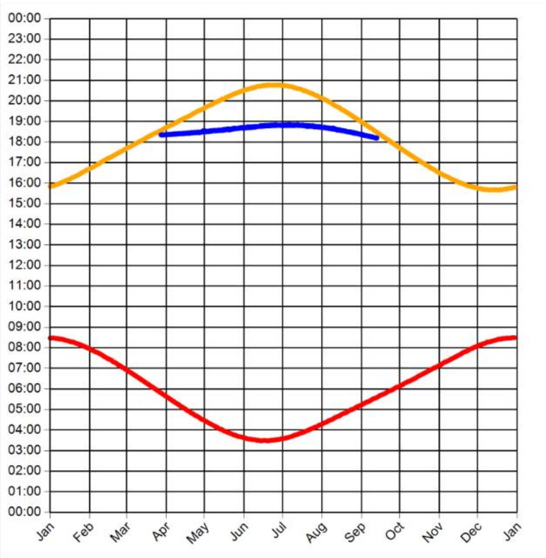
Min observer difference angle: 0.7°
Max observer difference angle: 12.7°

Observer Location

Sun azimuth range is 274.3° - 291.8° (yellow)

Observer 157 Results

Reflection Date/Time (GMT) Graph



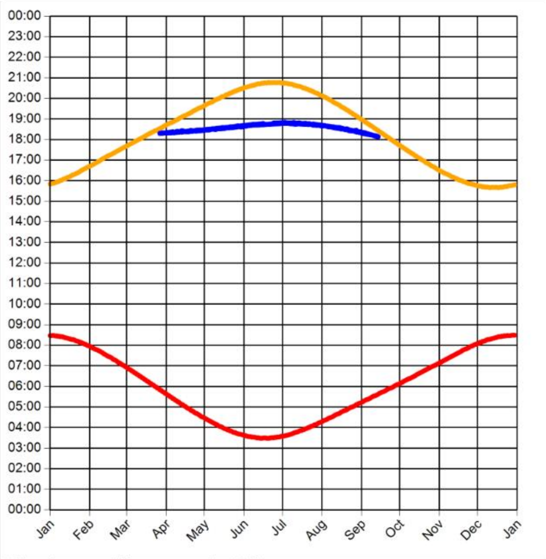
Min observer difference angle: 0.6°
Max observer difference angle: 12.6°

Observer Location

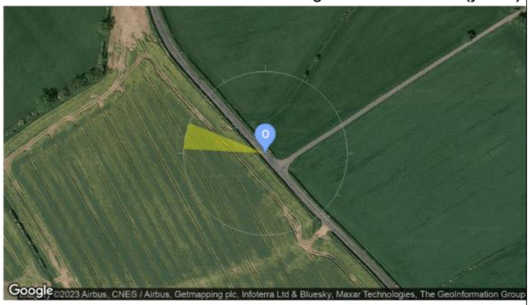
Sun azimuth range is 274.1° - 292.1° (yellow)

Observer 158 Results

Reflection Date/Time (GMT) Graph



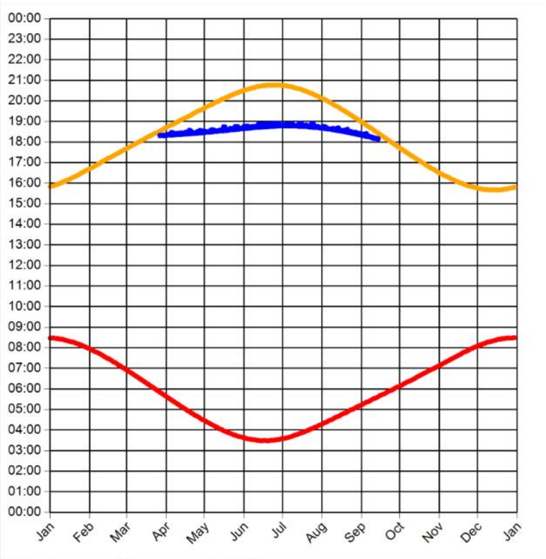
Observer Location Sun azimuth range is 273.2° - 291.8° (yellow)



Min observer difference angle: 1.1°
Max observer difference angle: 13.5°

Observer 159 Results

Reflection Date/Time (GMT) Graph

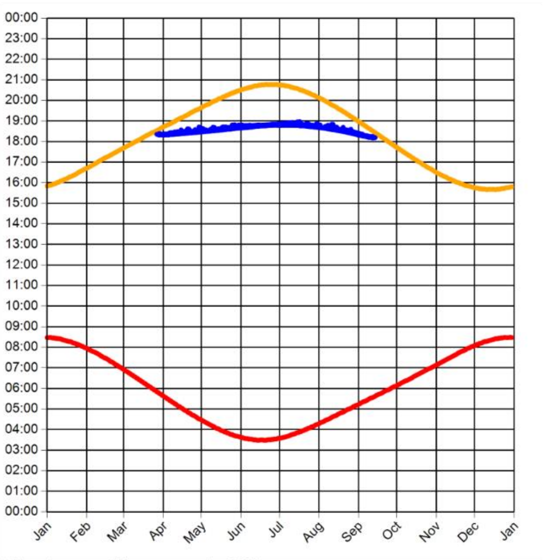


Observer Location Sun azimuth range is 273.3° - 292.8° (yellow)

Min observer difference angle: 0.3°
Max observer difference angle: 13.3°

Observer 160 Results

Reflection Date/Time (GMT) Graph

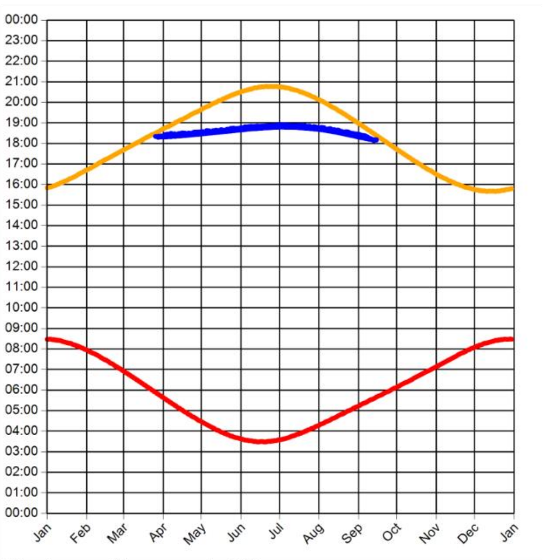


Min observer difference angle: 0.2°
Max observer difference angle: 13.1°

Observer Location   Sun azimuth range is 273.9° - 292.1° (yellow)

Observer 161 Results

Reflection Date/Time (GMT) Graph

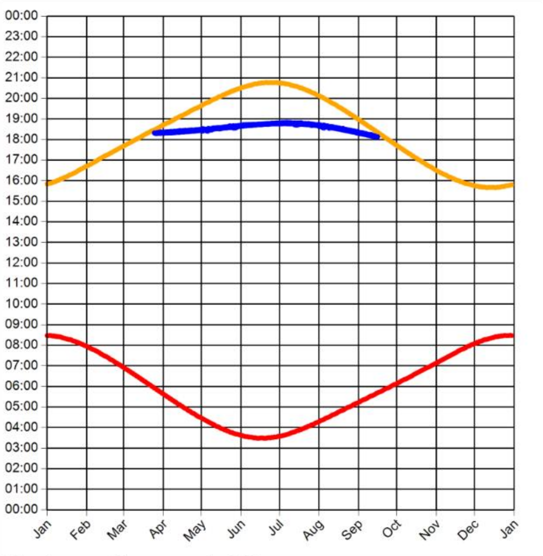


Min observer difference angle: 0.3°
Max observer difference angle: 13.1°

Observer Location   Sun azimuth range is 273.4° - 292.6° (yellow)

Observer 162 Results

Reflection Date/Time (GMT) Graph

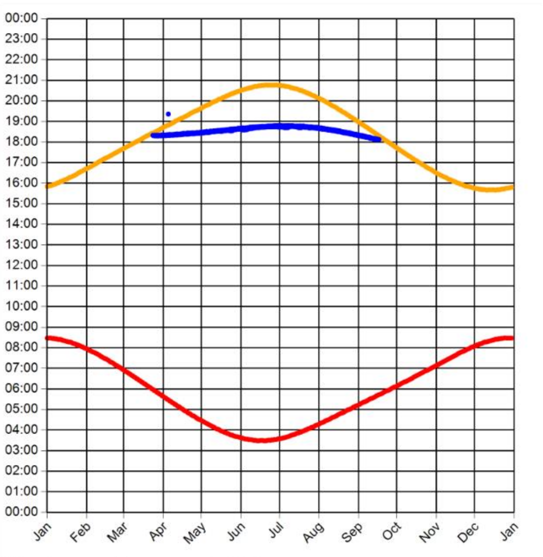


Min observer difference angle: 0.3°
Max observer difference angle: 13.6°

Observer Location   Sun azimuth range is 272.8° - 291.6° (yellow)

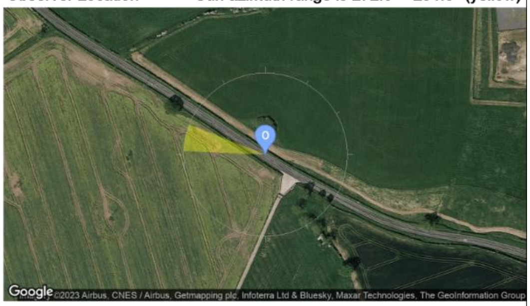
Observer 163 Results

Reflection Date/Time (GMT) Graph



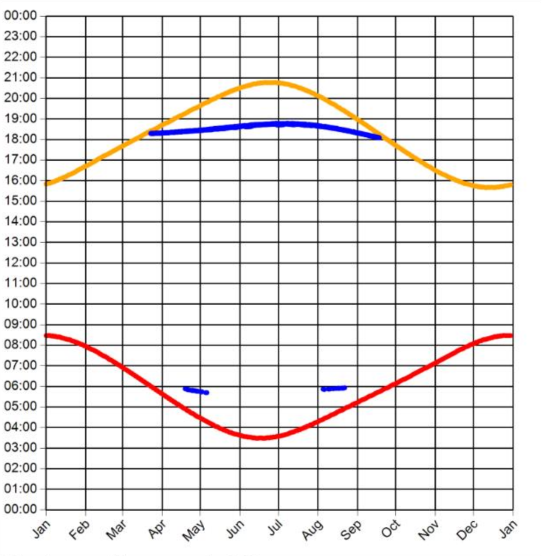
Min observer difference angle: 0.3°
Max observer difference angle: 14.6°

Observer Location   Sun azimuth range is 272.5° - 291.6° (yellow)



Observer 164 Results

Reflection Date/Time (GMT) Graph



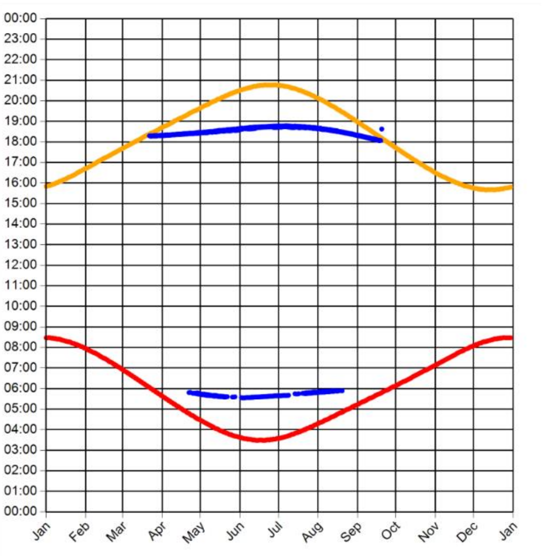
Min observer difference angle: 0.3°
Max observer difference angle: 14.6°

Observer Location

Sun azimuth ranges (yellow)

Observer 165 Results

Reflection Date/Time (GMT) Graph



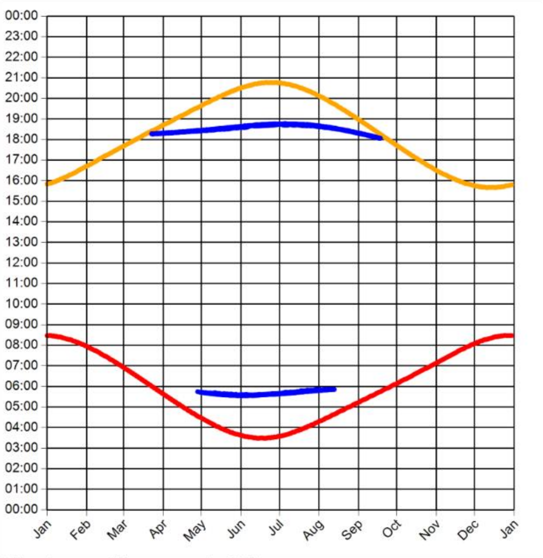
Min observer difference angle: 0.2°
Max observer difference angle: 16.3°

Observer Location

Sun azimuth ranges (yellow)

Observer 166 Results

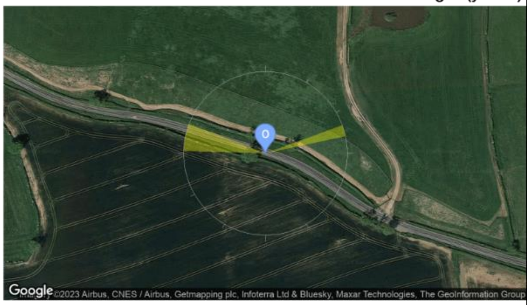
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.5°
Max observer difference angle: 16.5°

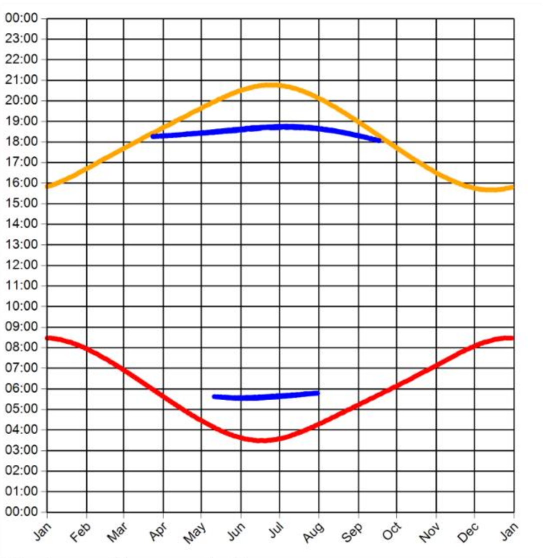
Observer Location

Sun azimuth ranges (yellow)



Observer 167 Results

Reflection Date/Time (GMT) Graph



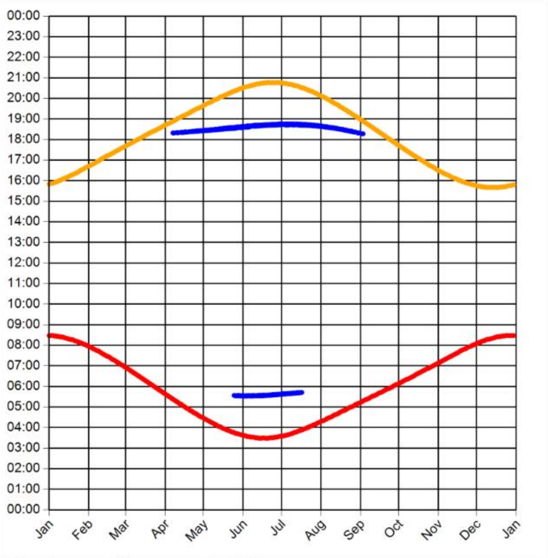
Min observer difference angle: 1°
Max observer difference angle: 16.7°

Observer Location

Sun azimuth ranges (yellow)

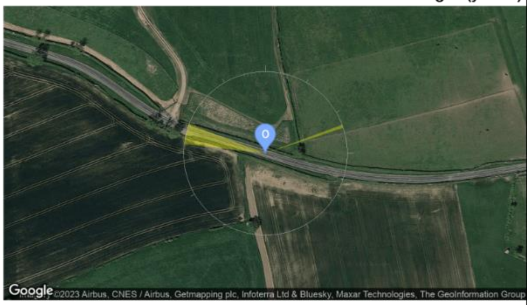
Observer 168 Results

Reflection Date/Time (GMT) Graph



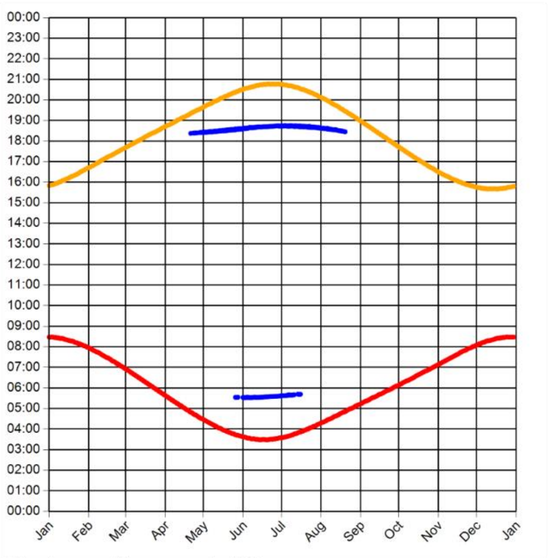
Min observer difference angle: 4.1°
Max observer difference angle: 15.6°

Observer Location | Sun azimuth ranges (yellow)



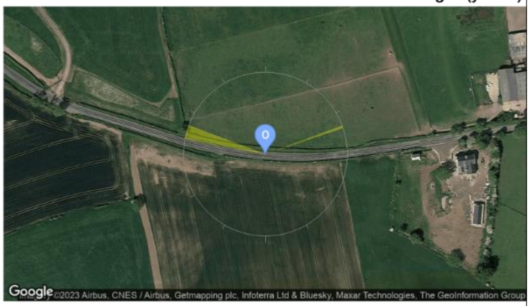
Observer 169 Results

Reflection Date/Time (GMT) Graph



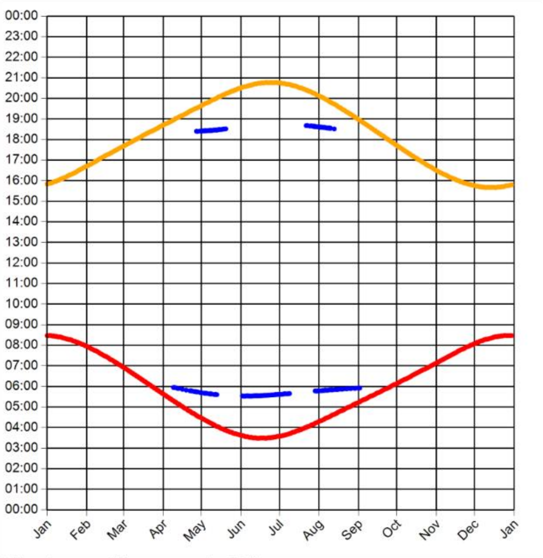
Min observer difference angle: 7.2°
Max observer difference angle: 15.3°

Observer Location | Sun azimuth ranges (yellow)



Observer 170 Results

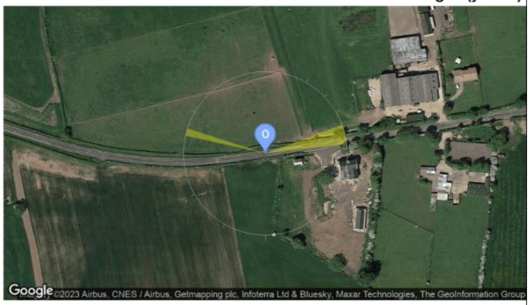
Reflection Date/Time (GMT) Graph



Min observer difference angle: 5.7°
Max observer difference angle: 15.3°

Observer Location

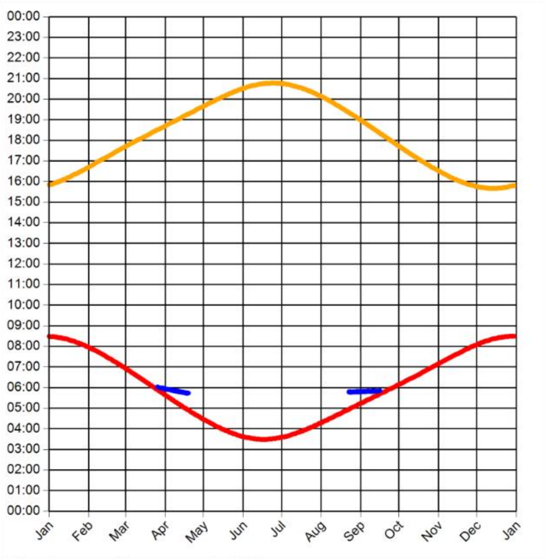
Sun azimuth ranges (yellow)



Dwelling Receptors

Observer 84 Results

Reflection Date/Time (GMT) Graph



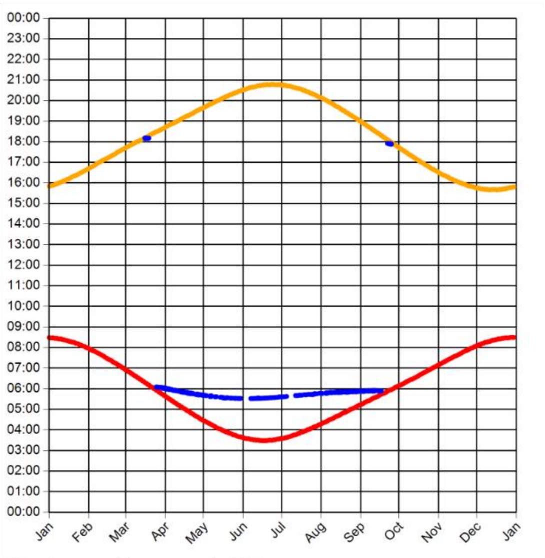
Min observer difference angle: 0.2°
Max observer difference angle: 5.4°

Observer Location

Sun azimuth range is 79.1° - 86.6° (yellow)

Observer 87 Results

Reflection Date/Time (GMT) Graph



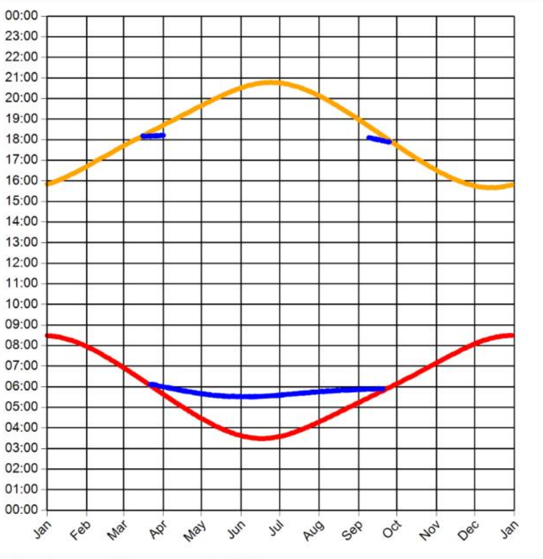
Min observer difference angle: 0.6°
Max observer difference angle: 15°

Observer Location

Sun azimuth ranges (yellow)

Observer 88 Results

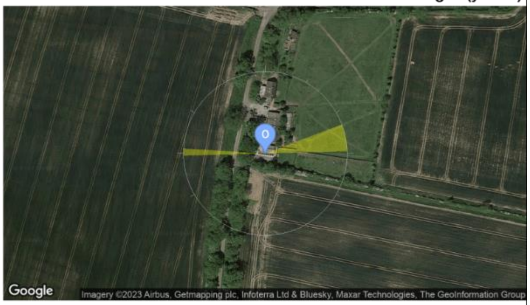
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.1°
Max observer difference angle: 14.8°

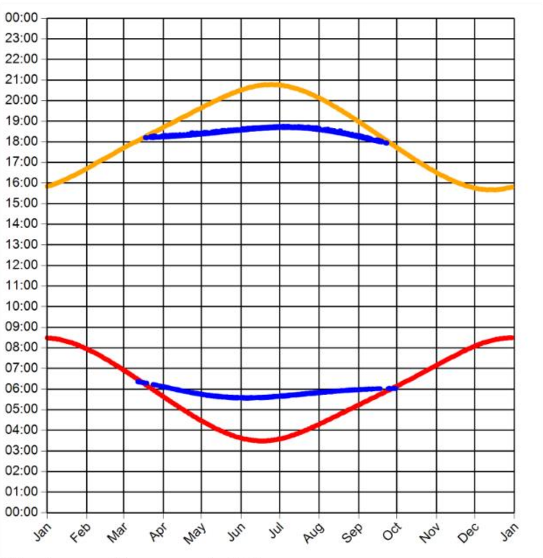
Observer Location

Sun azimuth ranges (yellow)



Observer 91 Results

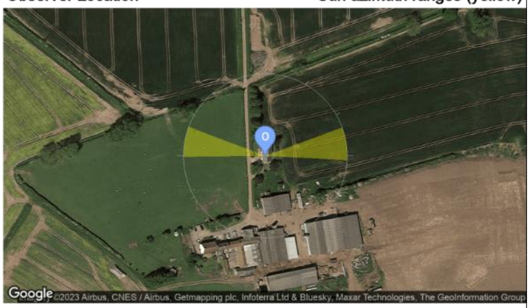
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 16.2°

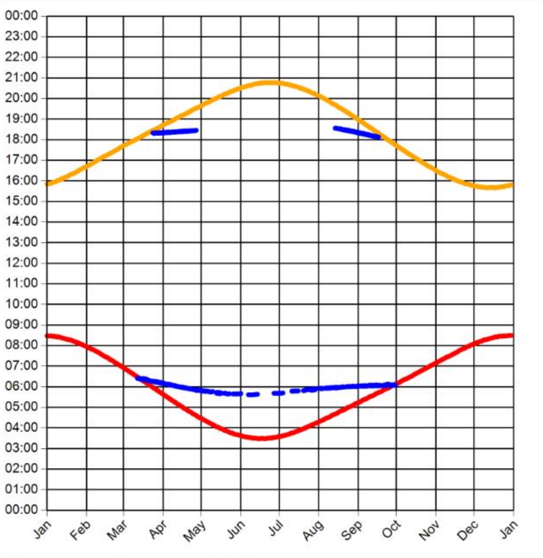
Observer Location

Sun azimuth ranges (yellow)



Observer 98 Results

Reflection Date/Time (GMT) Graph



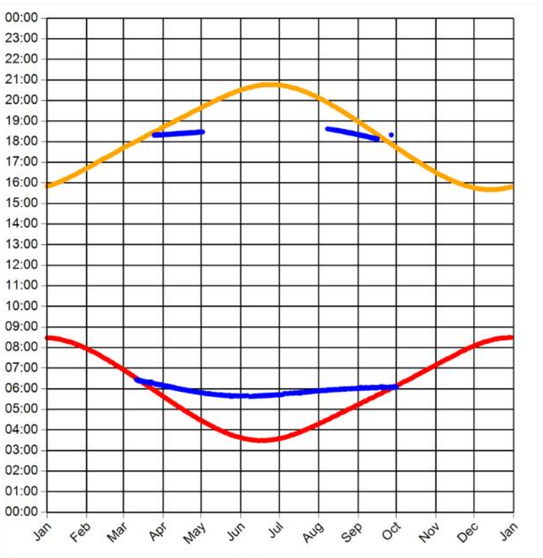
Min observer difference angle: 0.2°

Max observer difference angle: 17.1°

Observer Location | Sun azimuth ranges (yellow)

Observer 101 Results

Reflection Date/Time (GMT) Graph



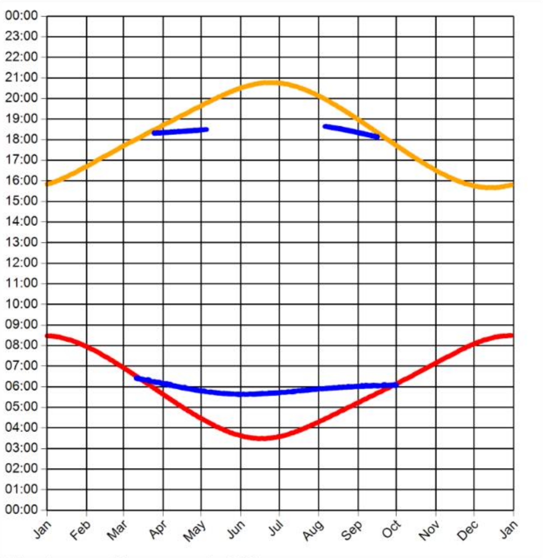
Min observer difference angle: 0.2°

Max observer difference angle: 17.8°

Observer Location | Sun azimuth ranges (yellow)

Observer 104 Results

Reflection Date/Time (GMT) Graph

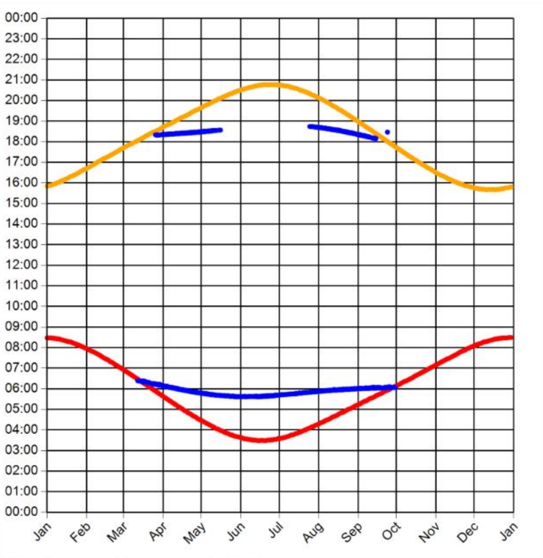


Min observer difference angle: 0.3°
Max observer difference angle: 17.8°

Observer Location | Sun azimuth ranges (yellow)

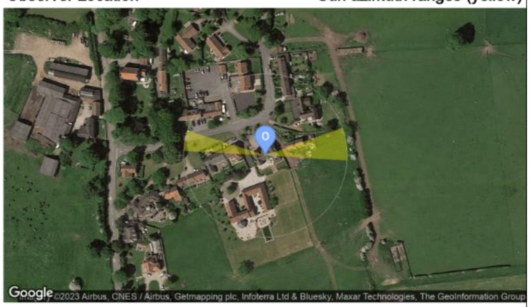
Observer 111 Results

Reflection Date/Time (GMT) Graph



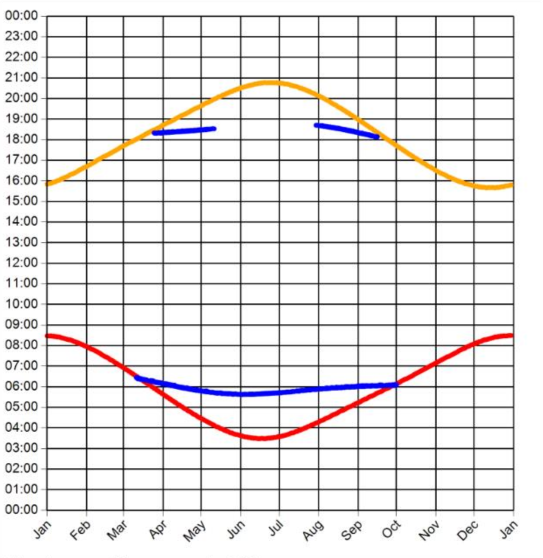
Min observer difference angle: 0.4°
Max observer difference angle: 17.1°

Observer Location | Sun azimuth ranges (yellow)



Observer 112 Results

Reflection Date/Time (GMT) Graph

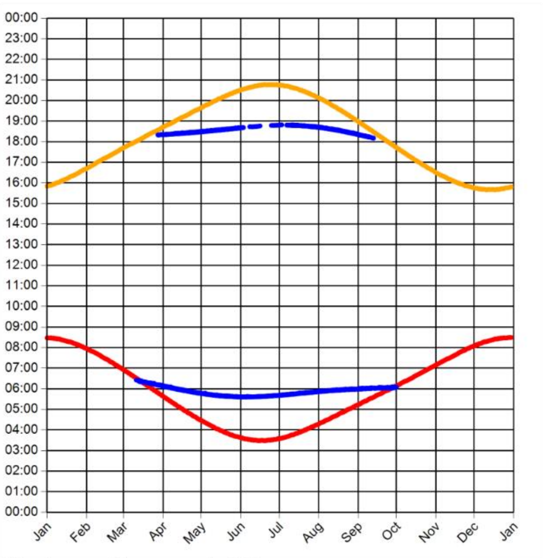


Min observer difference angle: 0.3°
Max observer difference angle: 17.6°

Observer Location | Sun azimuth ranges (yellow)

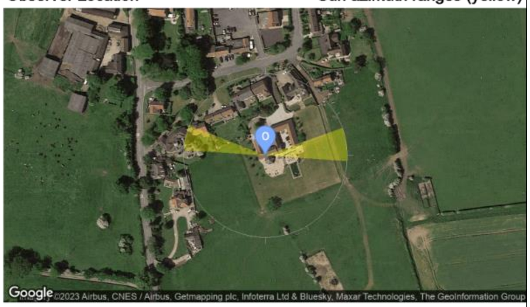
Observer 113 Results

Reflection Date/Time (GMT) Graph



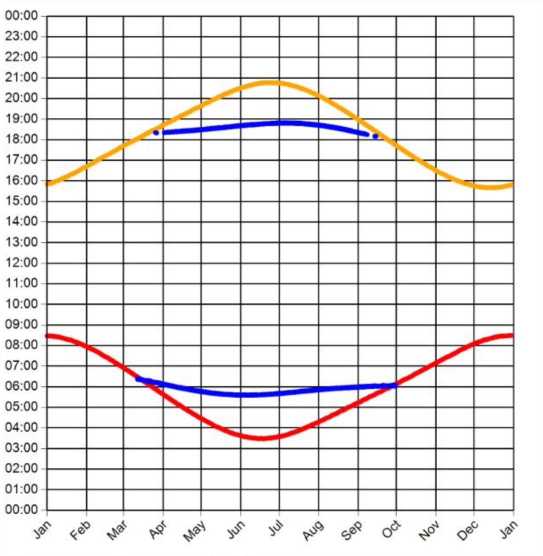
Min observer difference angle: 0.8°
Max observer difference angle: 16.8°

Observer Location | Sun azimuth ranges (yellow)



Observer 114 Results

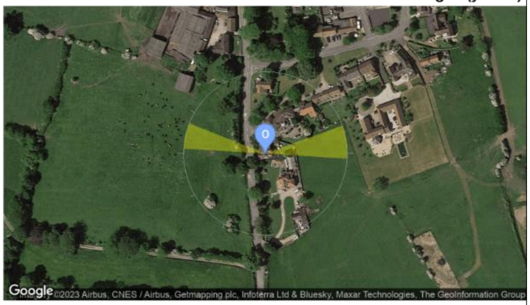
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 16.6°

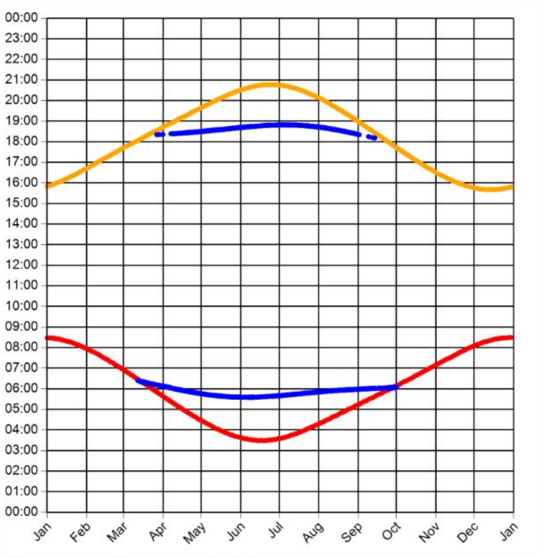
Observer Location

Sun azimuth ranges (yellow)



Observer 115 Results

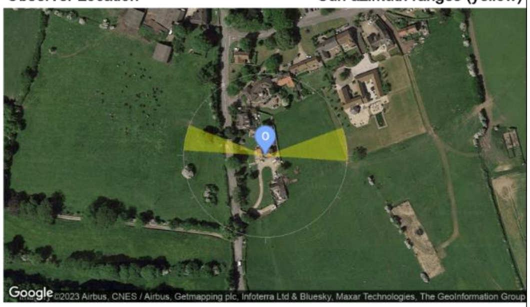
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 16.4°

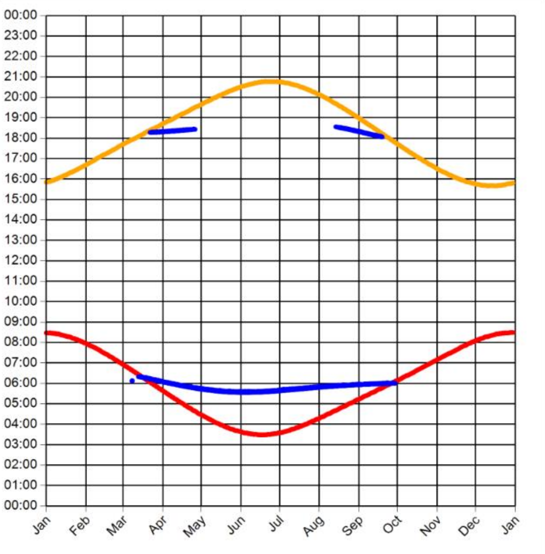
Observer Location

Sun azimuth ranges (yellow)



Observer 117 Results

Reflection Date/Time (GMT) Graph

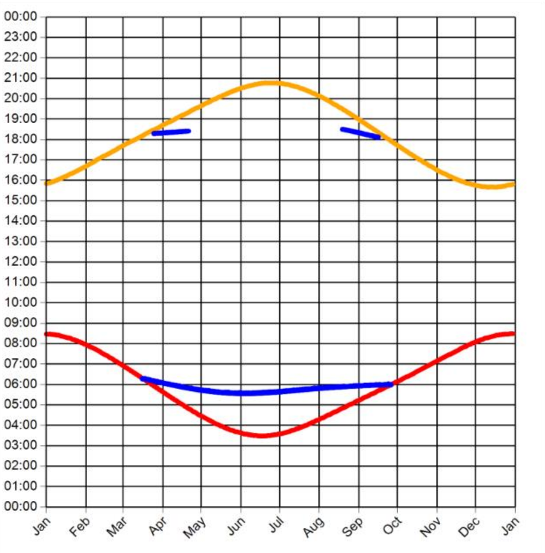


Min observer difference angle: 0.1°
Max observer difference angle: 16.6°

Observer Location   Sun azimuth ranges (yellow)

Observer 118 Results

Reflection Date/Time (GMT) Graph

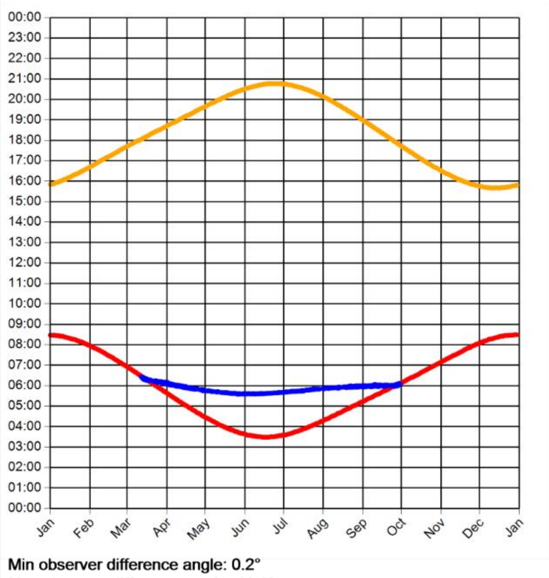


Min observer difference angle: 0.4°
Max observer difference angle: 16.6°

Observer Location   Sun azimuth ranges (yellow)

Observer 119 Results

Reflection Date/Time (GMT) Graph



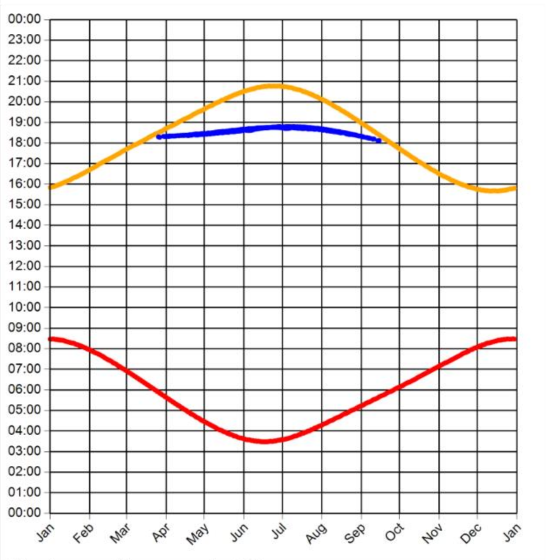
Min observer difference angle: 0.2°
Max observer difference angle: 16.6°

Observer Location

Sun azimuth range is 70.2° - 93.9° (yellow)

Observer 121 Results

Reflection Date/Time (GMT) Graph



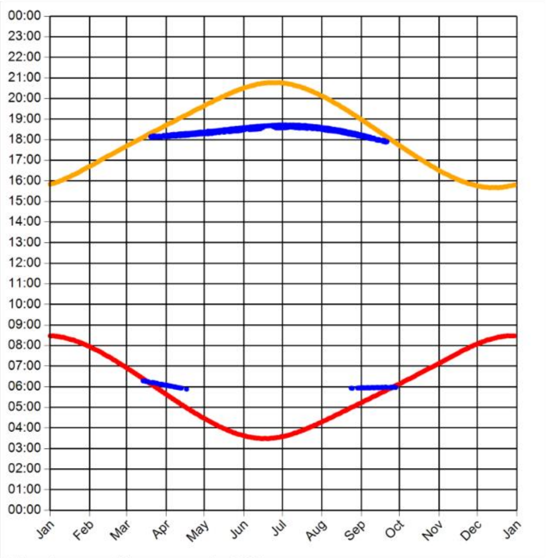
Min observer difference angle: 1.2°
Max observer difference angle: 14.5°

Observer Location

Sun azimuth range is 272.9° - 291.4° (yellow)

Observer 126 Results

Reflection Date/Time (GMT) Graph



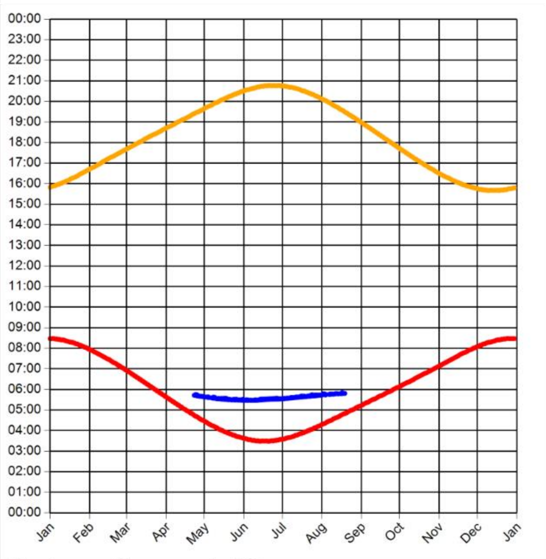
Min observer difference angle: 0.2°
Max observer difference angle: 17.6°

Observer Location

Sun azimuth ranges (yellow)

Observer 200 Results

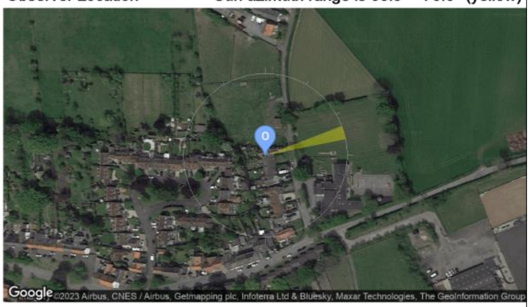
Reflection Date/Time (GMT) Graph



Min observer difference angle: 7.2°
Max observer difference angle: 14.8°

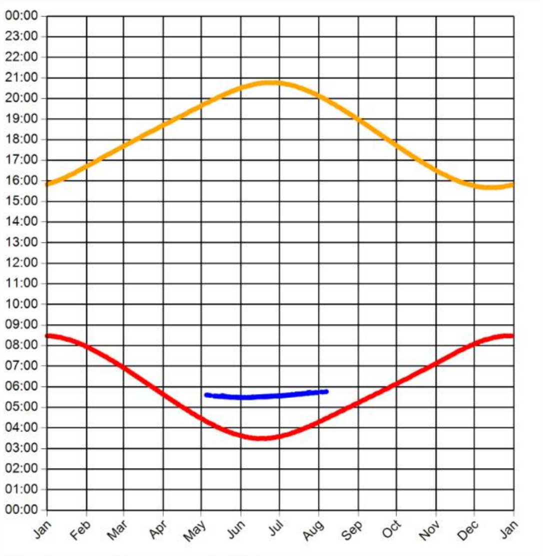
Observer Location

Sun azimuth range is 68.9° - 78.6° (yellow)



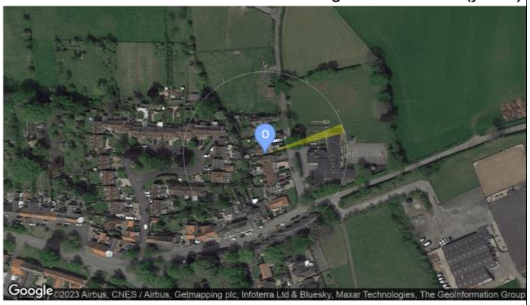
Observer 201 Results

Reflection Date/Time (GMT) Graph



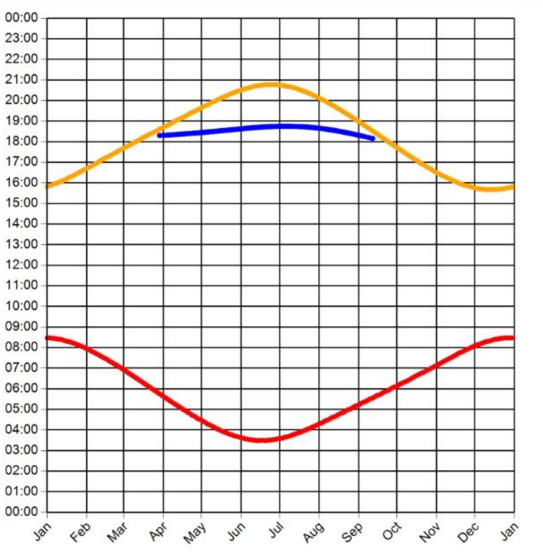
Min observer difference angle: 9.6°
Max observer difference angle: 14.5°

Observer Location — Sun azimuth range is 68.9° - 75.4° (yellow)



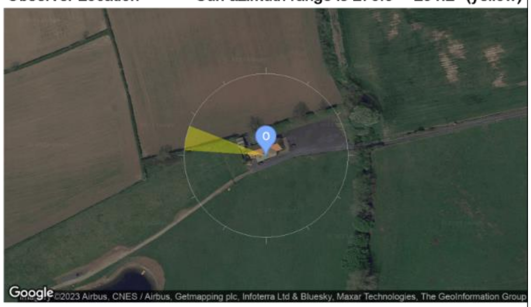
Observer 236 Results

Reflection Date/Time (GMT) Graph



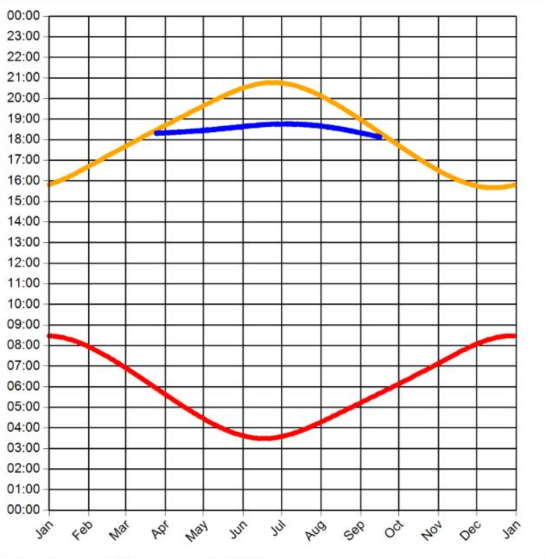
Min observer difference angle: 1.7°
Max observer difference angle: 14°

Observer Location — Sun azimuth range is 273.8° - 291.2° (yellow)



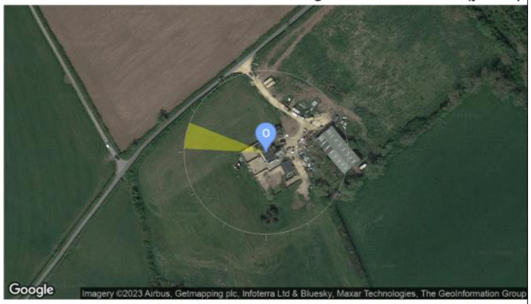
Observer 257 Results

Reflection Date/Time (GMT) Graph



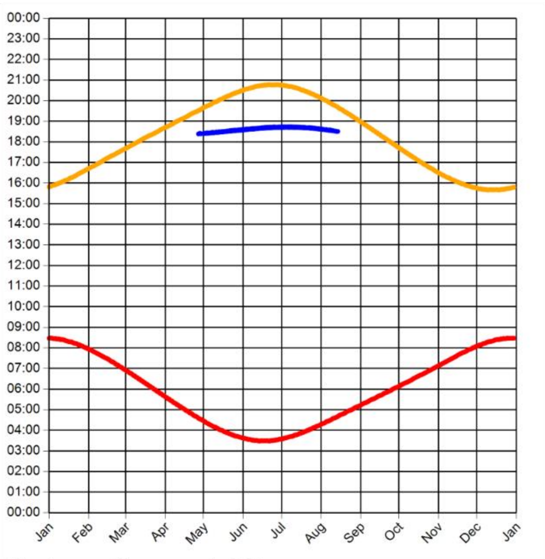
Min observer difference angle: 0.3°
Max observer difference angle: 13.7°

Observer Location — Sun azimuth range is 272.7° - 291.3° (yellow)



Observer 258 Results

Reflection Date/Time (GMT) Graph

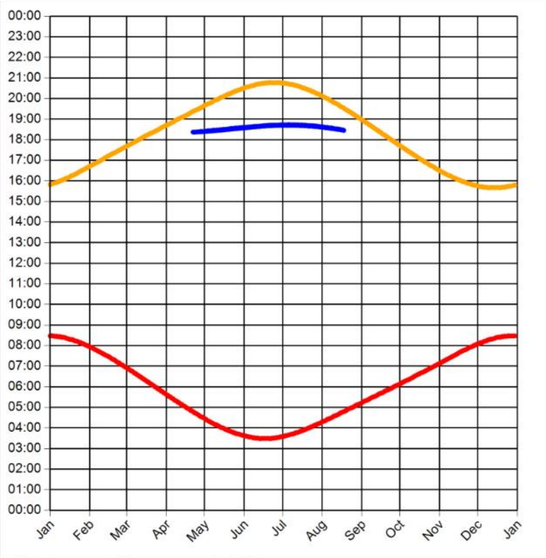


Min observer difference angle: 8.8°
Max observer difference angle: 14.8°

Observer Location — Sun azimuth range is 282.3° - 290.8° (yellow)

Observer 259 Results

Reflection Date/Time (GMT) Graph



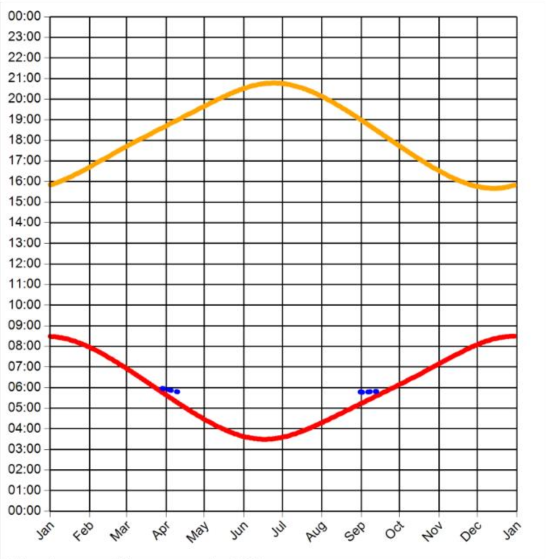
Min observer difference angle: 7.8°
Max observer difference angle: 14.9°

Observer Location — Sun azimuth range is 281° - 290.7° (yellow)

Train Driver Receptors

Observer 06 Results

Reflection Date/Time (GMT) Graph

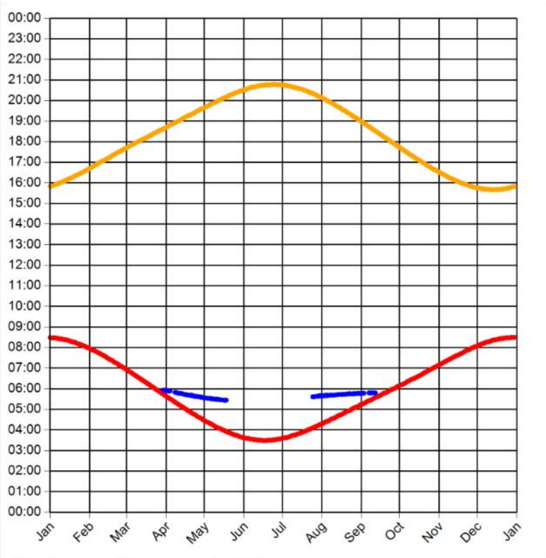


Min observer difference angle: 0.2°
Max observer difference angle: 2.8°

Observer Location — Sun azimuth range is 81.3° - 85.3° (yellow)

Observer 07 Results

Reflection Date/Time (GMT) Graph

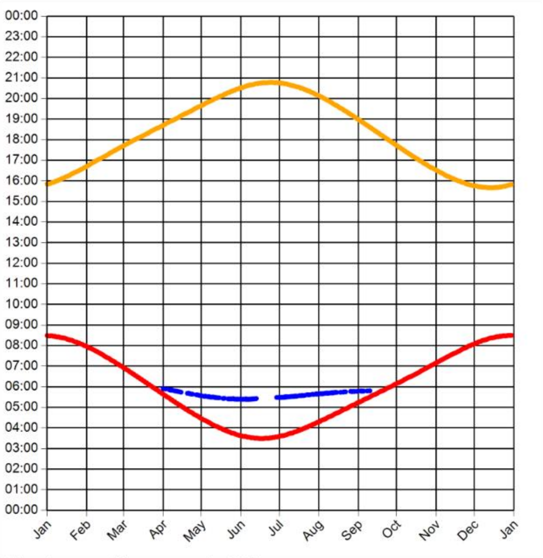


Min observer difference angle: 0.1°
Max observer difference angle: 9.8°

Observer Location — Sun azimuth range is 71.3° - 84.8° (yellow)

Observer 08 Results

Reflection Date/Time (GMT) Graph

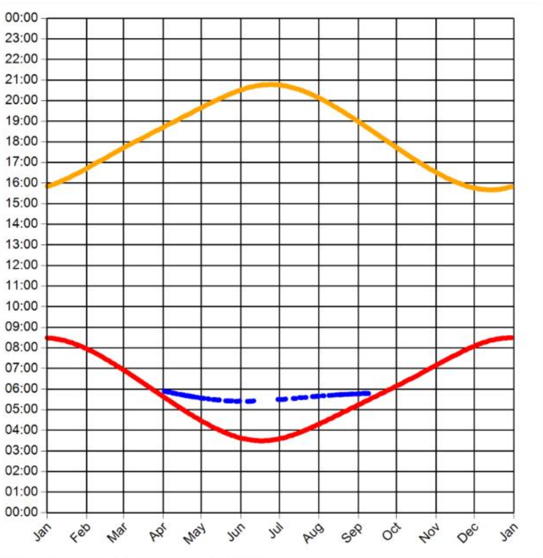


Observer Location — Sun azimuth range is 68.2° - 84.2° (yellow)

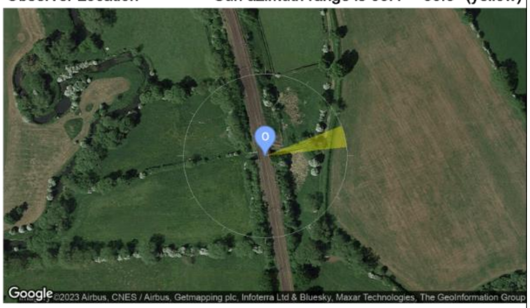
Min observer difference angle: 0.5°
Max observer difference angle: 12.1°

Observer 09 Results

Reflection Date/Time (GMT) Graph



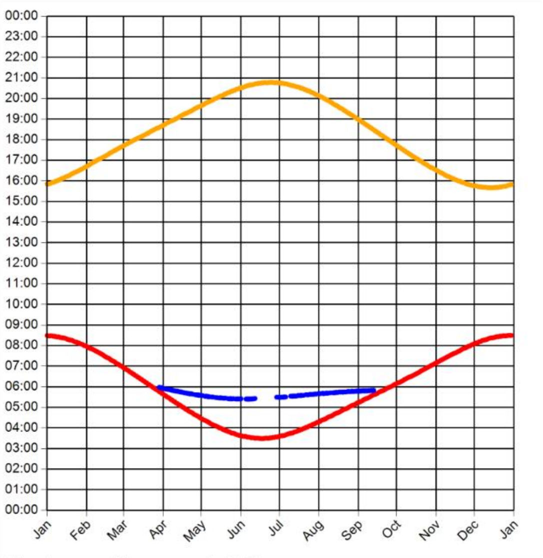
Observer Location — Sun azimuth range is 68.4° - 83.8° (yellow)



Min observer difference angle: 0.4°
Max observer difference angle: 12.2°

Observer 10 Results

Reflection Date/Time (GMT) Graph



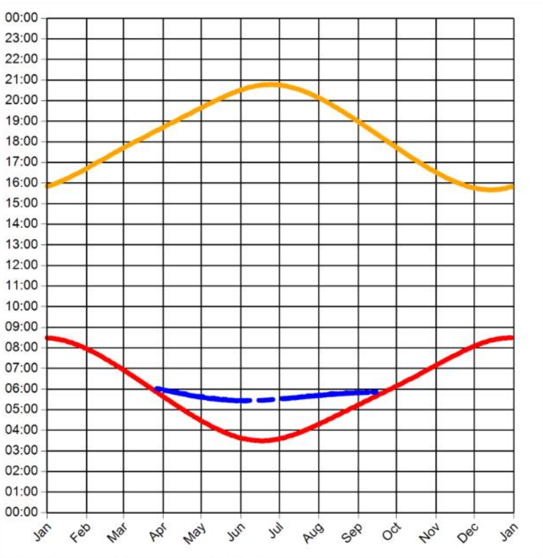
Min observer difference angle: 0.1°
Max observer difference angle: 12.3°

Observer Location

Sun azimuth range is 68.3° - 85.5° (yellow)

Observer 11 Results

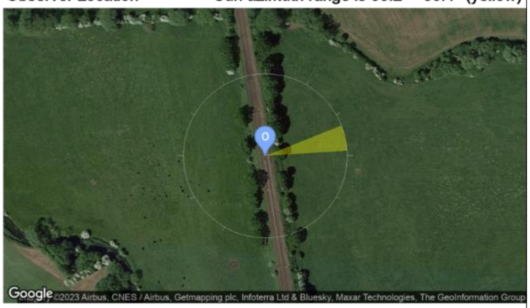
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 13°

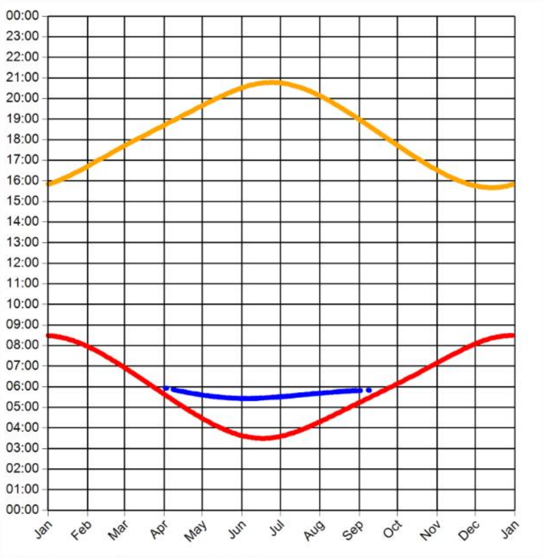
Observer Location

Sun azimuth range is 68.2° - 86.4° (yellow)



Observer 12 Results

Reflection Date/Time (GMT) Graph



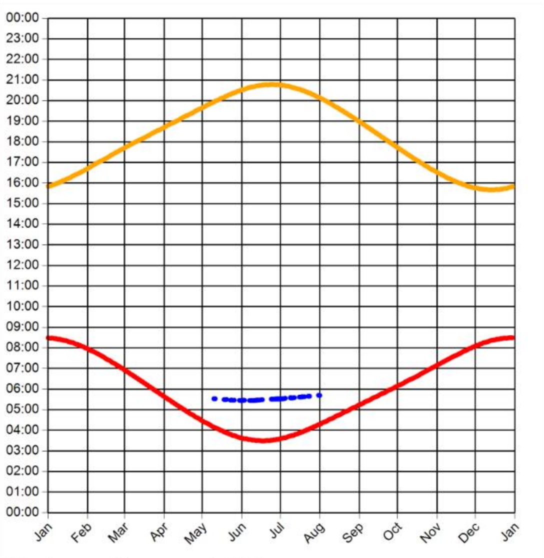
Min observer difference angle: 1.4°
Max observer difference angle: 12.9°

Observer Location

Sun azimuth range is 68.3° - 84.2° (yellow)

Observer 13 Results

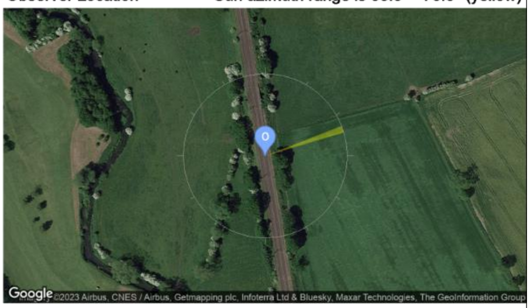
Reflection Date/Time (GMT) Graph



Min observer difference angle: 9.6°
Max observer difference angle: 13.3°

Observer Location

Sun azimuth range is 68.6° - 73.5° (yellow)



APPENDIX I – SCREENING REVIEW

Overview

The following pages show a selection of images detailing the significant screening for the assessed receptors, where existing screening is labelled in white/outlined in pink. Where appropriate, a single image is used to represent the screening for multiple receptors. Further imagery can be provided on request.

Roads

View towards reflecting panels from road receptor 4 (representative of the extent of screening for road section 2-5)

View towards reflecting panels from road receptor 7 (representative of the extent of screening for road section 6-7)

View towards reflecting panels from road receptor 31 (representative of the extent of screening for road section 31-33)

View towards reflecting panels from road receptor 35 (representative of the extent of screening for road section 34-36)

View towards reflecting panels from road receptor 48 (representative of the extent of screening for road section 47-49)

View towards reflecting panels from road receptor 83 (representative of the extent of screening for road section 81-83)

Screening for road section 109-112

View towards reflecting panels from road receptor 119 (representative of the extent of roadside screening for road section 118-123)

View towards reflecting panels from road receptor 130 (representative of the extent of roadside screening for road section 130-131)

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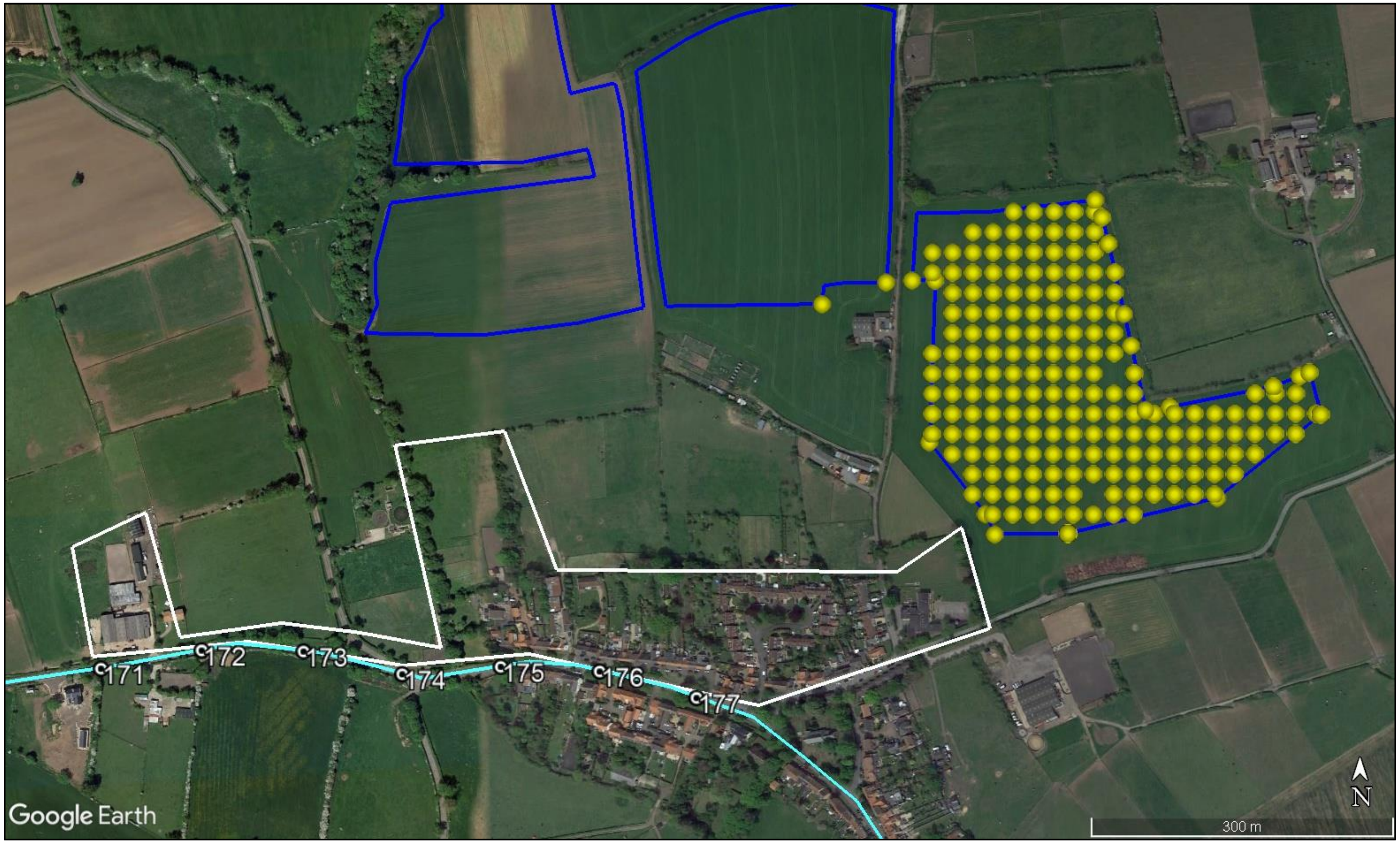
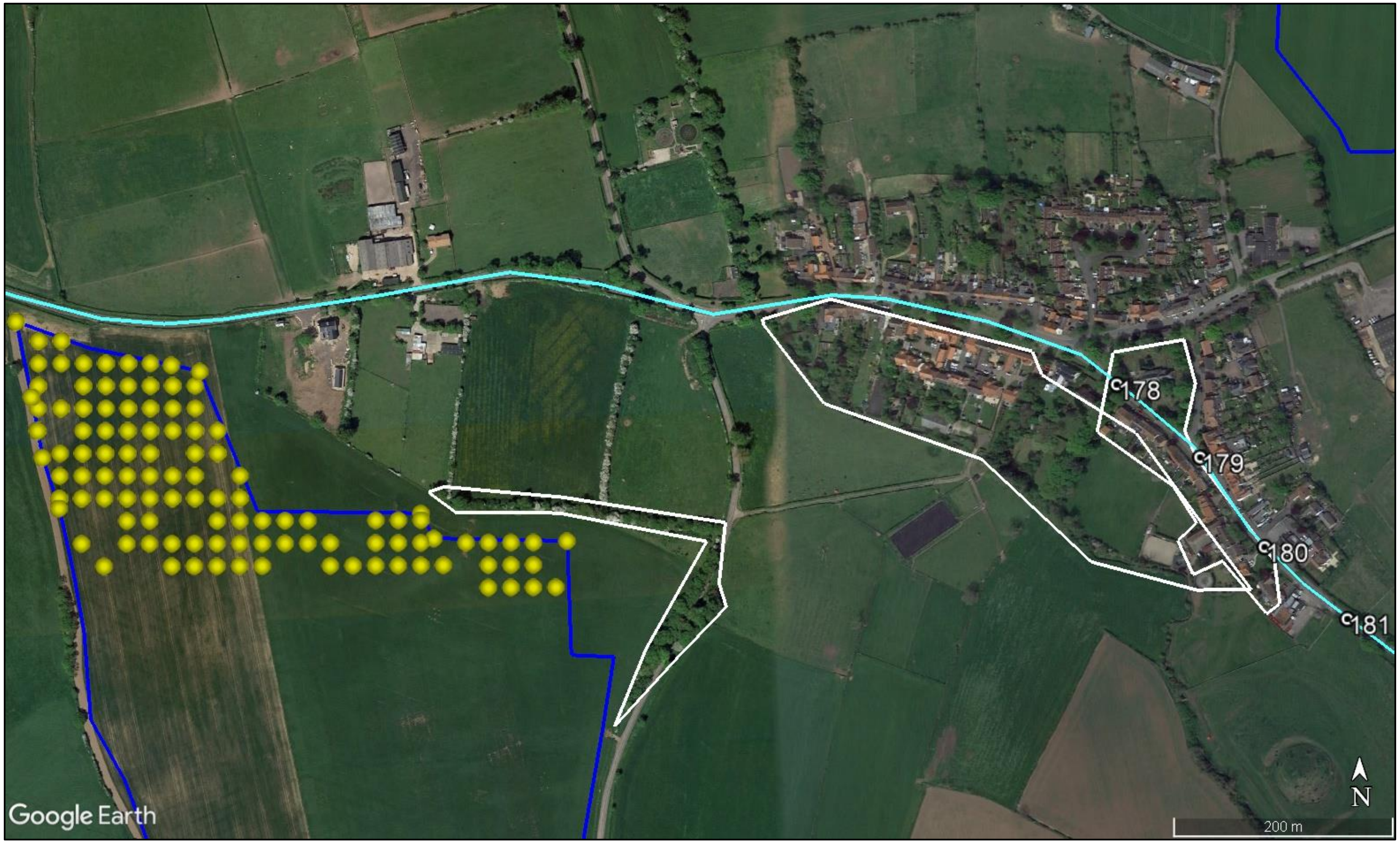


Reflecting points within 1km (yellow icons) and significant building/vegetation screening for road section 171-177



Reflecting points (yellow icons) and significant building/vegetation screening for road section 178-181

View towards reflecting panels from road receptor 182

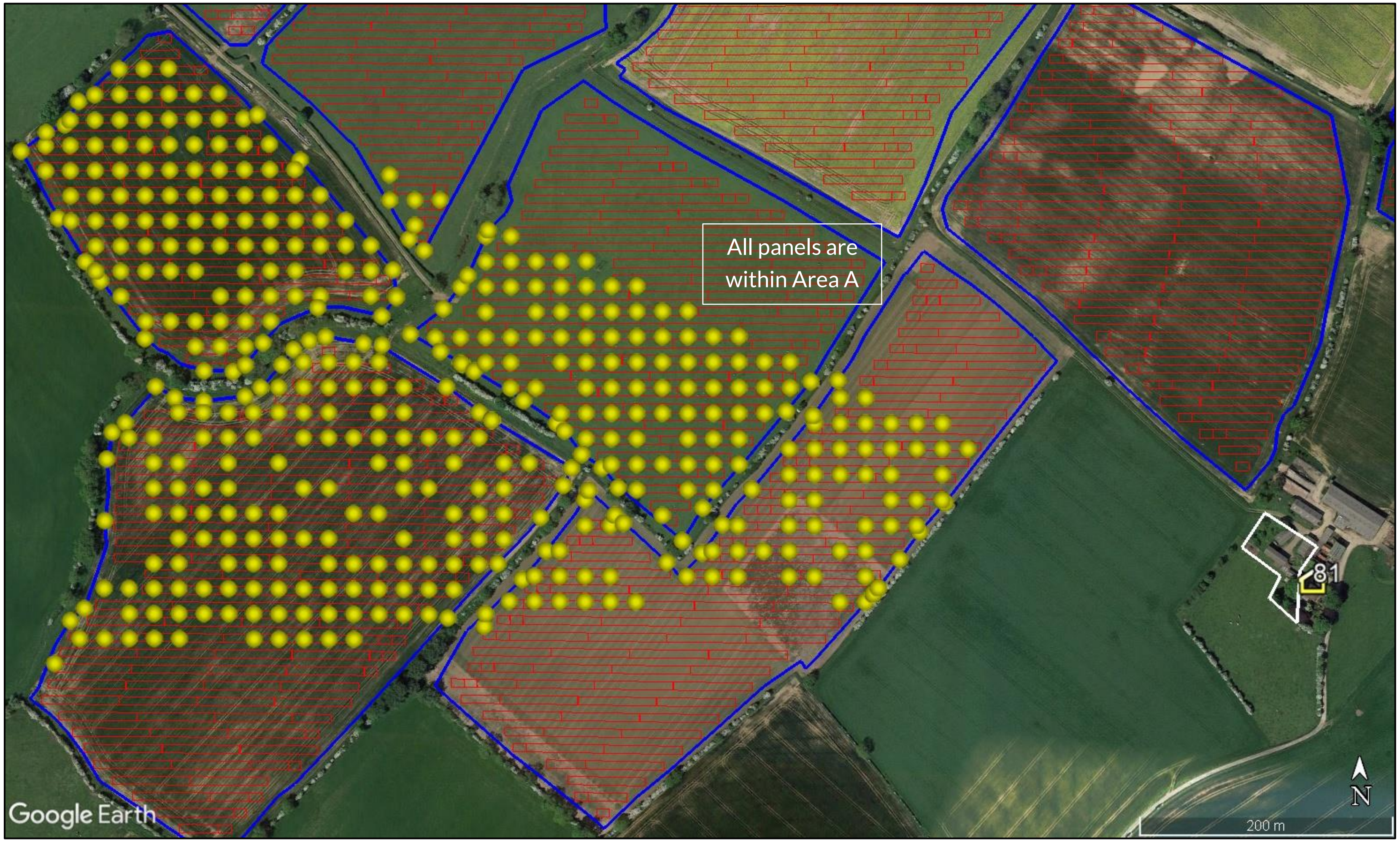
View towards reflecting panels from road receptor 184

View towards reflecting panels from road receptor 186

Dwellings

Reflecting points (yellow icons) and significant vegetation screening (white polygon) for dwellings 34 – 75

Reflecting points (yellow icons) and significant building/vegetation screening (white polygon) for dwelling 77

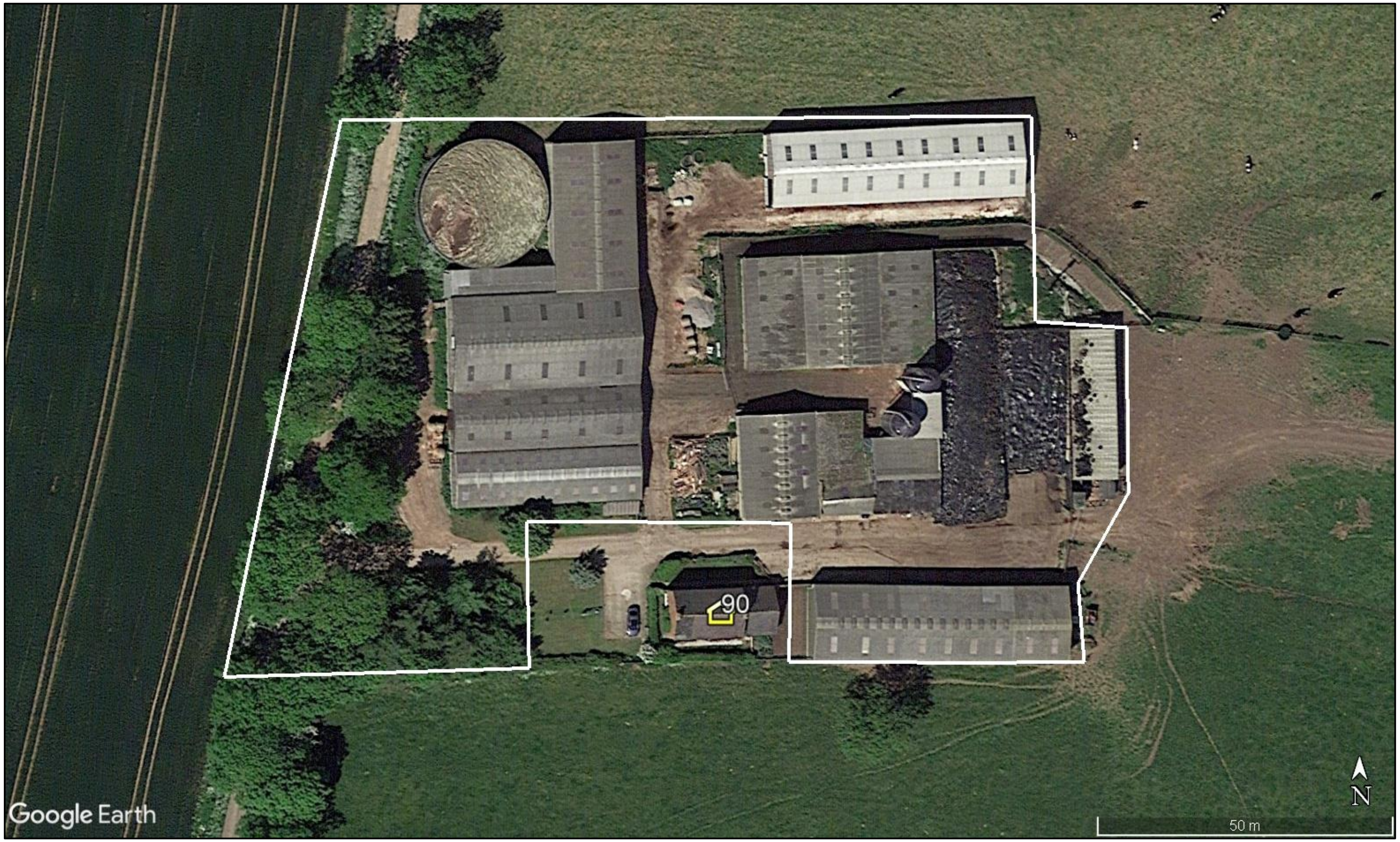


Reflecting points (yellow icons) and significant building/vegetation screening (white polygon) for dwelling 81

Reflecting points (yellow icons) and significant building/vegetation screening (white polygons) for dwelling 82

Reflecting points (yellow icons) and significant building/vegetation screening (white polygons) for dwelling 83

Reflecting points (yellow icons) and significant building/vegetation screening (white polygon) for dwelling 86

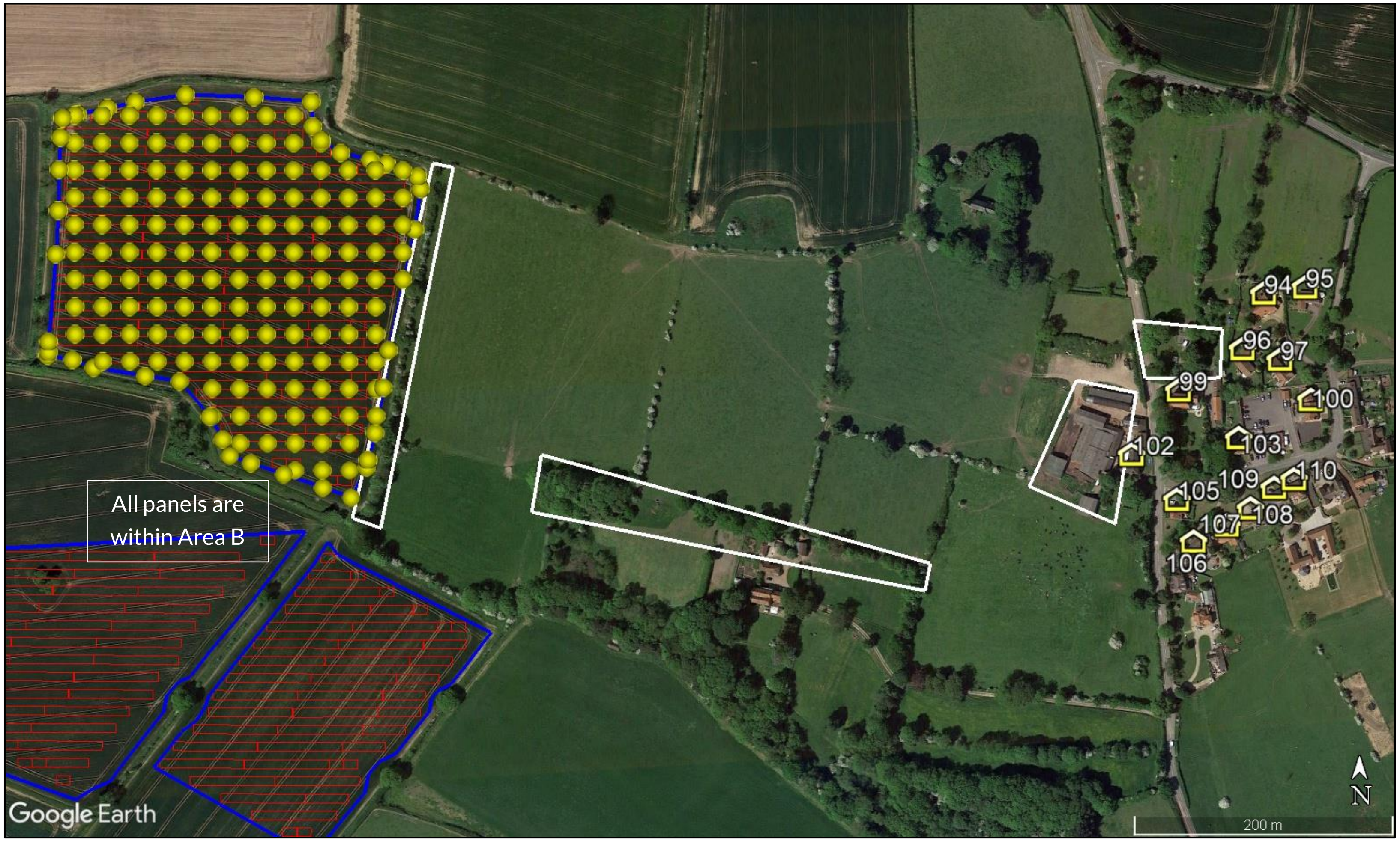


Significant building/vegetation screening (white polygon) for dwelling 90

Reflecting points (yellow icons) for dwellings 91 and 92 and proposed hedgerow/tree planting (green lines) expected to provide screening

Reflecting points (yellow icons) and significant building/vegetation screening (white polygon) for dwelling 92

Significant vegetation screening for dwelling 93

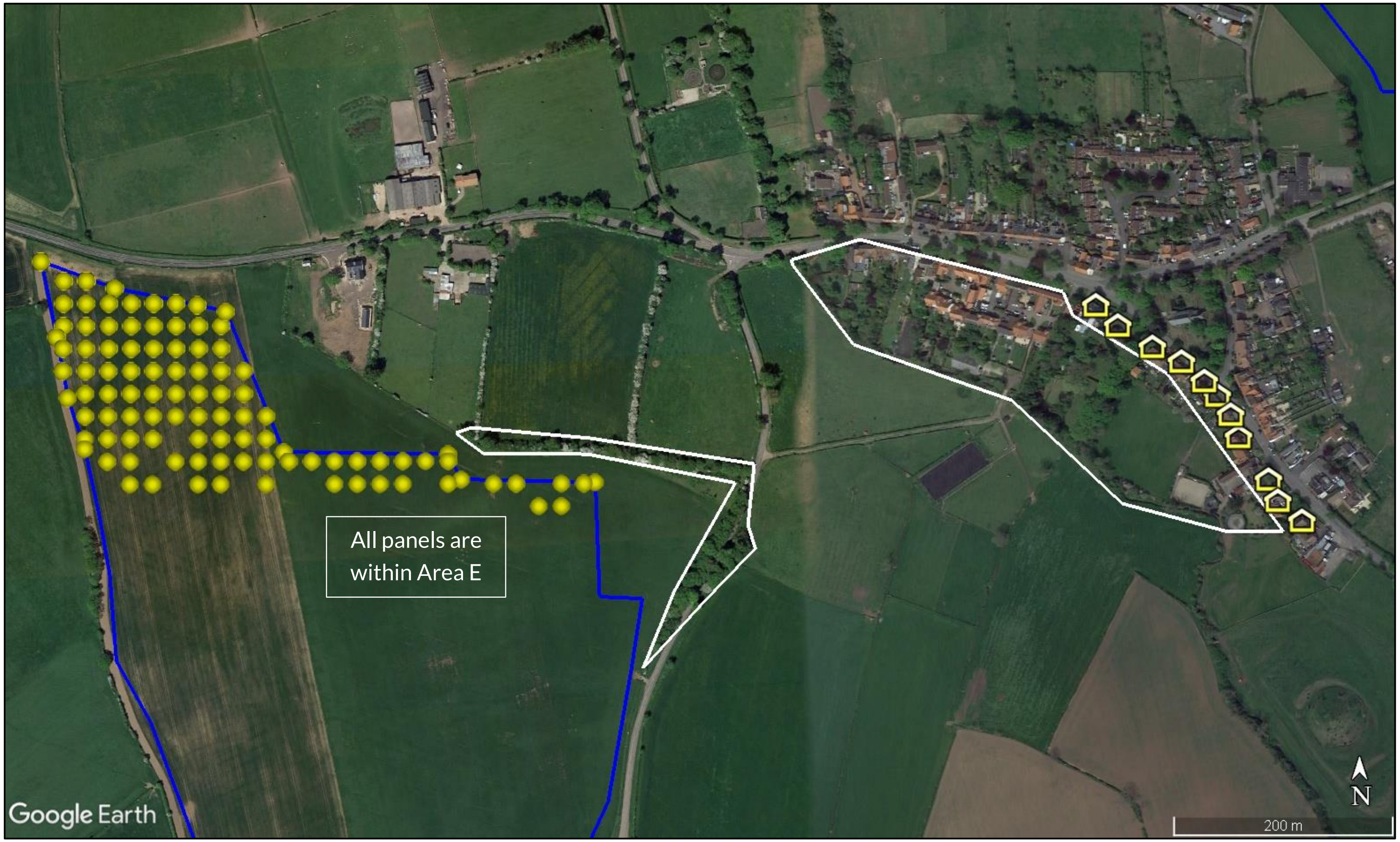


Reflecting points to the west (yellow icons) and significant building/vegetation screening (white polygons) for dwellings 94-97, 99-100, 102-103, 105-110

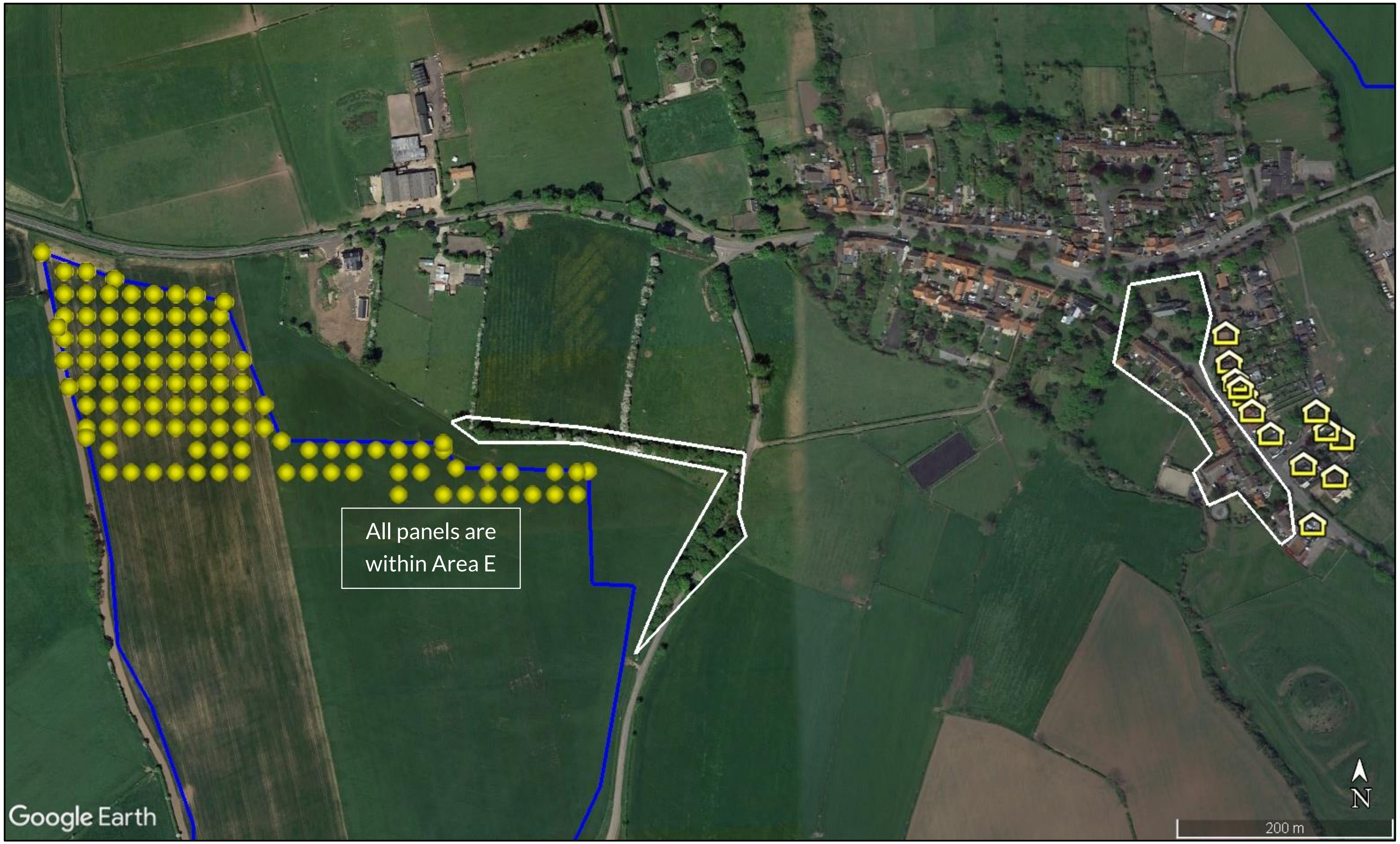
Reflecting points to the east (yellow icons) and significant building/vegetation screening (white polygon) for dwellings 94-97, 99-100, 102-103, 105-110

Significant vegetation screening for dwelling 116

Reflecting points (yellow icons) and significant building/vegetation screening (white polygon) for dwelling 202-203



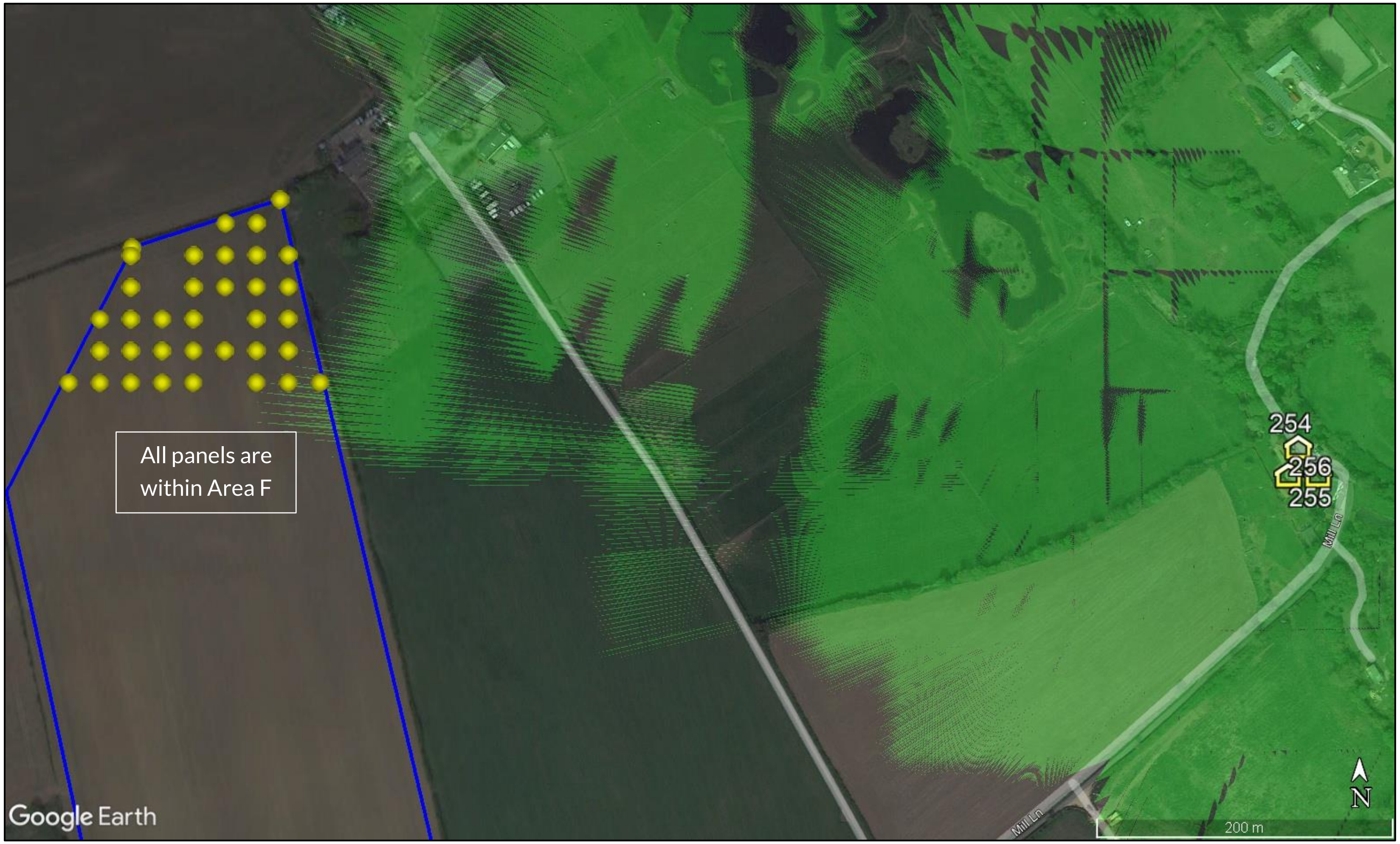
Reflecting points (yellow icons) and significant building/vegetation screening (white polygons) for dwelling 204-214



Reflecting points (yellow icons) and significant building/vegetation screening (white polygons) for dwelling 223-235

Reflecting points (yellow icons) and significant vegetation screening (white polygon) for dwelling 237

Significant vegetation screening for dwelling 257



Terrain visibility from 5m agl (height used to represent views from upper floors) at dwelling 256 – Google Earth viewshed tool

Railways

Significant screening for train driver receptor 06

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