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Solar Photovoltaic Glint and Glare Study

RWE Ltd (Formerly JBM Solar Projects UK Ltd)

Eden Meadows Solar

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1	3rd November 2023	Initial issue
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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a ground mounted solar photovoltaic development, located near Morton, Derbyshire, England. This assessment pertains to the potential impact upon road safety, residential amenity, railway operations and infrastructure and aviation activity associated with Ripley Airfield.

Overall Conclusions

No significant impacts are predicted on road safety, residential amenity railway operations and infrastructure and aviation activity.

No additional impact is predicted due to cumulative effects with respect to exist nearby solar developments, detailed modelling is not recommended.

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. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology. A specific national guidance policy for determining the impact of glint and glare on road safety, residential amenity, railway operations and infrastructure, and aviation activity has also not been produced to date. Therefore, in the absence of this, Pager Power reviewed more general existing planning guidelines and the available studies (discussed below) in the process of defining its own glint and glare assessment guidance and methodology[1]. This methodology defines the process for determining the impact upon road safety, residential amenity, railway operations and infrastructure, and aviation activity.

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. For aviation activity, where appropriate, solar intensity calculations are undertaken in line with the Sandia National Laboratories' FAA methodology[2]. 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

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

[2] Formerly mandatory for on-airfield solar developments in the USA under the FAA's interim policy, superseded in 2021 with a policy that effectively requires individual airports to sign off on their on-airfield development as they see fit.

produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[3].

Conclusions – Roads

Solar reflections are geometrically possible towards approximately 1.3km of the A61, 0.3km of the B6014 and 1.7km of Morton Road/Stretton Road/B6014.

For all sections of road where a solar reflection is geometrically possible, screening in the form of existing vegetation, buildings and/or terrain is predicted to significantly obstruct views of reflecting panels such that solar reflections will not be experienced by road users. No impact is predicted, and mitigation is not required.

Conclusions – Dwellings

Solar reflections are geometrically possible towards 74 of the 100 assessed dwellings.

For 68 of these dwellings, screening in the form of existing vegetation, buildings and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. Therefore, no impact is predicted, and no mitigation is required.

For the six remaining dwellings, screening in the form of proposed vegetation within the landscape strategy plan (see Section 2.2) is predicted to significantly obstruct views of reflecting panels. Therefore, no impact is predicted, and no mitigation is required.

For the one remaining dwelling, no sufficient mitigating factors have been identified. However, the duration of reflections is predicted to be less than three months per year and less than 60 minutes in any given day. A low impact is predicted, and mitigation is not recommended.

Conclusions – Railway

Solar reflections are geometrically possible towards approximately 1.4km of railway. Screening in the form of existing vegetation and intervening terrain is predicted to significantly obstruct views of reflecting panels, such that solar reflections are not predicted to be experienced by train drivers. No impact is predicted, and mitigation is not required.

No signals or assets have been identified from a review of the available imagery. This report can be updated if railway signals or assets are identified by Network Rail.

High-Level Assessment Conclusions – Aviation

For aviation activity associated with Ripley Airfield, any solar reflections are predicted to be acceptable in accordance with the associated guidance (Appendix D) and industry best practice, as any possible solar reflections will be outside the pilot’s field of view (50 degrees horizontally either side of the direction of travel) for pilots approaching runway thresholds 08 and 26.

Therefore, no significant impacts are predicted upon aviation activity at Ripley Airfield and detailed modelling is not recommended.

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

High-Level Assessment Conclusions – Cumulative

Considering the results of the assessment for roads, railway, dwellings and aviation, no cumulative impacts are predicted. This is because the receptors within shared assessment areas of both the proposed and existing developments are predicted to experience no impact from solar reflections from the proposed development.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 59 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a ground mounted solar photovoltaic development, located near Morton, Derbyshire, England. This assessment pertains to the potential impact upon road safety, residential amenity, railway operations and infrastructure and aviation activity associated with Ripley Airfield.

This report contains the following:

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

The relevant technical analysis is presented in each section. Following the assessment, conclusions and recommendations are made.

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 i.e. glint and glare.

[4] These definitions are aligned with those of the Draft National Policy Statement for Renewable Energy Infrastructure and the Federal Aviation Administration (FAA) in the United States of America.

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Layout

The proposed development site layout[5] is shown in Figure 1 on the following page. The solar panels are shown as blue rectangles.

Following the decision of North East Derbyshire District Council ("NEDDC") to refuse a Planning Application for Full Planning Permission (ref: 23/01089/FL) an Appeal has now been lodged. At the time of lodging the Appeal, the Appellant submitted a number of proposed minor amendments to the site layout. This report has been updated to include the amended scheme (Figure 1). The amendments include:

- Updates to reflect the alignment of historic lost hedgerows to encapsulate alignment with the Tithe mapping;
- Extending the previously proposed permissive footpath route looping around the land parcels to the east of Evershill Lane / PRoW to create a looped walk;
- Addition of information boards incorporated along the permissive footpath route;
- All of the hybrid inverter containers have been moved outside of the Risk of Surface Water Flooding ("RoSWF") extents;
- Additional orchard tree planting in the southern extent of Field 10.

This glint and glare assessment has been undertaken on the basis of the original submitted site layout (Rev H) which included for a 'worst-case' extent of solar arrays within the site. The amended scheme would represent a reduction in possible glint and glare impacts and therefore the conclusions of this report remain valid.

[5] Source: A032_1000_L (cropped)

Figure 1 *Proposed development site layout*

2.2 Landscape Strategy

Figure 2[6] on the following page shows the Landscape Strategy for the proposed development.

[6] Source: EdenMeadows_Masterplan_01.

Figure 2 *Landscape strategy*

2.3 Reflector Areas

Figure 3 below shows the boundary of the proposed solar arrays for the proposed development overlaid onto aerial imagery.

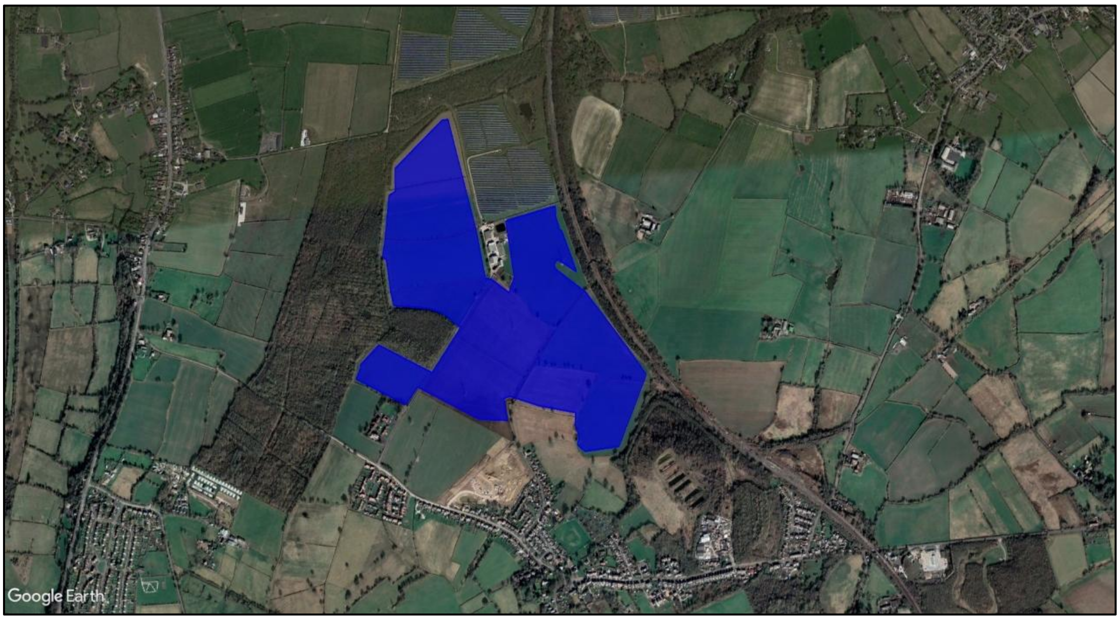

Figure 3 *Proposed solar array boundary*

2.4 Solar Panel Technical Information

The technical information used for the modelled panels in this assessment are presented in Table 1 below. The centre of the solar panel has been used as the assessed height in metres above ground level (agl)[7]. A mean elevation angle has been used for modelling purposes[8].

Solar Panel Technical Information	
Azimuth angle[9]	180°
Assessed Elevation angle (tilt)[10]	20°
Assessed centre height	1.9 agl

Table 1 *Solar panel information*

[7] Minimum height = 0.8m agl, maximum height = 3.0m agl.
[8] Minimum elevation angle = 15°, maximum elevation angle = 25°
[9] Relative to true north.
[10] Relative to the horizontal.

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

Appendices A and B present a review of relevant guidance and independent studies regarding 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.

3.2 Background

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

3.3 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;
- 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;
- 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 - including intensity calculations where appropriate;
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Ground-Based Receptors 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.

A 1km assessment area is considered appropriate for glint and glare effects on ground-based receptors, and a 500m assessment area appropriate for railway receptors – bounded by the green and light-blue outlined areas respectively in Figure 4 below. Receptors within this distance are identified based on mapping and aerial photography of the region. Receptors to the north of the development are not included because solar reflections would not be geometrically possible towards the north when the azimuth angle is considered[11].

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OS Terrain 50 DTM[12] data.

Figure 4 *1km and 500m assessment areas*

[11] For fixed, south-facing panels at this latitude, reflections towards ground-based receptors located further north than any proposed panel are highly unlikely
[12] Digital Terrain Model

4.2 Road Receptors

4.2.1 Road Receptors Overview

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 one or more carriageways with a maximum speed limit of 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;
- 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 therefore considered major national, national, and regional roads that:

- Are within the 1km assessment area;
- Have a potential view of the panels.

4.2.2 Identified Road Receptors

The assessed receptors along 1.3km of the A61 [A1 – A14], 0.3km of the B6014 [B1 – B4] and 2.8km of Morton Road/Stretton Road/B6014 [C1 – C30] are shown in Figures 5 to 8 on the following pages. A height of 1.5 metres above ground level has been taken as the typical eye level of a road user[13].

[13] This fixed height for the road receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views for elevated drivers are also considered in the results discussion, if appropriate.

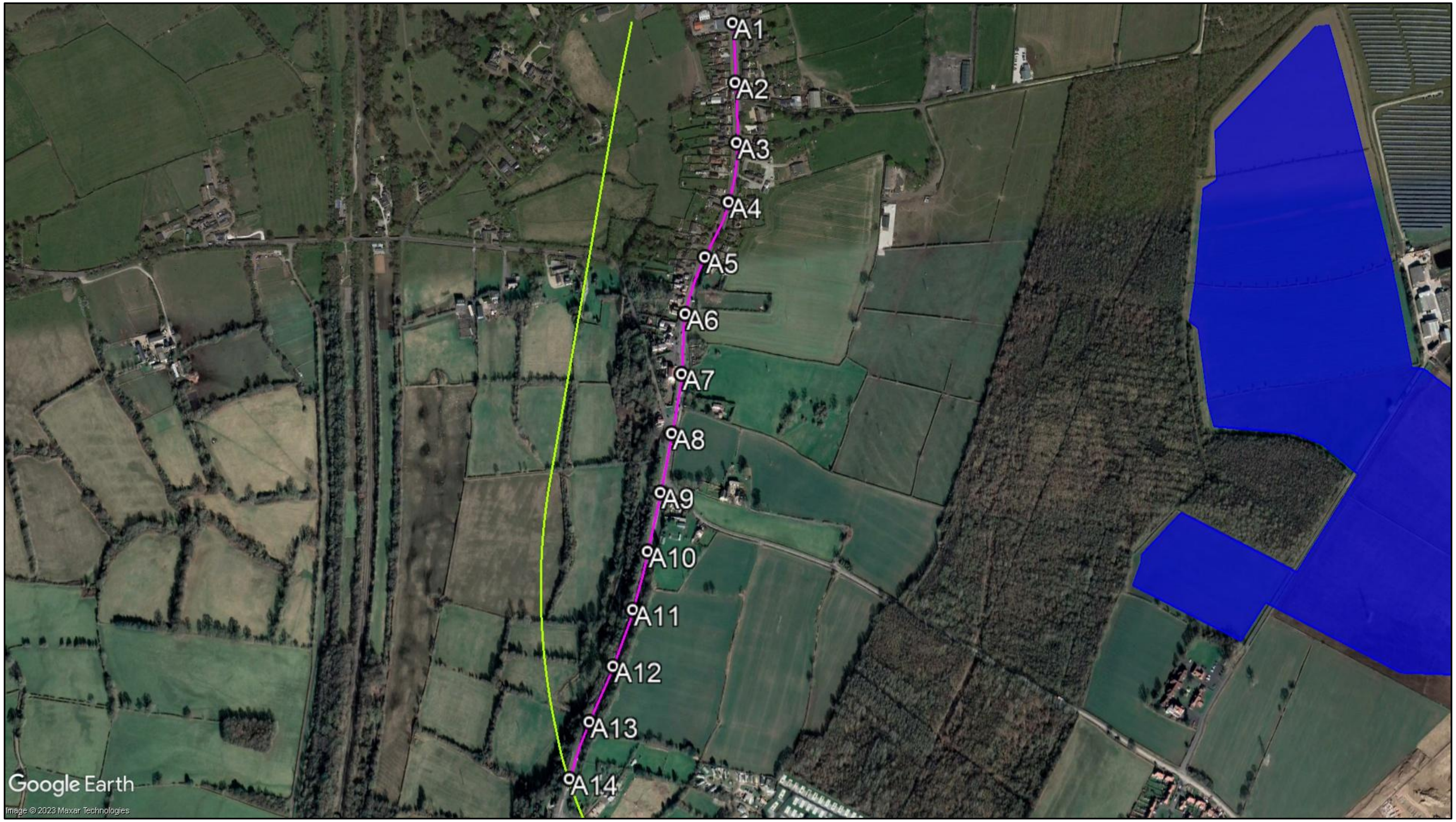

Figure 5 *Assessed road receptors A1 to A14*

Figure 6 *Assessed road receptors B1 to B4*

Figure 7 *Assessed road receptors C1 to C15*

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Figure 8 *Assessed road receptors C16 to C30*

4.3 Dwelling Receptors

4.3.1 Dwelling Receptors Overview

The analysis has considered dwellings that:

- Are situated within the 1km assessment 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. This is because the line of sight will be removed, or they will experience comparable effects to the closest assessed dwelling.

Additionally, in some cases, a single receptor point may be used to represent a small number of separate addresses. In such cases, the results for the receptor will be representative of the adjacent observer locations, such that the overall level of effect in each area is captured reliably.

4.3.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figure 9 on the following page. In total, 100 dwellings have been assessed. An additional 1.8m height above ground is used in the modelling to simulate the typical viewing height of an observer on the ground floor[14].

Additionally, the following assessment considers the new Padley Wood View housing development, which is to the south of the proposed solar development shown in Figure 10 on page 24. To ensure that the new housing development is assessed conservatively, dwelling receptor points (50 to 57) have been placed around the perimeter. However, these points are indicators of the housing development, and appropriately represent the potential effects towards the housing development regardless of the final layout.

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[14] 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.

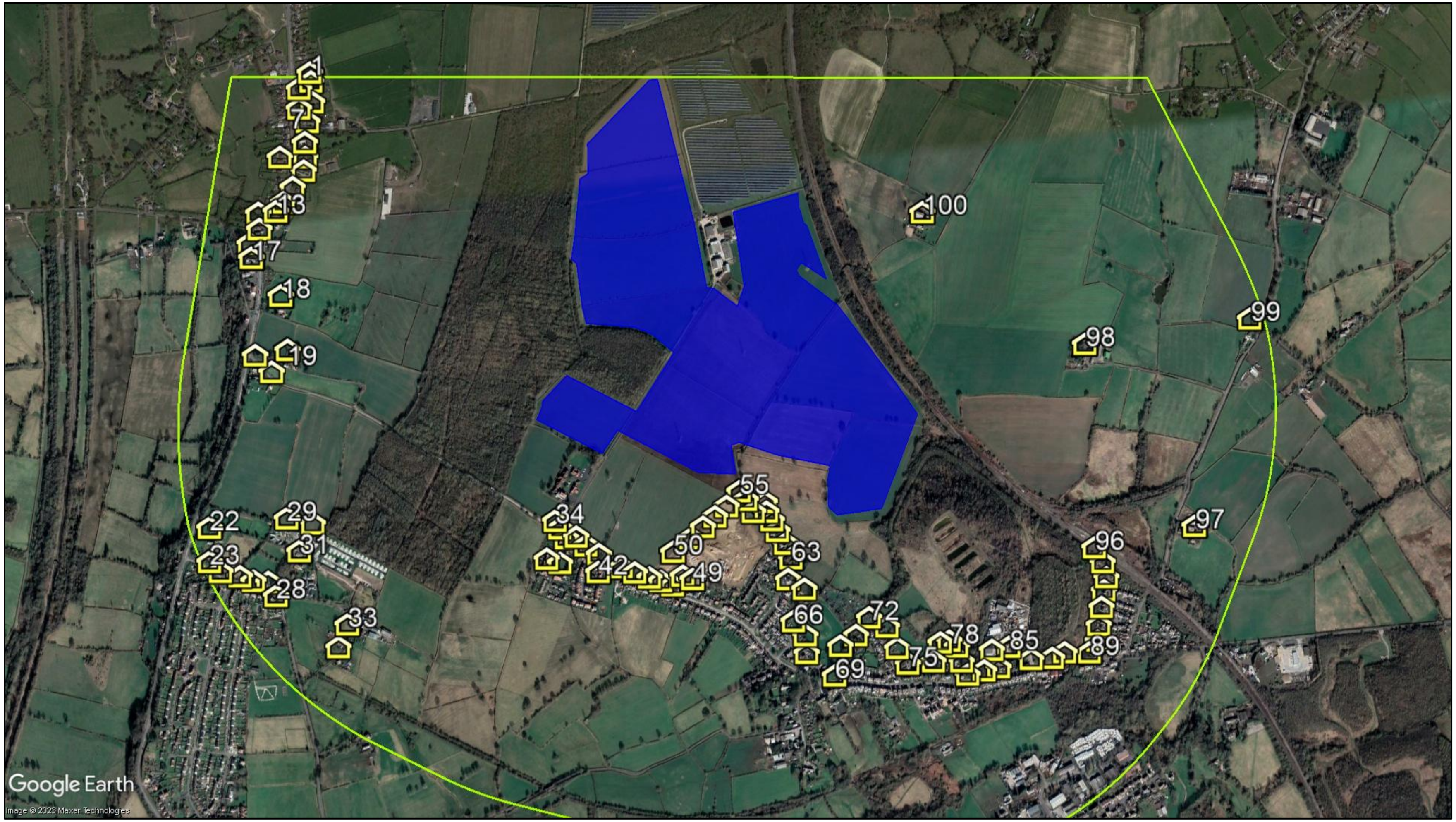

Figure 9 *Overview of assessed dwelling receptors 1 to 100*

Figure 10 *Overview of receptor points 50 – 57 representing Padley Wood View housing development*

4.4 Railway Receptors

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 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 by determining its intensity. Only where a solar reflection occurs under certain conditions and is of a particular intensity may it cause a reaction from a train driver and thus potentially affect safe operations. Therefore, intensity calculations are undertaken where a solar reflection is identified and where its presence 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.[15]*'*

4.4.1 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) describes disability glare as[16]:

'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

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[15] Source: Glossary of Signalling Terms, Railway Group Guidance Note GK/GN0802. Issue One. Date April 2004.
[16] CIE 146:2002 & CIE 147:2002 Collection on glare (2002).

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).

4.4.2 Railway Signal Receptors

The analysis has considered railway signal receptors that:

- Are within the 500m assessment area;
- Have a potential view of the panels.

No railway signals have been identified following an initial review of the available imagery. This report can be updated if other railway signals are identified by Network Rail.

4.4.3 Train Driver Receptors

The analysis has considered train driver receptors that:

- Are within the 500m assessment area;
- Have a potential view of the panels.

The assessed receptors along the railway line are shown along the purple line in Figure 11 on the following page. Receptors are taken approximately every 100m and a height of 2.75 metres above ground level has been taken as typical eye level of a train driver[17].

[17] Confirmed by Network Rail during previous consultation.

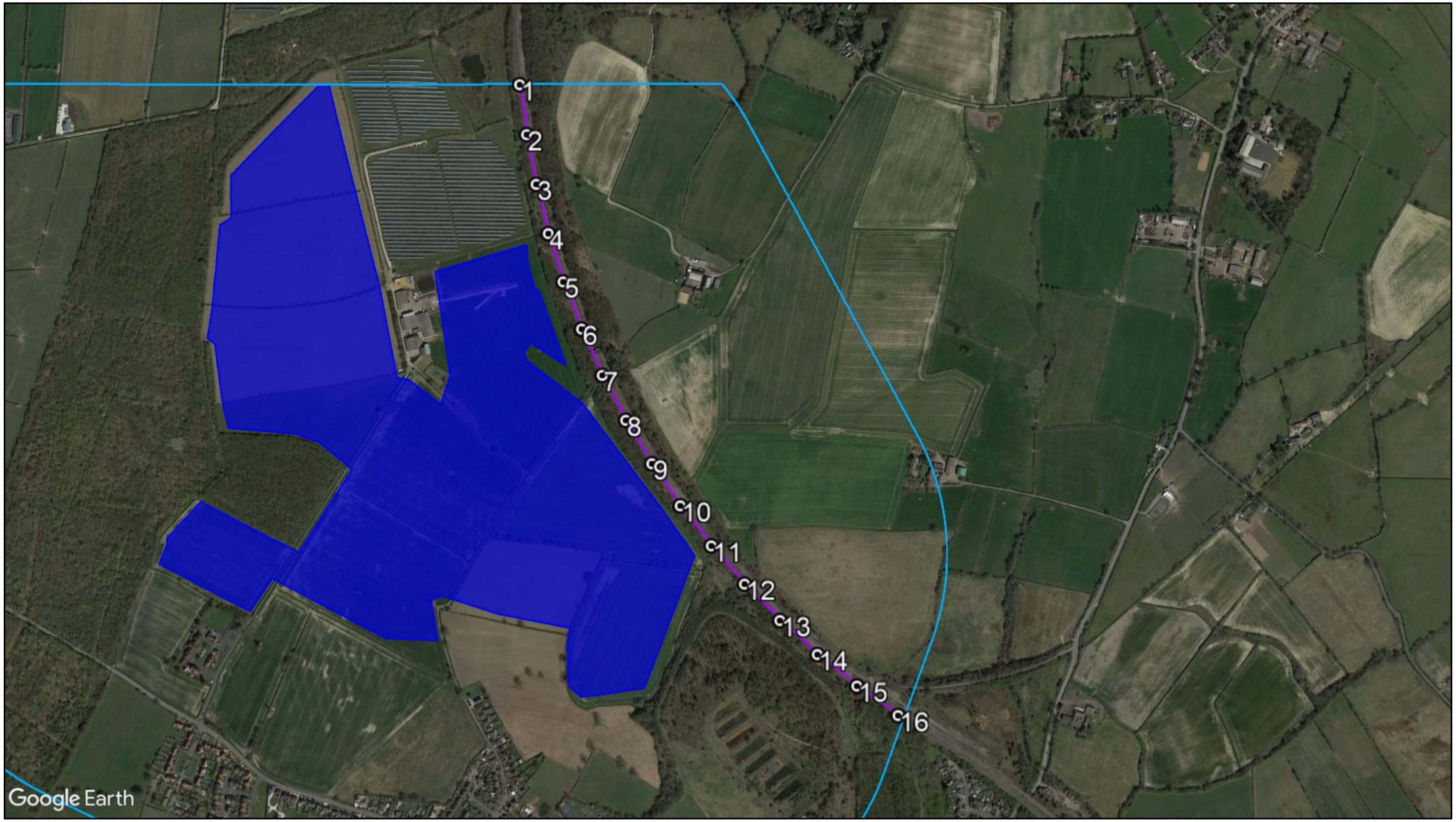

Figure 11 *Overview of assessed rail receptors*

5 ASSESSED REFLECTOR AREA

5.1 Reflector Area

The bounding coordinates for the proposed development have been extrapolated from the site plans. The data can be found in Appendix G. Figure 12 below shows the assessed reflector area that has been used for modelling purposes.

The Pager Power model has used a resolution of 25m for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 25m 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. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed solar development.

Figure 12 *Assessed reflector area*

6 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

6.1 Overview

The following sub-section presents the results of the assessment, the significance of any predicted impact in the context of existing screening and the relevant criteria set out in each sub-section. 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 has been undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

6.2 Road Results

6.2.1 Key Considerations

The process for quantifying impact significance is defined in the report appendices. The key considerations for road users along major national, national, and regional roads are:

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

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 reflections originate from outside of a road user's main field of view (50 degrees either side of the direction of travel), or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not recommended.

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

- 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;
- Whether a solar reflection is fleeting in nature. Small gap/s in screening (e.g., an access point to the site) may not result in a sustained reflection for a road user;
- 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;
- 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.

Following consideration of these relevant factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

Where 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 Overview

The results of the modelling indicate that solar reflections are geometrically possible towards 1.3km of the A61, 0.3km of the B6014 and 1.7km of Morton Road/Stretton Road/B6014.

Table 2 on the following pages presents the following:

- Geometric modelling results (without consideration of screening);
- Desk-based review of identified screening (presented in more detail in the following sub-section);
- Consideration of any mitigating factors (where appropriate);
- Predicted impact significance.

Road Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
A1 – A4	Solar reflections would originate from **outside** a road user's main horizontal field of view	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
A5 – A6	Solar reflections would originate from **inside** a road user's main horizontal field of view	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
A7 – A11	Solar reflections would originate from **outside** a road user's main horizontal field of view	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
A12 – A14	Solar reflections would originate from **outside** a road user's main horizontal field of view	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
B1	Solar reflections would originate from **inside** a road user's main horizontal field of view	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Road Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
B2 – B4	Solar reflections would originate from **outside** a road user's main horizontal field of view	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
C1 – C8	Solar reflections would originate from **inside** a road user's main horizontal field of view	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
C9 - C10	Solar reflections would originate from **inside** a road user's main horizontal field of view	Existing terrain screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
C11	Solar reflections would originate from **outside** a road user's main horizontal field of view	Existing terrain screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
C12	Solar reflections would originate from **inside** a road user's main horizontal field of view	Existing building and terrain screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Road Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
C13 – C14	Solar reflections would originate from **inside** a road user's main horizontal field of view	Existing building screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
C15 – C25	No solar reflections geometrically possible	N/A	N/A	No impact
C26 – C30	Solar reflections would originate from **inside** a road user's main horizontal field of view	Existing terrain screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Table 2 *Geometric modelling results and assessment of impact significance – road receptors*

6.2.3 Desk-Based Review of Imagery

A desk-based review of the available imagery is presented on the following pages for road receptors where solar reflections are geometrically possible.

The identified screening in the form vegetation is outlined in green, buildings outlined in blue, and cumulative reflecting panel areas shown in yellow in Figures 13 to 17 on the following pages. Street view imagery represents views of the proposed development along the sections of road where the reflecting panels are predicted to be significantly obstructed. High-level Zones of Theoretical Visibility (ZTV Viewshed) generated by Google Earth have been used to show the intervening terrain between the proposed development and relevant road receptors in Figures 16 and 17 on pages 40 and 41 respectively[18].

[18] The green highlighted extents show the areas of terrain from the relevant receptor point that is visible to an observer. The viewing height for road receptors is set to 2m above ground level (agl) to account for the views of a typical driver at eye level.

Figure 13 *Screening relevant to road receptors A1 to A14, including a representative example of solar reflections for receptor A8*

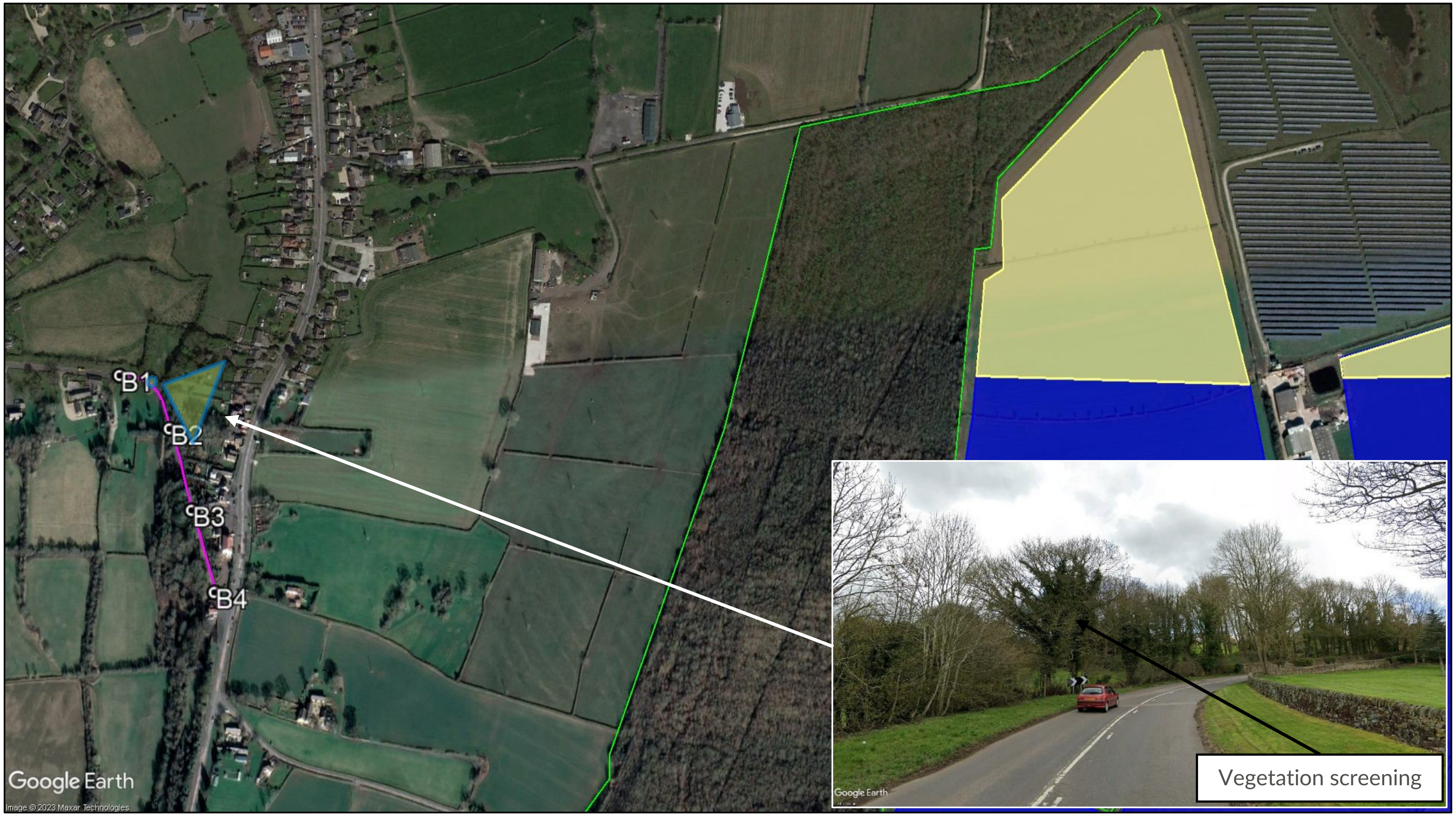

Figure 14 *Screening relevant to road receptors B1 to B4, including a representative example of solar reflections for receptor B1*

Figure 15 *Screening relevant to road receptors C1 to C9, including a representative example of solar reflections for receptor C6*

Figure 16 *Terrain screening relevant to road receptors C10 to C14, including a representative example of solar reflections and viewshed taken from receptor C12*

Figure 17 *Terrain screening relevant to receptors A18 to A22, including a representative example of solar reflections and viewshed taken from receptor A19*

6.3 Dwelling Results

6.3.1 Key Considerations

The key considerations for quantifying the impact significance for dwelling receptors are:

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

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 effects are predicted to be experienced for **less** than three months per year and **less** than 60 minutes on any given day, or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not recommended.

Where effects 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 relevant factors is required to determine the impact significance:

- Whether solar reflections will be experienced from all storeys. The ground floor is typically considered the main living space and therefore 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;
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light;
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look from a wide angle to observe the reflecting areas.

Following consideration of these relevant factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

Where effects are predicted to be experienced for **more** than three months per year and **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 Overview

Solar reflections are geometrically possible towards dwelling receptors 1 to 61, and 88 to 100, totalling 74 of the 100 assessed dwelling receptors.

Table 3 on the following pages presents the following:

- Geometric modelling results (without consideration of screening);
- Desk-based review of identified screening (presented in more detail in the following sub-section);
- Consideration of relevant mitigating factors (where appropriate);
- Predicted impact significance.

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Relevant Factors	Predicted Impact Classification
1 - 10	Solar reflections predicted for **less** than three months of the year but **less** than 60 minutes on any given day	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
11 - 31	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
32 - 33	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing buildings screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
34 - 35	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing terrain and vegetation screening Predicted to significantly obstruct views of the reflecting panels for the ground floor	N/A	Low impact
36 - 37	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing buildings screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Relevant Factors	Predicted Impact Classification
38 - 41	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing terrain and vegetation screening Predicted to significantly obstruct views of the reflecting panels for the ground floor	N/A	Low impact
42 - 43	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing buildings screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
44 - 49	Solar reflections predicted for **less** than three months of the year but **less** than 60 minutes on any given day	Existing buildings screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
50 - 54	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing buildings screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
55 - 56	Solar reflections predicted for **more than** three months of the year but less than 60 minutes on any given day	Proposed vegetation screening (see Section 2.2) Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Relevant Factors	Predicted Impact Classification
57	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing buildings screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
58 - 60	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Proposed vegetation screening (see Section 2.2) Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
61	Solar reflections predicted for **less** than three months of the year but **less** than 60 minutes on any given day	No screening identified	N/A	Low impact
62 - 87	No solar reflections geometrically possible	N/A	N/A	No impact
88 - 92	Solar reflections predicted for **less** than three months of the year but **less** than 60 minutes on any given day	Existing terrain screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Relevant Factors	Predicted Impact Classification
93 - 100	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day	Existing terrain screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Table 3 Geometric modelling results and assessment of impact significance - dwelling receptors

6.3.3 Desk-Based Review of Imagery

A desk-based review of the available imagery is presented on the following pages for the dwellings where solar reflections are geometrically possible.

The identified screening in the form of existing vegetation is outlined in green, buildings in light blue, proposed vegetation (see Section 2.2) in pink, and cumulative reflecting panel areas shown in yellow, within Figures 18 to 24 on the following pages. Where relevant, High-level ZTV Viewshed generated by Google Earth have been used to show the intervening terrain between the proposed development and dwelling receptors experiencing terrain screening[19].

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[19] The green highlighted extents show the areas of terrain from the relevant receptor point that is visible to an observer. For dwellings receptors, viewing height is set to 5m agl to account for views above ground level, unless stated otherwise.

Figure 18 *Screening relevant to receptors 1 to 21*

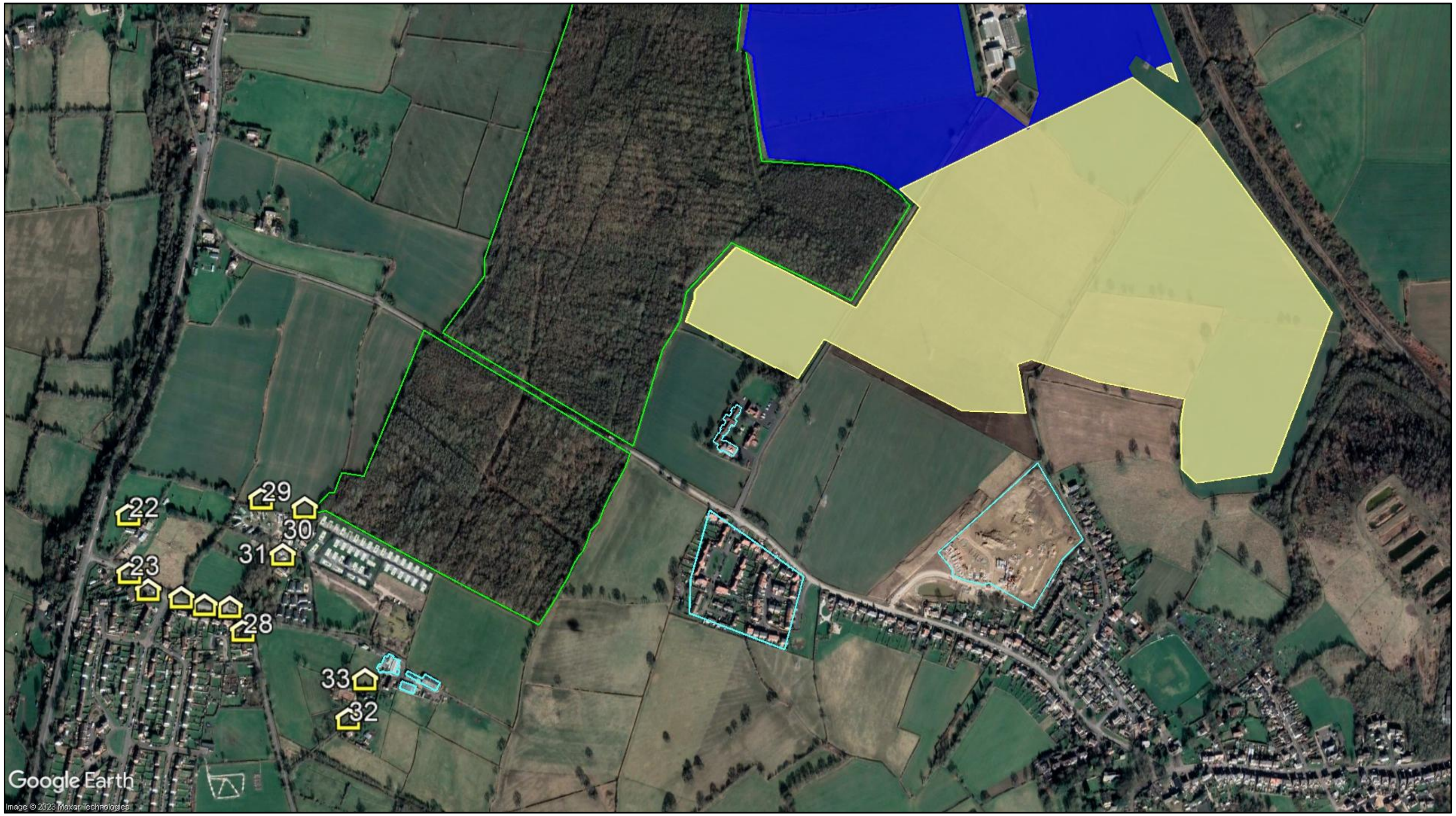

Figure 19 *Screening relevant to receptors 22 to 33*

Figure 20 *Screening relevant to dwelling receptors 34 to 42, including viewshed taken from receptor 39*

Figure 21 *Screening relevant to dwelling receptors 43 to 54, and 57*

Figure 22 *Screening relevant to dwelling receptors 55 and 56, and 58 to 61*

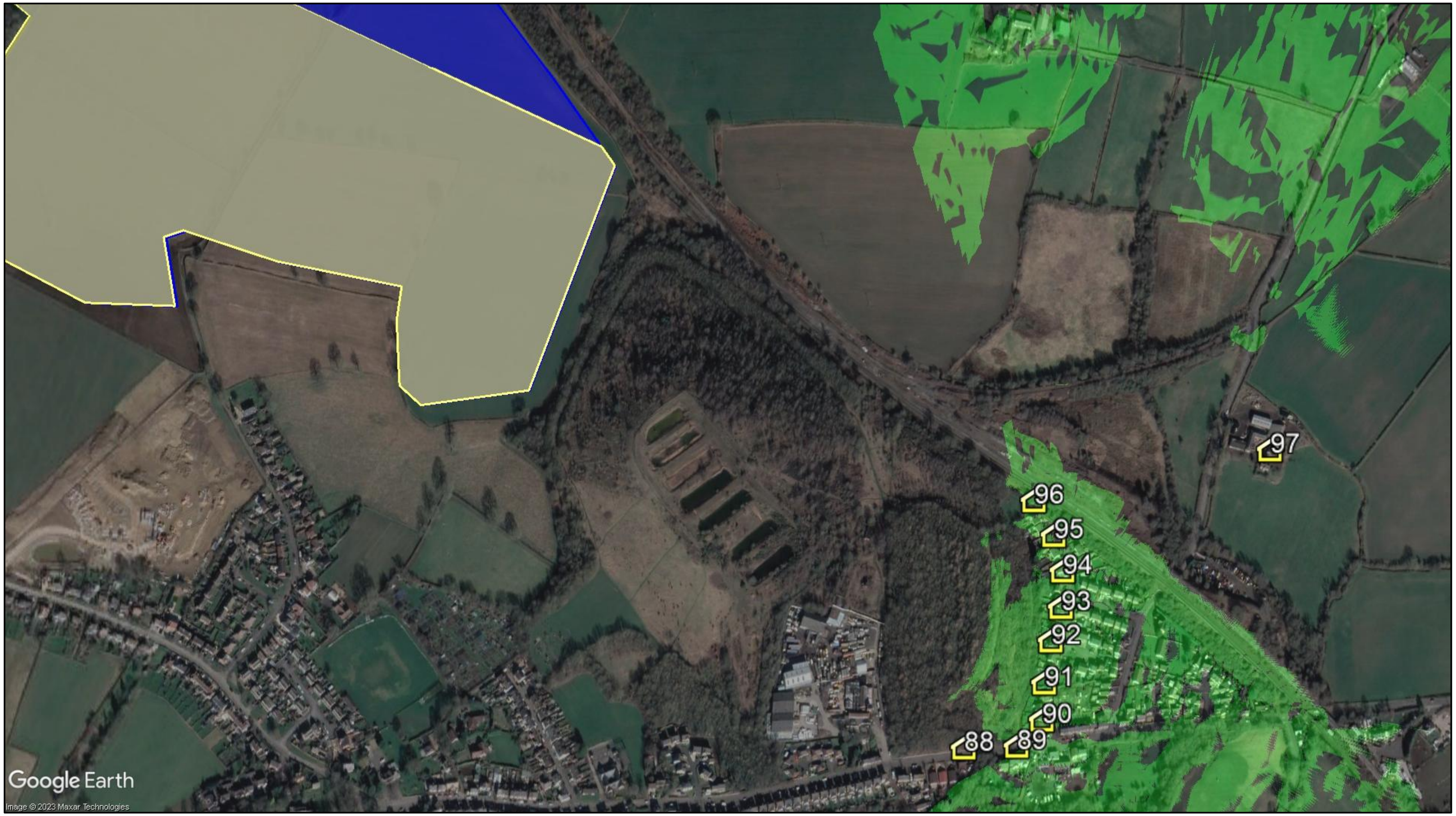

Figure 23 *Terrain screening relevant to dwelling receptors 88 to 97, including viewshed taken from receptor 92*

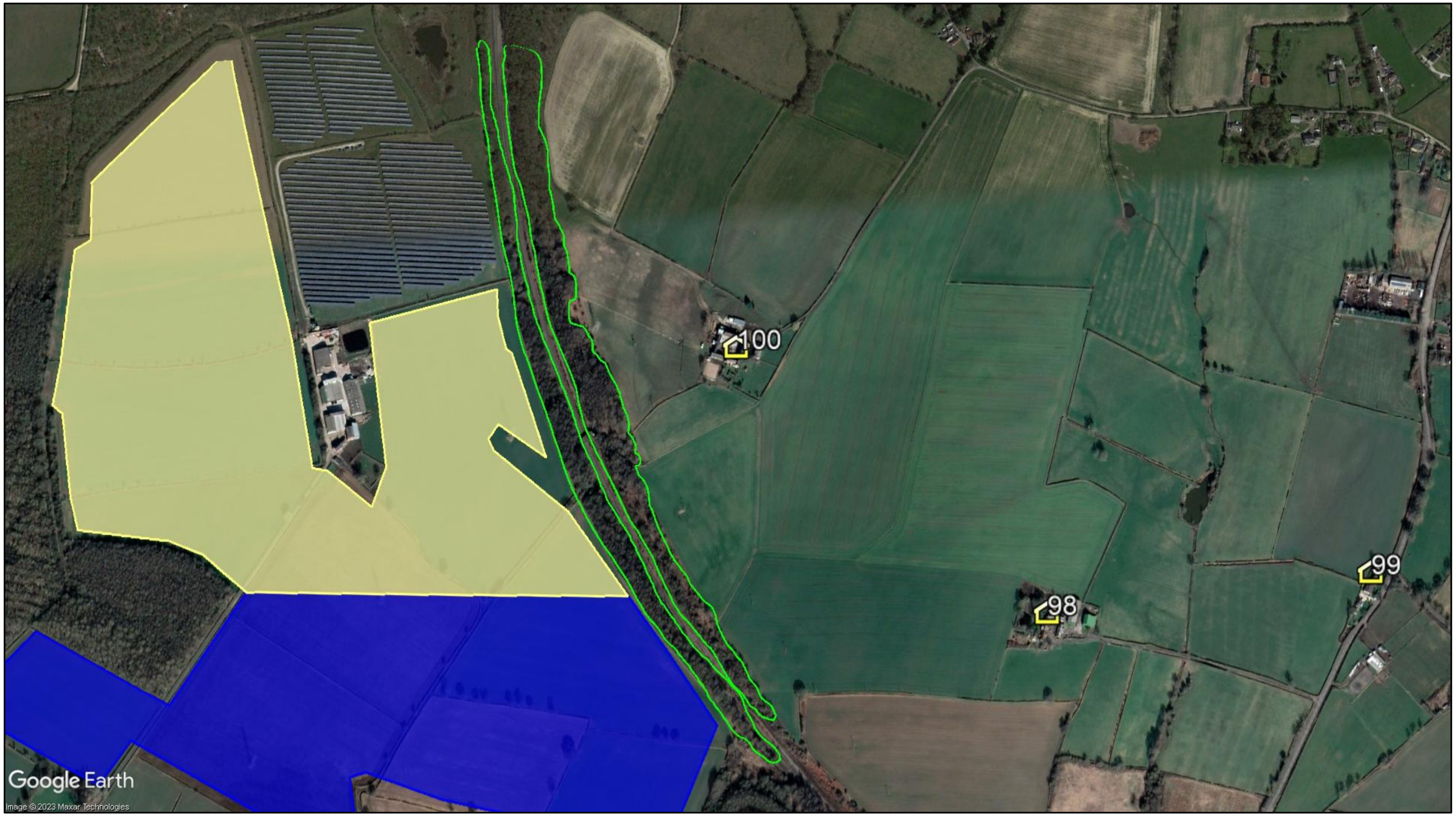

Figure 24 *Screening relevant to dwelling receptor 98 to 100*

6.4 Railway Results

6.4.1 Key Considerations

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

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

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 reflections originate from outside of a train driver's main field of view (30 degrees either side of the direction of travel), or where the separation distance to the nearest visible reflecting panel is over 500m, the impact significance is low, and mitigation is not recommended.

Where reflections originate from inside of a train driver's main field of view, expert assessment of the following relevant factors is required to determine the impact significance:

- Whether the solar reflection originates from directly in front of a train driver. Solar reflections that are directly in front of a road user are more hazardous;
- Whether a solar reflection is fleeting in nature. Small gap/s in screening, e.g. an access point to the site, may not result in a sustained reflection for a train driver;
- 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 workload of a train driver experiencing a solar reflection. Is there visibility of a railway signal or level crossing when solar reflections are predicted to be received? Is there a switch in the railway line when solar reflections are predicted to be received?
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light.

Following consideration of these relevant factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

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

6.4.2 Geometric Modelling Results Overview

The modelling indicates that solar reflections are geometrically possible towards train drivers along approximately 1.4km of railway line.

Table 4 on the following page presents the following:

- Geometric modelling results (without consideration of screening);
- Desk-based review of identified screening (presented in more detail in the following sub-section);
- Consideration of relevant mitigating factors (where appropriate);
- Predicted impact significance.

Results where a moderate impact is predicted are highlighted in red for ease of reference. See section 6.5 for further analysis.

Railway Receptors	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
1	No solar reflections geometrically possible	N/A	N/A	No impact
2 - 4	Solar reflections predicted from **outside** a train driver's main horizontal field of view	Existing terrain and vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact
5 - 16	Solar reflections predicted from **within** a train driver's main horizontal field of view	Existing terrain and vegetation screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact

Table 4 *Geometric modelling results and assessment of impact significance - railway receptors*

6.4.3 Desk-Based Review of Imagery

A desk-based review of the available imagery is presented on the following pages for railway receptors where solar reflections are geometrically possible.

The cumulative reflecting panel areas are shown in yellow, within Figures 25 and 27 on the following pages. High-level ZTV Viewshed generated by Google Earth have been used to show the intervening terrain between the proposed development and railway receptors experiencing terrain screening[20].

[20] The green highlighted extents show the areas of terrain from the relevant receptor point that is visible to an observer. For railway receptors, viewing height is set to 3m agl to account for the average eyelevel of a typical train driver.

Figure 25 *Screening relevant to railway receptors 2 to 11, including viewshed taken from receptor 6*

Figure 26 *Point-of-view from receptor 12*

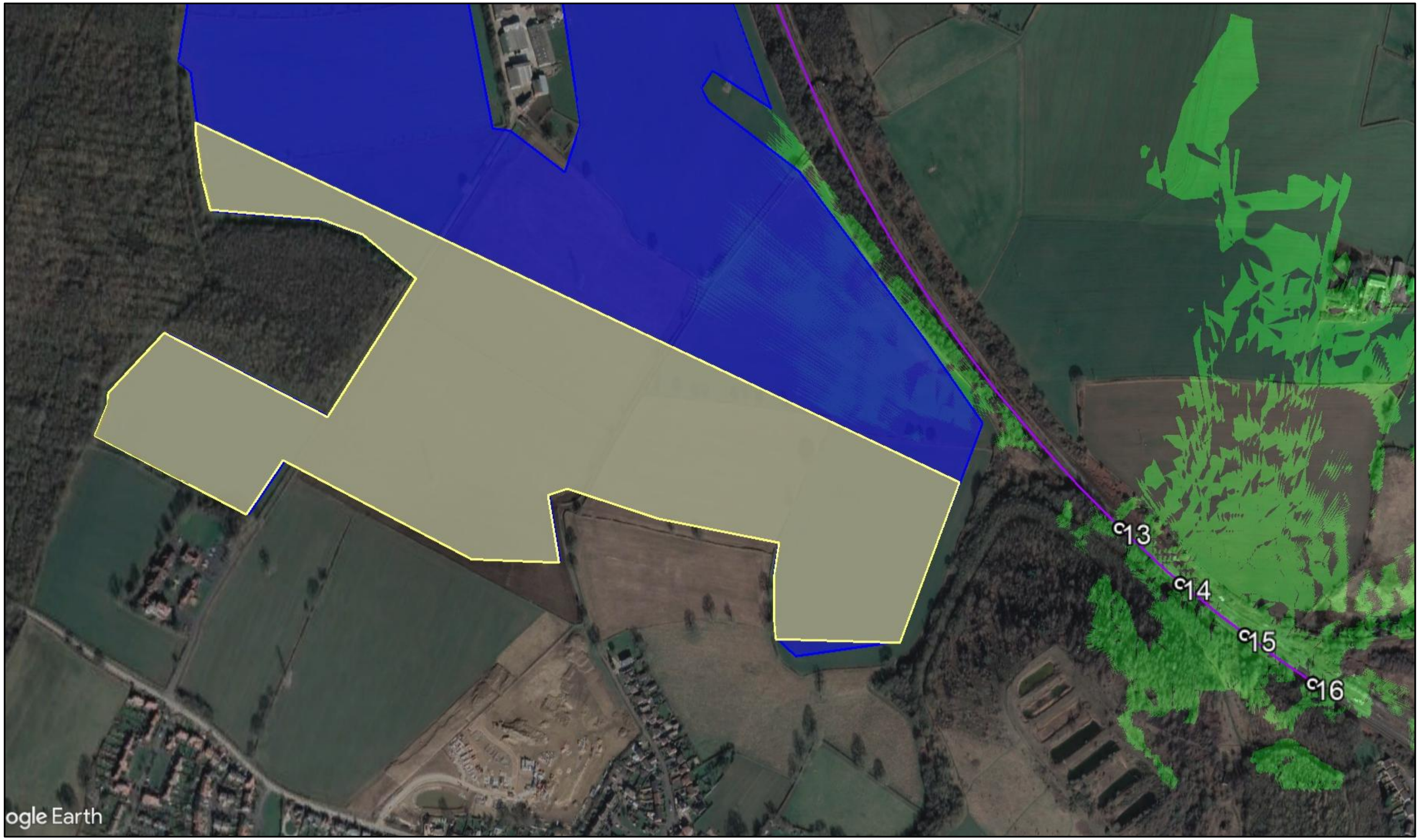

Figure 27 *Screening relevant to receptors 13 to 16, including viewshed taken from receptor 15*

7 HIGH-LEVEL AVIATION CONSIDERATIONS

7.1 Overview

Glint and glare assessments for aviation receptors are typically undertaken for licensed aerodromes within 10km of a proposed solar development. Geometric modelling for GA aerodromes is typically required within 5km of a proposed development. At ranges of 10-20km, the requirement for assessment is much less common, particularly for unlicensed aerodromes. Assessment of any aviation effects for developments over 20km is not a usual requirement.

The following section presents an overview of the possible effects of glint and glare concerning aviation activity at Ripley Airfield.

Ripley Airfield is approximately 8.4km south relative to the proposed development.

7.2 Aerodrome Details

Ripley Airfield is an unlicenced airfield and is not understood to have an ATC Tower. The aerodrome has one runway, the details of which are presented below[21]:

- 08/26 measuring 640 x 20 metres (grass).

The locations of the aerodrome relative to the proposed development and 1-mile splayed approach paths for Ripley Airfield are shown in Figure 28 below.

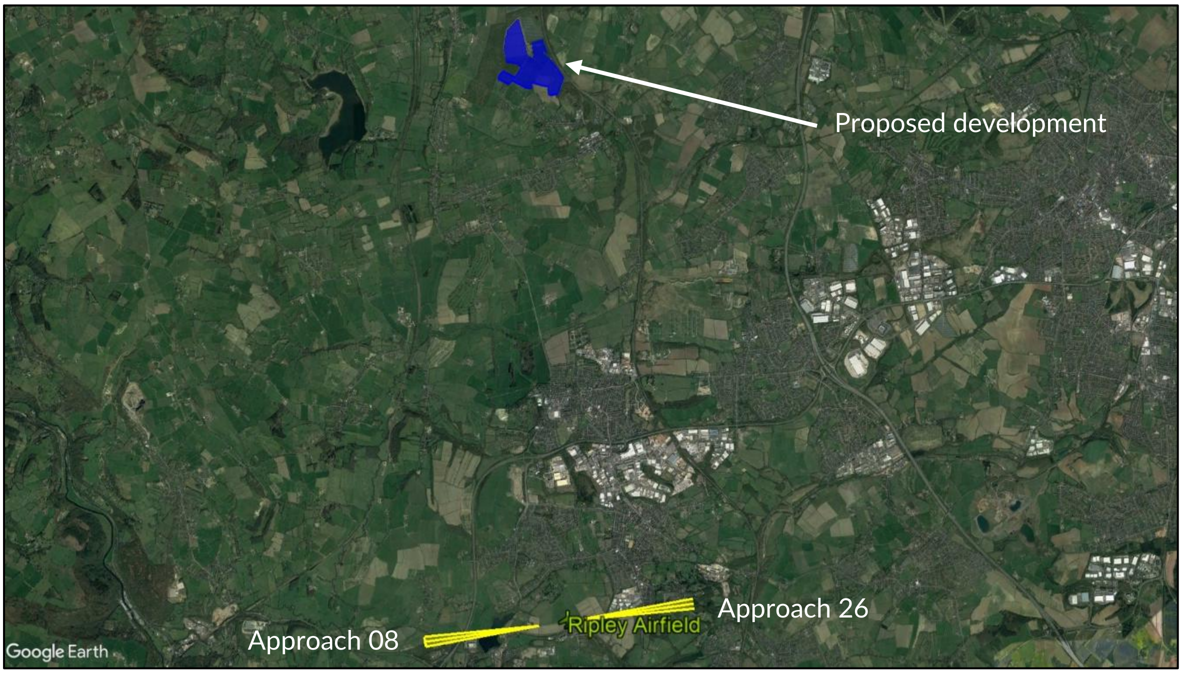

Figure 28 *Proposed development relative to the 1-mile splayed approach paths for Ripley Airfield*

[21] As determined by aerial imagery.

7.3 High-Level Assessment Conclusions - Aviation

The proposed development size, distance between the aerodromes and proposed development, and industry experience are considered during the assessment.

For aviation activity associated with Ripley Airfield, any solar reflections are predicted to be acceptable in accordance with the associated guidance (Appendix D) and industry best practice, as any possible solar reflections will be outside the pilot's field of view (50 degrees horizontally either side of the direction of travel) for pilots approaching both runway thresholds.

Therefore, no significant impacts are predicted upon aviation activity at Ripley Airfield and detailed modelling is not recommended.

8 HIGH-LEVEL ASSESSMENT OF CUMULATIVE EFFECTS

8.1 Overview

This section presents analysis of cumulative effects of solar reflections, from the existing solar development in the surrounding area with respect to the receptors within shared assessment areas of both the proposed and existing developments.

8.2 Assessment

The cumulative assessment considers existing solar development near to the proposed development. Figure 29 below shows the existing development relative to the proposed development outlined in orange.

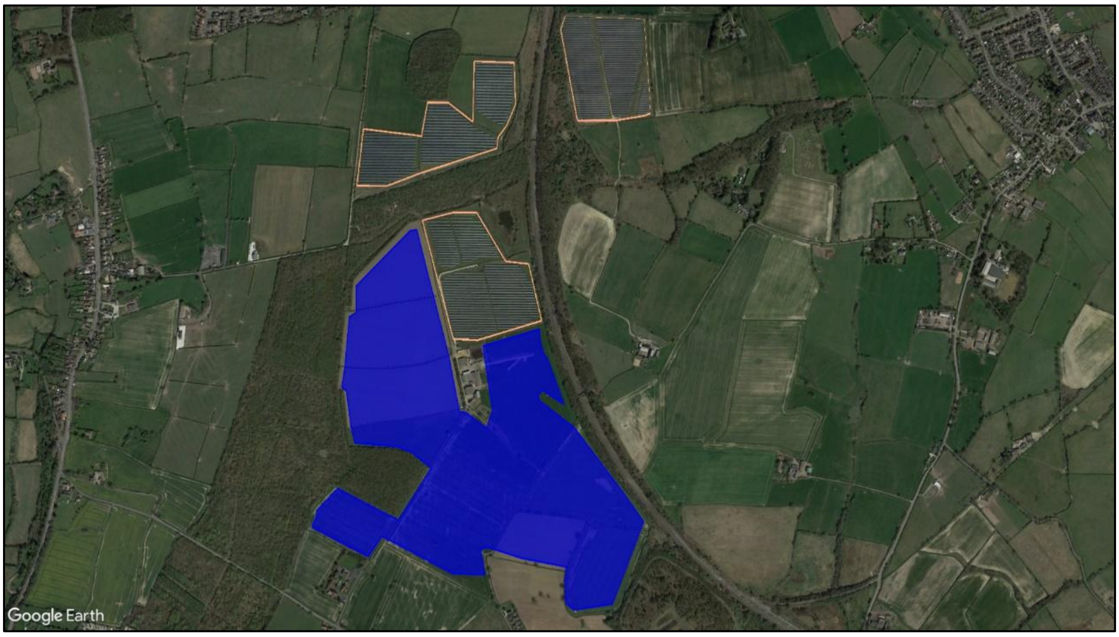

Figure 29 *Existing developments relative to proposed development*

The existing have fixed south-facing panels, and therefore solar reflections could only be possible for the following shared identified receptors:

- Railway Receptors (1 to 8)
- One dwelling receptor (100).

8.3 High-Level Assessment Conclusions – Cumulative Effects

Considering the results of the assessment for roads, railway, dwellings and aviation, no cumulative impacts are predicted. This is because the receptors within shared assessment areas of both the proposed and existing developments are predicted to experience no impact from solar reflections from the proposed development due to sufficient terrain and vegetation screening.

9 OVERALL CONCLUSIONS

9.1 Conclusions – Roads

Solar reflections are geometrically possible towards approximately 1.3km of the A61, 0.3km of the B6014 and 1.7km of Morton Road/Stretton Road/B6014.

For all sections of road where a solar reflection is geometrically possible, screening in the form of existing vegetation, buildings and/or terrain is predicted to significantly obstruct views of reflecting panels such that solar reflections will not be experienced by road users. No impact is predicted, and mitigation is not required.

9.2 Conclusions – Dwellings

Solar reflections are geometrically possible towards 74 of the 100 assessed dwellings.

For 68 of these dwellings, screening in the form of existing vegetation, buildings and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. Therefore, no impact is predicted, and no mitigation is required.

For the six remaining dwellings, screening in the form of proposed vegetation within the landscape strategy plan is predicted to significantly obstruct views of reflecting panels. Therefore, no impact is predicted, and no mitigation is required.

For the one remaining dwelling, no sufficient mitigating factors have been identified. However, the duration of reflections is predicted to be less than three months per year and less than 60 minutes in any given day. A low impact is predicted, and mitigation is not recommended.

9.3 Conclusions – Railway

Solar reflections are geometrically possible towards approximately 1.4km of railway. Screening in the form of existing vegetation and intervening terrain is predicted to significantly obstruct views of reflecting panels, such that solar reflections are not predicted to be experienced by train drivers. No impact is predicted, and mitigation is not required.

No signals or assets have been identified from a review of the available imagery. This report can be updated if railway signals or assets are identified by Network Rail.

9.4 High-Level Assessment Conclusions – Aviation

For aviation activity associated with Ripley Airfield, any solar reflections are predicted to be acceptable in accordance with the associated guidance (Appendix D) and industry best practice, as any possible solar reflections will be outside the pilot's field of view (50 degrees horizontally either side of the direction of travel) for pilots approaching runway thresholds 08 and 26.

Therefore, no significant impacts are predicted upon aviation activity at Ripley Airfield and detailed modelling is not recommended.

9.5 High-Level Assessment Conclusions – Cumulative

Considering the results of the assessment for roads, railway, dwellings and aviation, no cumulative impacts are predicted. This is because the receptors within shared assessment areas of both the proposed and existing developments are predicted to experience no impact from solar reflections from the proposed development.

9.6 Overall Conclusions

No significant impacts are predicted on road safety, residential amenity railway operations and infrastructure and aviation activity.

No additional impact is predicted due to cumulative effects with respect to exist nearby solar developments, detailed modelling is not recommended.

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[22] (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.'

[22] Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[23] 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.[24] 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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[23] Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: March 2023, accessed on: 05/04/2023.

[24] *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[25] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

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*

[25] Solar Photovoltaic Development Glint and Glare Guidance, Fourth Edition, March 2022. Pager Power.

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.

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'[26] 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.

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

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.*

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'[27] 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.

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

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.

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.

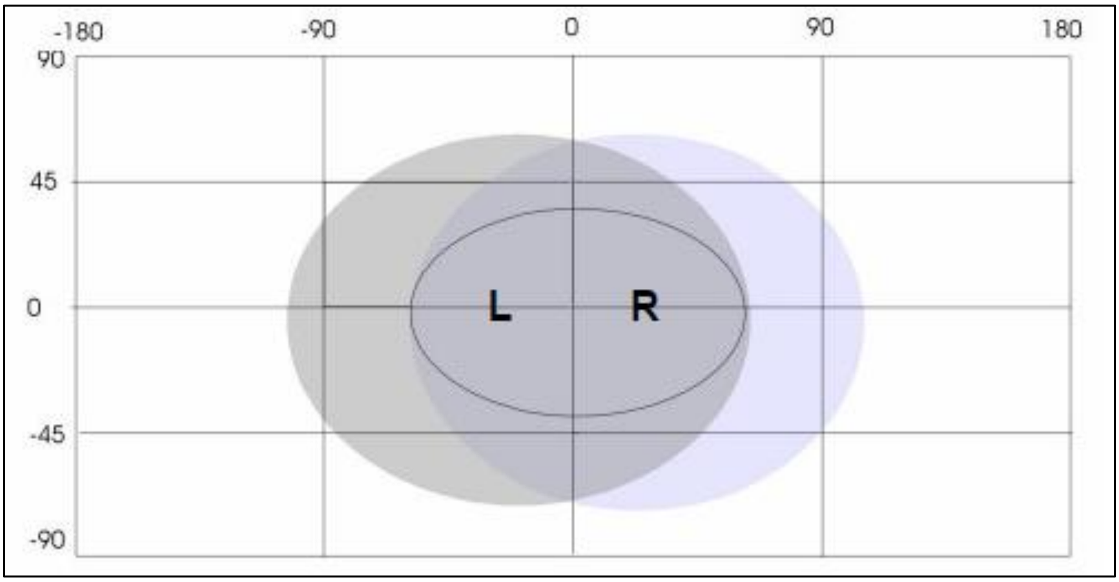

Figure G 21 - Field of view

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° 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.

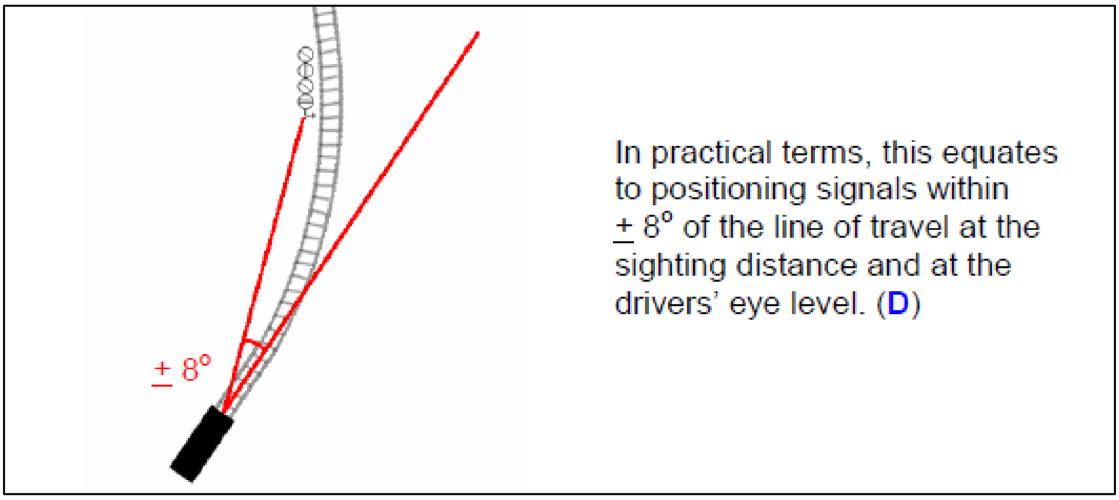

Figure G 22 - Signal positioning

'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^o 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^o 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^o cone at 25.46 m in front of the driver*

Table G 5 – 8^o 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[28];

[28] 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[29,30,31] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

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 formal policy was cancelled on September 7th, 2012[32] however the advice is still applicable[33] 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

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[29] Source: http://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf. (Last accessed 21.02.18).
[30] Source: http://www.vmstech.co.uk/downloads/Rail.pdf. (Last accessed 21.02.18).
[31] Source: Siemens, Sigmaguard LED Tri-Colour L Signal – LED Signal Technology at Incandescent Prices. Datasheet 1A-23. (Last accessed 22.02.18).
[32] Archived at Pager Power
[33] Reference email from the CAA dated 19/05/2014.

is the responsibility of the ALH[34], 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.'

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'[35], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'[36], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[37].

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.

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[34] Aerodrome Licence Holder.

[35] Archived at Pager Power

[36] 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.

[37] 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.

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 analysed 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 analyse 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 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'[38]. 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[39].

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

[39] 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.

- 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[40], 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.
- 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

[40] First figure in Appendix B.

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[41] 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 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[42] 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

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[41] 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.
[42] The Air Navigation Order 2016. [online] Available at: <https://www.legislation.gov.uk/uksi/2016/765/contents/made> [Accessed 4 February 2022].

(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.

Endangering safety of any person or property

241. A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

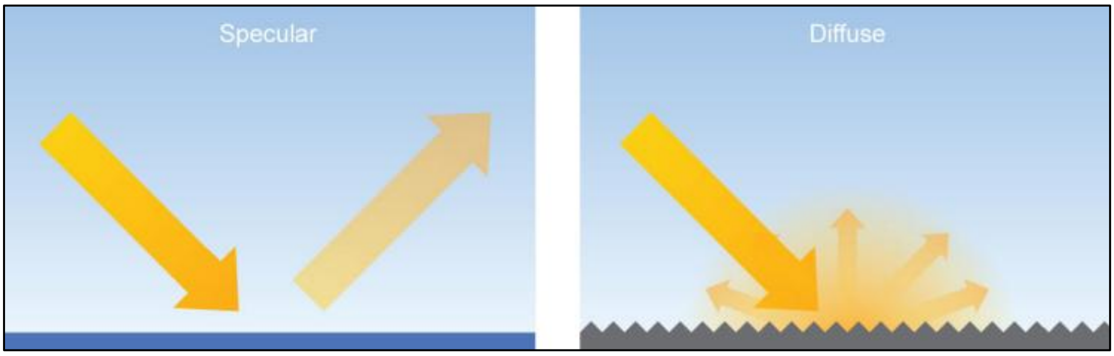
Overview

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[43], 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

Solar Reflection Studies

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

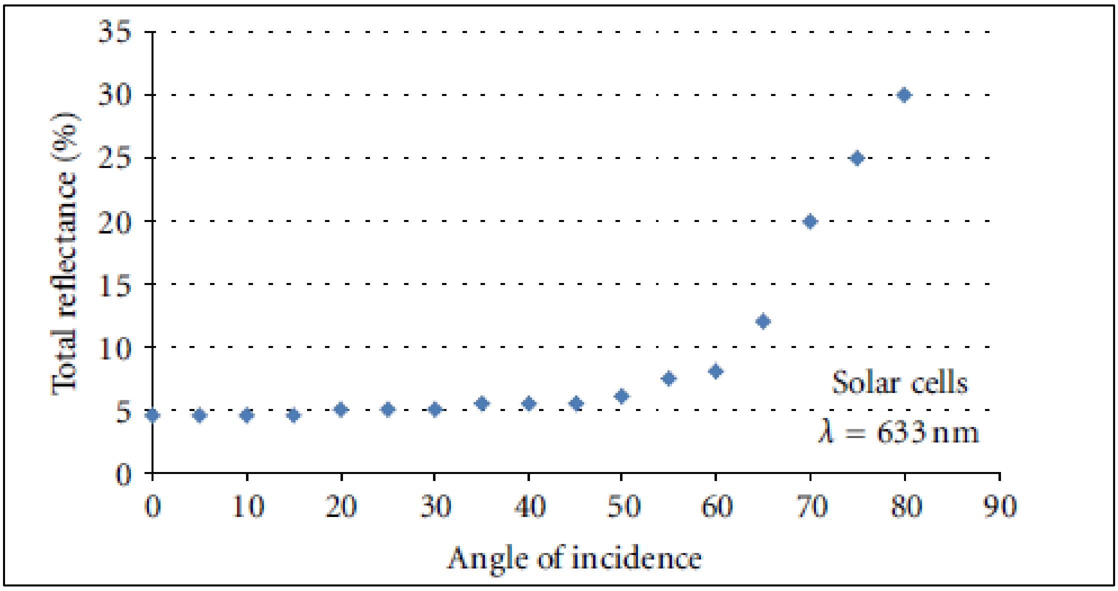
Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"

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[44]". They researched the

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

[44] 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

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.

FAA Guidance – "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[45]

The 2010 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.

[45] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

Surface	Approximate Percentage of Light Reflected[46]
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).

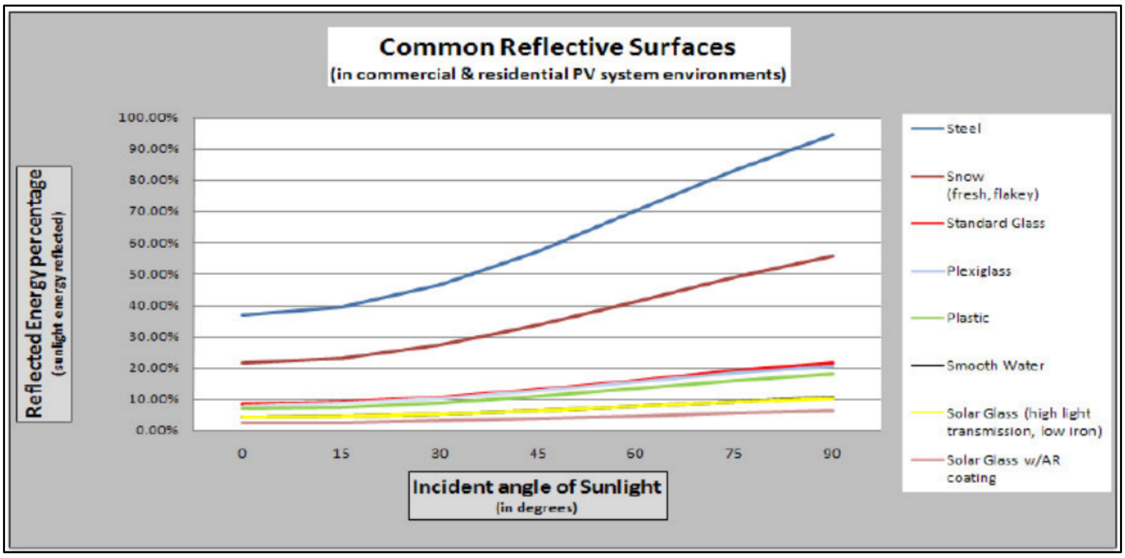
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

[46] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[47] 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.

[47] 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).

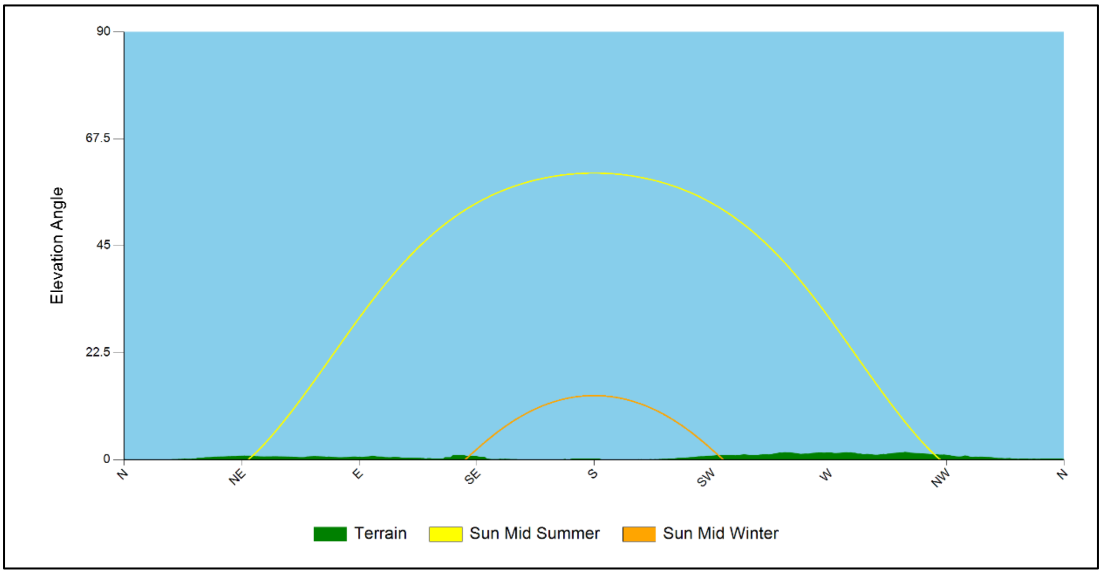
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- 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 from the proposed development location as well as the sunrise and sunset curves throughout the year.



Sunrise and sunset curves

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

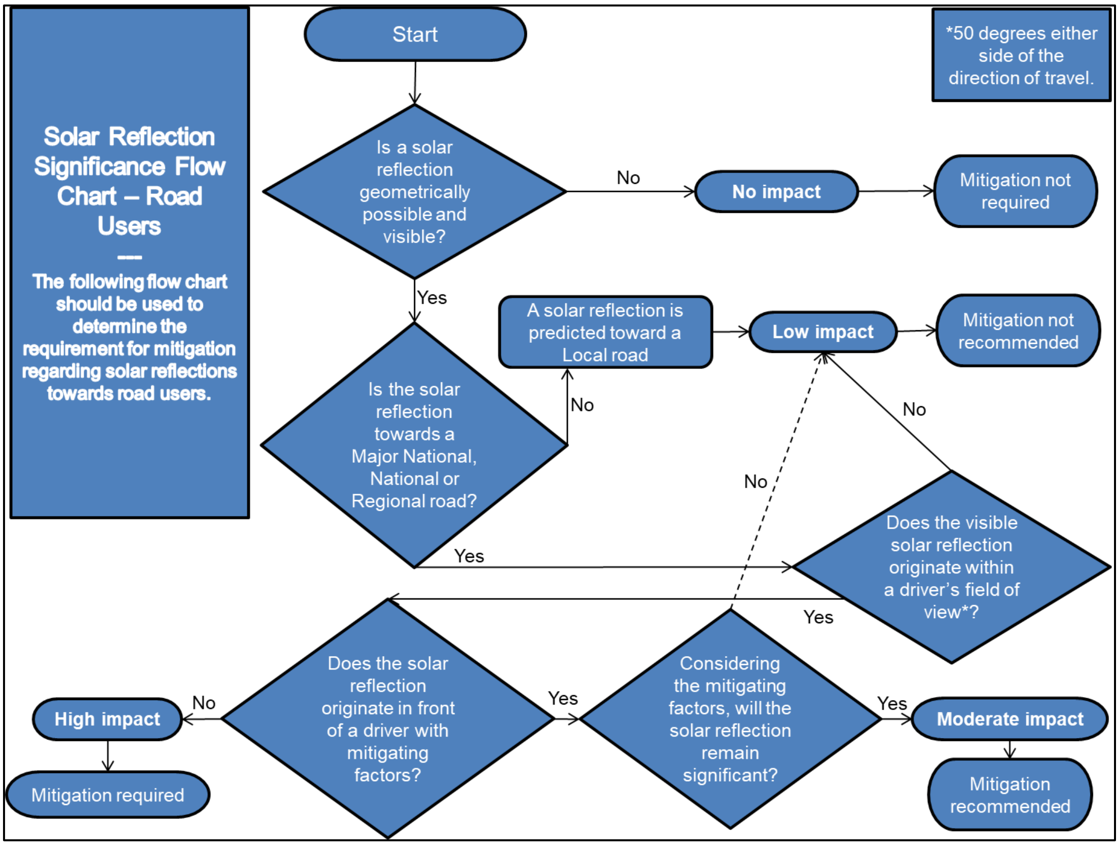
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation
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 significantly.	No mitigation recommended.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case given individual receptor criteria.	Mitigation recommended.
High	A solar reflection is geometrically possible and visible under worst-case conditions that will produce a significant impact given individual receptor criteria	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

Impact Significance Determination for Road Receptors

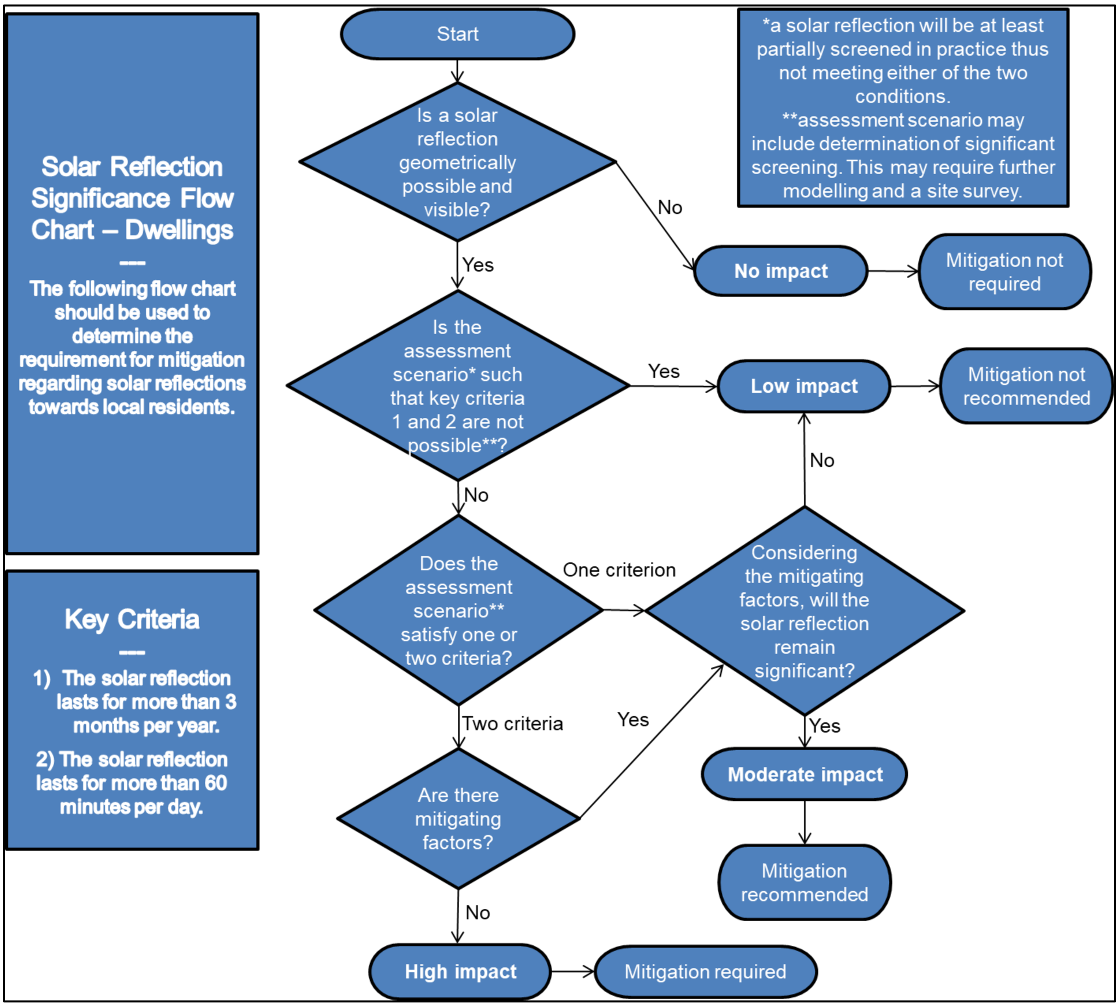
The flow chart presented below has been followed when determining the impact significance for road receptors.



Road user impact significance flow chart

Impact Significance Determination for Dwelling Receptors

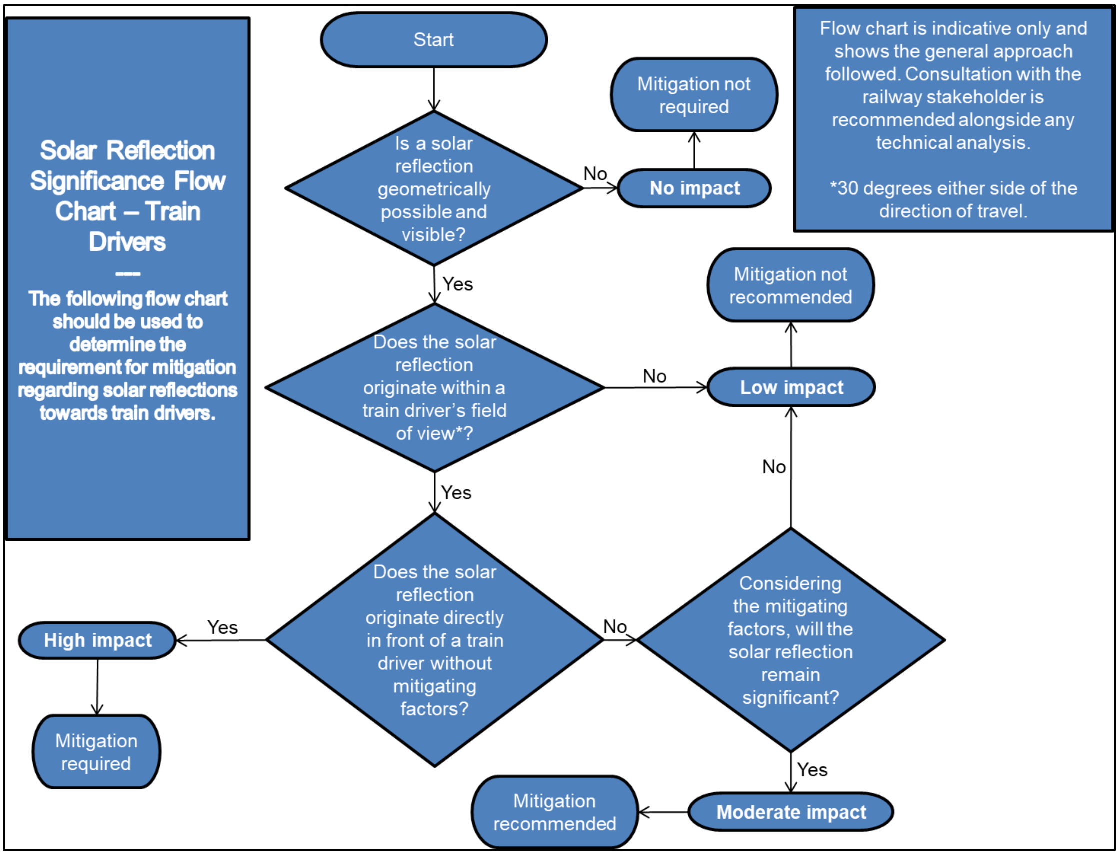
The flow chart presented below has been followed when determining the impact significance for dwelling receptors.



Dwelling impact significance flow chart

Impact Significance Determination for Train Drivers

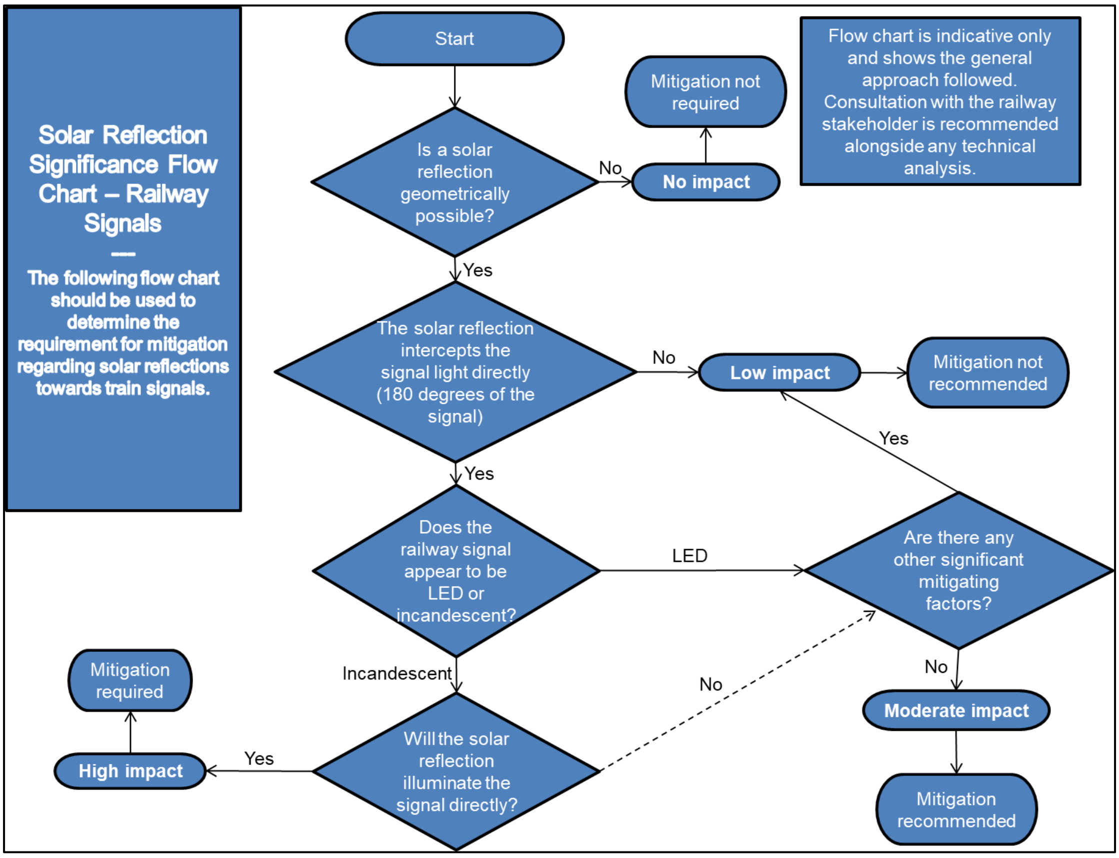
The flow chart presented below has been followed when determining the impact significance and mitigation requirement for train drivers.



Train Driver impact significance flow chart

Impact Significance Determination for Railway Signals

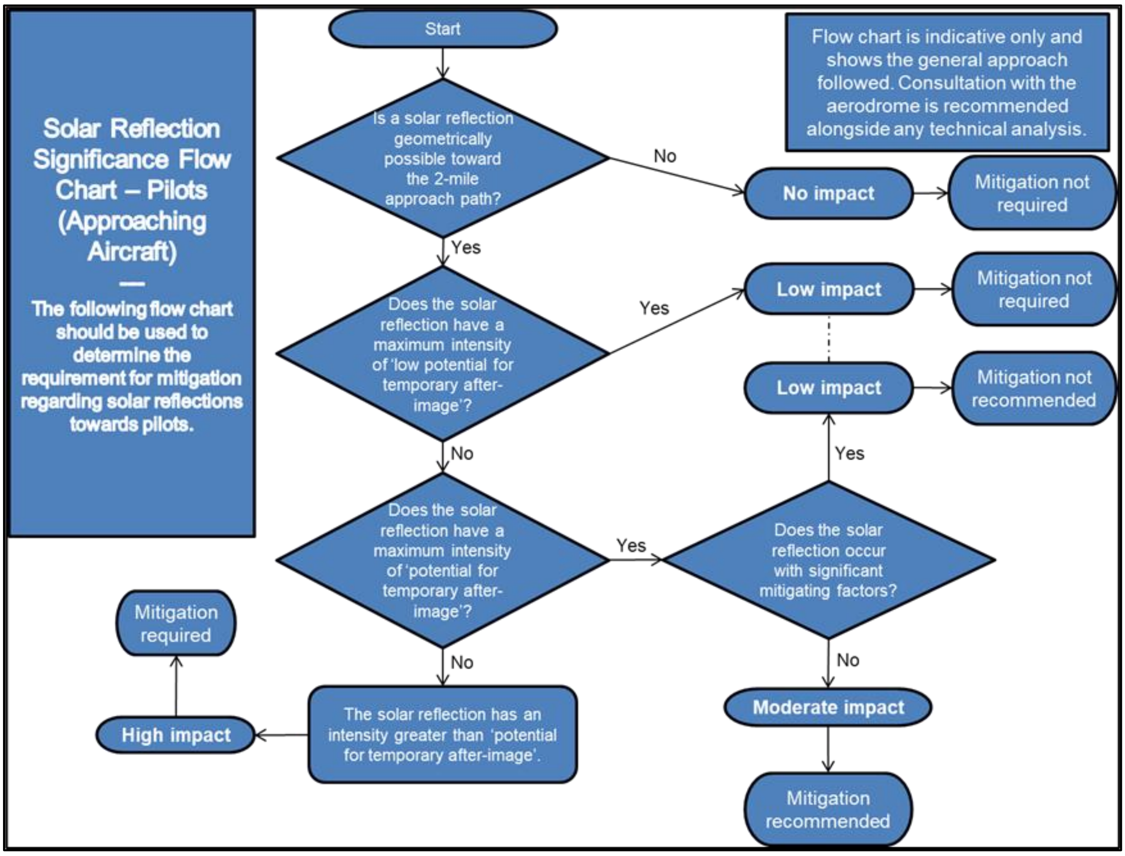
The flow chart presented below has been followed when determining the impact significance mitigation requirement for railway signals.



Railway signal impact significance flow chart

Impact Significance Determination for Approaching Aircraft

The flow chart presented below has been followed when determining the impact significance for approaching aircraft.



Approaching aircraft receptor impact significance flow chart

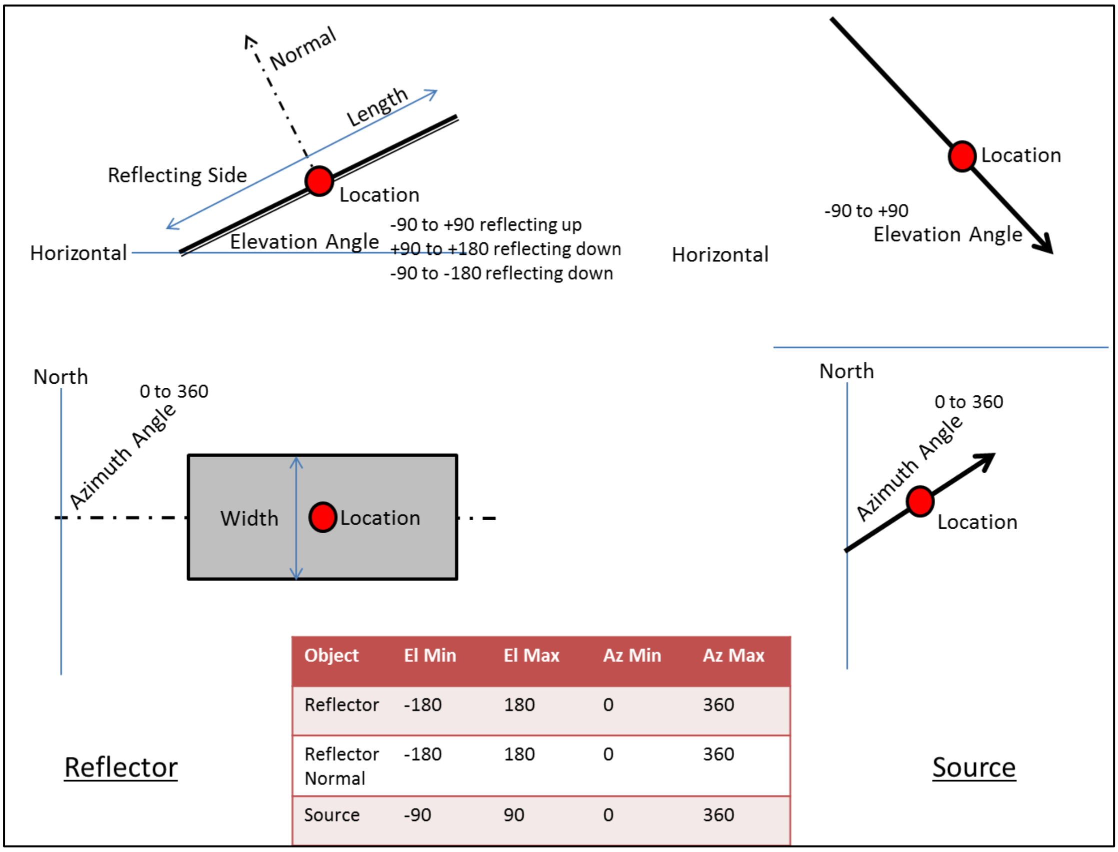
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power 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

Reflection calculation process

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)[48].

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

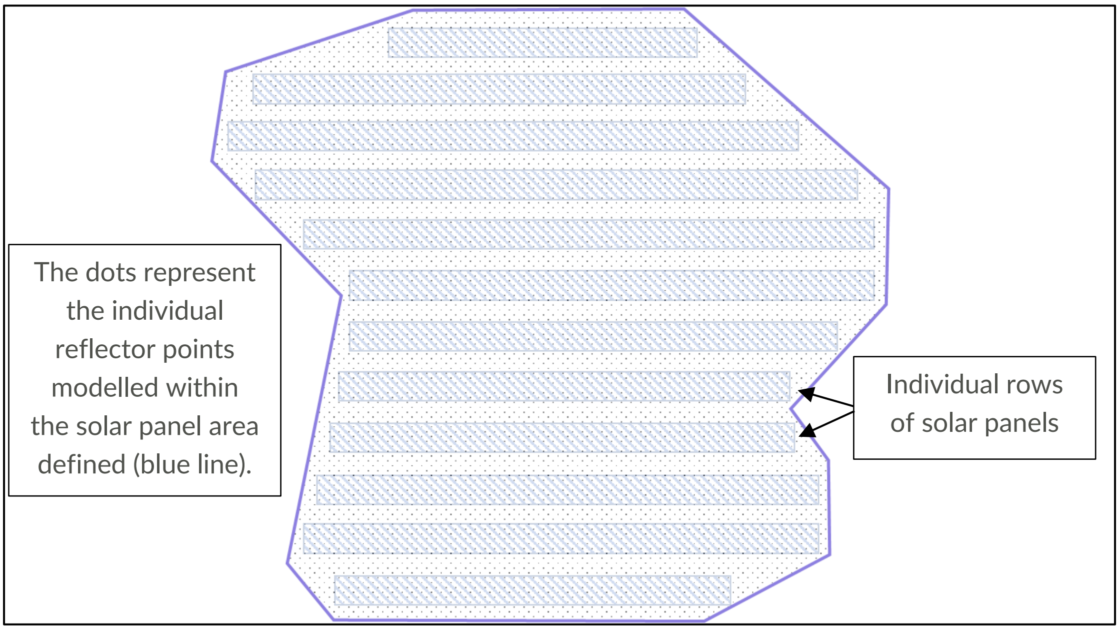
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

Only a reflection from the face of the panel has been considered. The frame or the reverse or 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 below which illustrates this process.

[48] 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.

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Road Receptor Data

The road receptor data is presented in the table below. An additional 1.5m height has been added to the elevation to account for the eye-level of a road user.

A61

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
A1	-1.413138	53.15174	152.76	A8	-1.414654	53.14559	156.53
A2	-1.413071	53.15084	153.50	A9	-1.414935	53.14471	154.02
A3	-1.413037	53.14994	153.74	A10	-1.415256	53.14383	153.39
A4	-1.413236	53.14905	156.74	A11	-1.415625	53.14296	154.31
A5	-1.413826	53.14822	161.50	A12	-1.41612	53.14211	153.85
A6	-1.414316	53.14738	161.24	A13	-1.41671	53.14128	151.78
A7	-1.414405	53.14648	161.64	A14	-1.417203	53.14043	153.50

A61 receptor data

B6014

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
B1	-1.416748	53.14827	131.57	B3	-1.415321	53.14684	153.18
B2	-1.41576	53.14770	146.19	B4	-1.414903	53.14597	156.42

B6014 receptor data

Morton Road/Stretton Road/B6014

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
C1	-1.41418	53.14448	154.73	C16	-1.39445	53.13821	139.50
C2	-1.41288	53.14406	152.50	C17	-1.39345	53.13754	141.29
C3	-1.41146	53.14378	147.50	C18	-1.39221	53.13705	142.25
C4	-1.41010	53.14340	140.64	C19	-1.39085	53.13678	140.08
C5	-1.40880	53.14295	139.50	C20	-1.38936	53.13677	135.25
C6	-1.40750	53.1425	139.50	C21	-1.38786	53.13671	133.06
C7	-1.40621	53.14204	139.50	C22	-1.38636	53.13674	131.50
C8	-1.40491	53.14159	139.50	C23	-1.38487	53.1368	126.27
C9	-1.40364	53.14111	139.50	C24	-1.38340	53.13698	122.63
C10	-1.40237	53.14063	140.78	C25	-1.38193	53.13716	119.50
C11	-1.40111	53.14015	139.59	C26	-1.38044	53.13726	114.43
C12	-1.40000	53.13955	140.21	C27	-1.37895	53.13736	111.57
C13	-1.39861	53.13921	140.25	C28	-1.37746	53.13746	109.77
C14	-1.39719	53.13893	139.89	C29	-1.37597	53.13756	110.42
C15	-1.39578	53.13862	139.16	C30	-1.37493	53.13763	111.50

Morton Road/Stretton Road/B6014 receptor data

Dwelling Receptor Data

The dwelling receptor data is presented in the table below. An additional 1.8m height has been added to the elevation to account for ground-floor views.

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	-1.41237	53.15151	152.66	51	-1.39667	53.13999	141.60

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
2	-1.41234	53.15129	152.80	52	-1.39617	53.14028	141.80
3	-1.41282	53.15111	153.80	53	-1.39567	53.14053	141.80
4	-1.41229	53.15078	152.80	54	-1.39519	53.14079	141.80
5	-1.41282	53.15062	153.80	55	-1.39467	53.14116	141.80
6	-1.41248	53.15029	152.80	56	-1.39440	53.14095	141.80
7	-1.41256	53.14978	153.45	57	-1.39409	53.14065	141.25
8	-1.41257	53.14942	153.80	58	-1.39361	53.14089	140.80
9	-1.41359	53.14942	156.70	59	-1.39354	53.14065	140.80
10	-1.41263	53.14909	155.27	60	-1.39332	53.14044	139.73
11	-1.41307	53.14867	157.84	61	-1.39308	53.14018	139.67
12	-1.41345	53.1483	160.48	62	-1.39274	53.13986	139.58
13	-1.41372	53.14807	161.80	63	-1.39252	53.13949	140.08
14	-1.41447	53.14803	160.86	64	-1.39265	53.13897	140.29
15	-1.41442	53.14764	161.80	65	-1.39197	53.13874	141.53
16	-1.41482	53.14728	162.02	66	-1.39242	53.13794	141.80
17	-1.41473	53.14692	162.67	67	-1.39193	53.13759	141.80
18	-1.41355	53.14600	154.43	68	-1.39188	53.13715	142.02
19	-1.41330	53.14466	151.89	69	-1.39071	53.13659	139.18
20	-1.41460	53.14452	155.52	70	-1.39048	53.13732	140.93
21	-1.41394	53.14411	154.80	71	-1.38983	53.13758	140.80
22	-1.41645	53.14027	153.80	72	-1.38928	53.13802	137.93

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
23	-1.41648	53.13943	153.52	73	-1.38854	53.1378	136.81
24	-1.41608	53.13917	153.34	74	-1.38812	53.13726	135.85
25	-1.4153	53.13906	149.80	75	-1.38768	53.13687	133.69
26	-1.41475	53.13894	147.80	76	-1.38661	53.13692	131.80
27	-1.41414	53.13891	146.00	77	-1.38632	53.13739	132.80
28	-1.41380	53.13857	145.24	78	-1.38595	53.13744	132.15
29	-1.41335	53.14049	147.57	79	-1.38564	53.13729	131.55
30	-1.41232	53.14036	145.18	80	-1.38543	53.13691	129.69
31	-1.41285	53.13968	144.28	81	-1.38517	53.13658	127.26
32	-1.41127	53.13728	139.80	82	-1.38448	53.13668	124.93
33	-1.41087	53.13786	139.80	83	-1.38387	53.13676	124.28
34	-1.40228	53.14043	140.64	84	-1.38416	53.13720	125.63
35	-1.40210	53.14024	140.80	85	-1.38345	53.13727	123.73
36	-1.40264	53.13948	139.40	86	-1.38251	53.13696	121.80
37	-1.4021	53.13938	139.80	87	-1.38163	53.13699	119.80
38	-1.40183	53.13999	140.57	88	-1.38110	53.13712	116.98
39	-1.40142	53.14003	139.80	89	-1.38006	53.13711	113.91
40	-1.40102	53.13981	139.80	90	-1.37971	53.13741	113.96
41	-1.40048	53.1396	139.80	91	-1.37967	53.13780	114.80
42	-1.40050	53.13916	139.80	92	-1.37956	53.13825	114.80
43	-1.39955	53.13927	139.97	93	-1.37946	53.13867	114.88

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
44	-1.399	53.13914	140.74	94	-1.37935	53.13899	115.52
45	-1.39839	53.13902	140.37	95	-1.37951	53.13937	115.80
46	-1.39792	53.13893	140.20	96	-1.37987	53.13974	117.01
47	-1.39743	53.13882	139.87	97	-1.37567	53.14028	113.54
48	-1.39701	53.13906	140.45	98	-1.38030	53.14482	129.21
49	-1.39660	53.13898	140.26	99	-1.37342	53.14545	123.80
50	-1.39740	53.13966	140.87	100	-1.38707	53.14809	140.89

Dwelling receptor data

Railway Receptor Data

The railway receptor data is presented in the table below. An additional 2.75m height has been added to the elevation to account for the eye-level of a train driver.

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	-1.39242	53.15179	122.62	9	-1.38850	53.14506	138.64
2	-1.39221	53.15090	123.70	10	-1.38766	53.14432	136.16
3	-1.39193	53.15002	127.44	11	-1.38674	53.14360	132.75
4	-1.39157	53.14915	130.45	12	-1.38576	53.14292	133.20
5	-1.39113	53.14829	132.42	13	-1.38471	53.14228	132.75
6	-1.39058	53.14745	136.05	14	-1.38360	53.14167	127.87
7	-1.38997	53.14663	138.75	15	-1.38243	53.14111	123.16
8	-1.38927	53.14583	137.75	16	-1.38121	53.14059	120.96

Railway receptor data

Modelled Reflector Areas

The modelled reflector areas are presented in the tables below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.40184803	53.1443750	27	-1.39220456	53.1485984
2	-1.40284595	53.1437356	28	-1.39224449	53.1489344
3	-1.40286675	53.1436056	29	-1.39491791	53.1484537
4	-1.40307769	53.1432754	30	-1.39471002	53.1476294
5	-1.40036202	53.1424416	31	-1.39474797	53.1475593
6	-1.39972899	53.1430196	32	-1.39446712	53.1466128
7	-1.39637196	53.1419686	33	-1.39474549	53.1460951
8	-1.39481993	53.1419357	34	-1.39571436	53.1465335
9	-1.39501697	53.1426505	35	-1.39603606	53.1465699
10	-1.39468268	53.1427196	36	-1.39655828	53.1481192
11	-1.39307460	53.1423988	37	-1.39720584	53.1497102
12	-1.39109918	53.1421779	38	-1.39807753	53.1517725
13	-1.39113726	53.1418122	39	-1.39840066	53.1517481
14	-1.39090667	53.1413600	40	-1.40097154	53.1501561
15	-1.39101068	53.1411356	41	-1.40095072	53.1494092
16	-1.39061119	53.1409118	42	-1.40128696	53.1492782
17	-1.38875090	53.1410671	43	-1.40150547	53.1478183
18	-1.38725237	53.1434134	44	-1.40164378	53.1472773
19	-1.38783084	53.1439132	45	-1.40142974	53.1471710
20	-1.39055372	53.1460988	46	-1.40118188	53.1460543
21	-1.39219663	53.1468732	47	-1.40102521	53.1456844
22	-1.39231900	53.1470001	48	-1.39904733	53.1455830
23	-1.39209749	53.1472012	49	-1.39831286	53.1454207

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
24	-1.39105594	53.1467831	50	-1.39737051	53.1449555
25	-1.39187433	53.1481108	51	-1.39893588	53.1434761
26	-1.39198614	53.148168	52	-1.40184803	53.1443750

Panel Area

APPENDIX H – DETAILLED MODELLING RESULTS

Overview

The Pager Power charts for selected receptors are shown on the following pages. Further modelling charts can be provided upon request. Each chart shows:

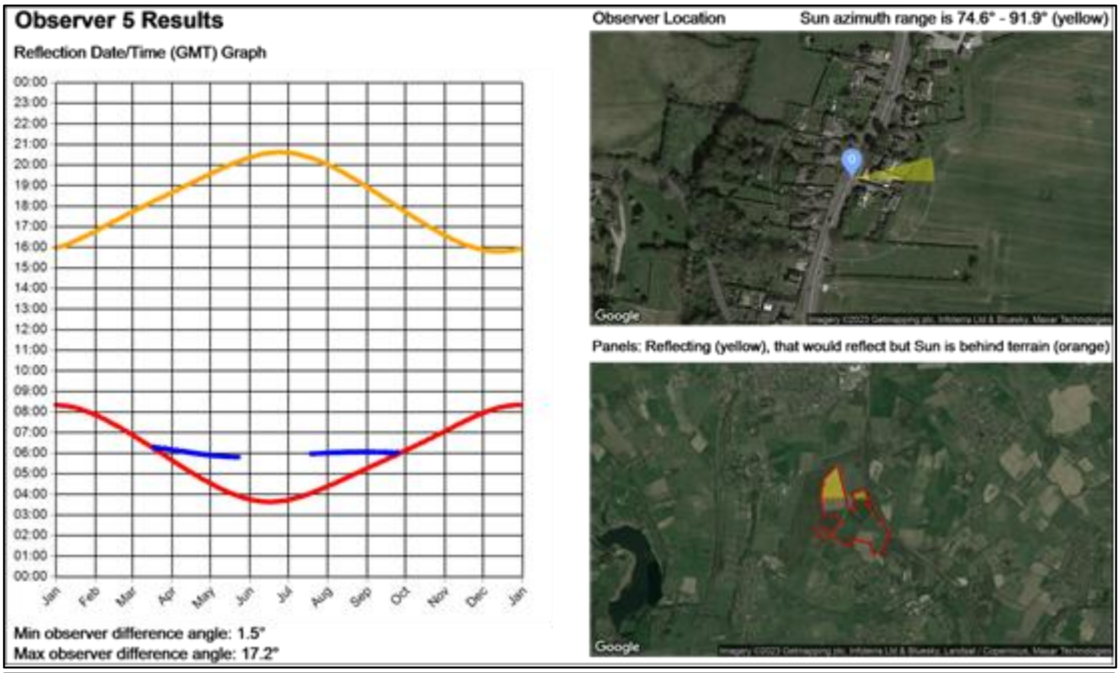
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting panels – bottom right image. The reflecting area is shown in yellow. If the yellow panels are not visible from the observer location, no issues will occur in practice. Additional obstructions which may obscure the panels from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of image. 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).

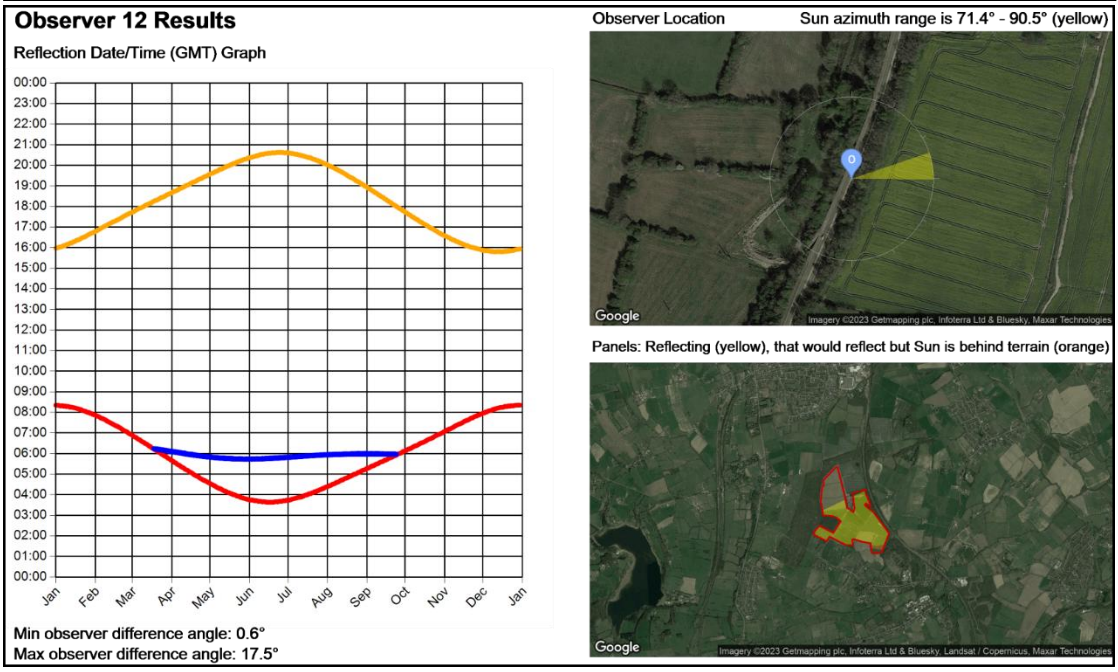
Full modelling results can be provided upon request.

Road Receptors

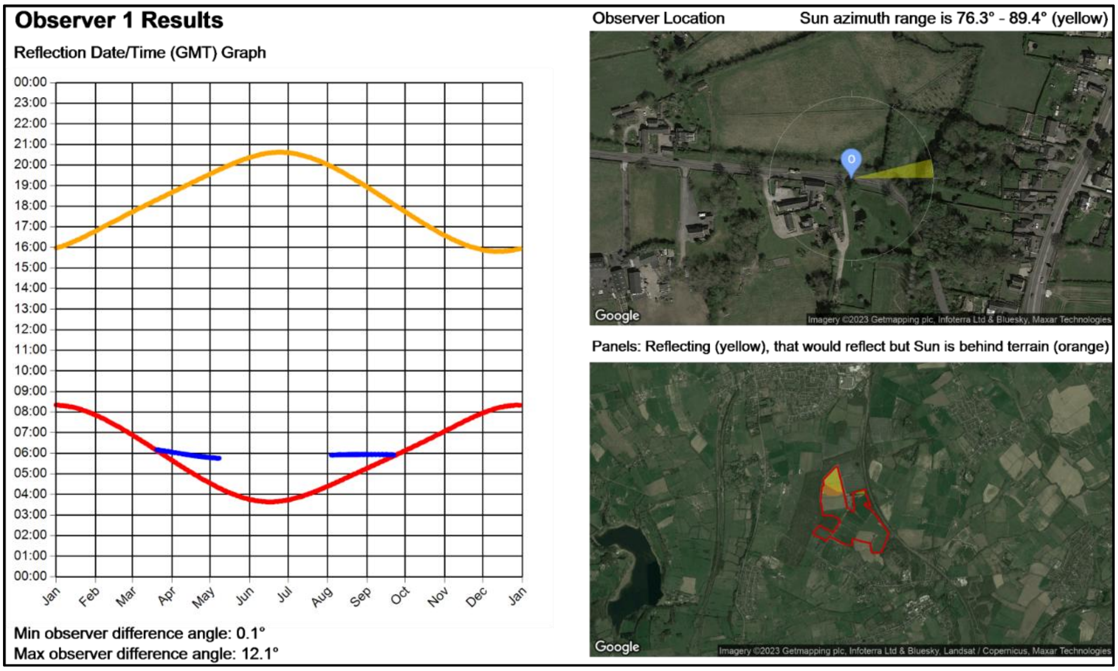
Results have been included for a selection of road receptors to show a range of representative results.

A61

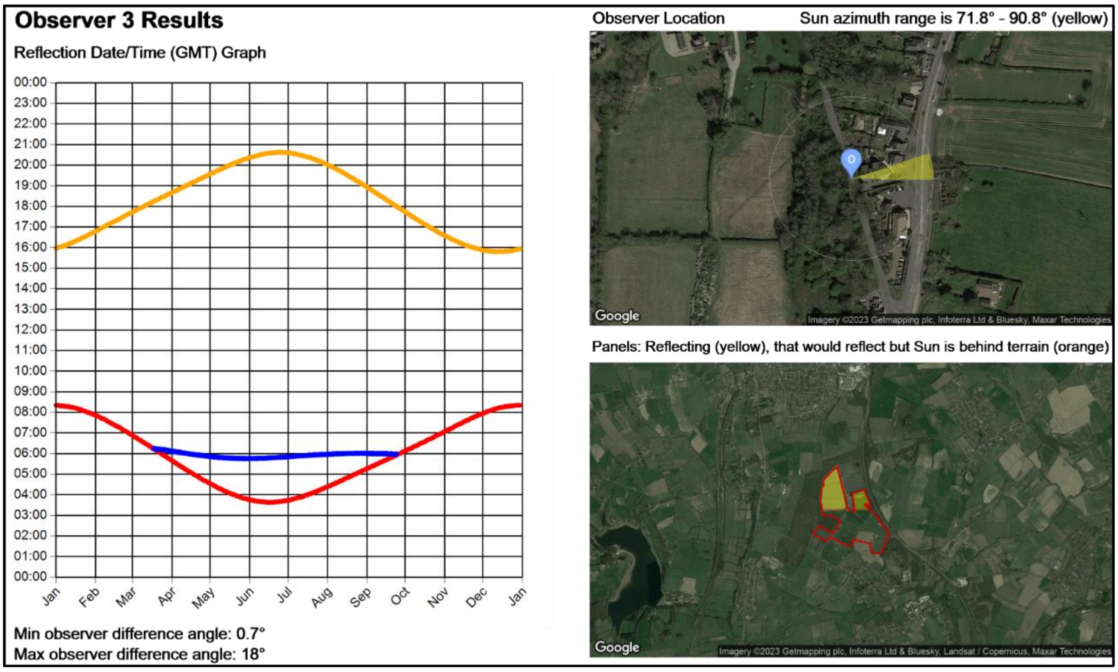




B6014

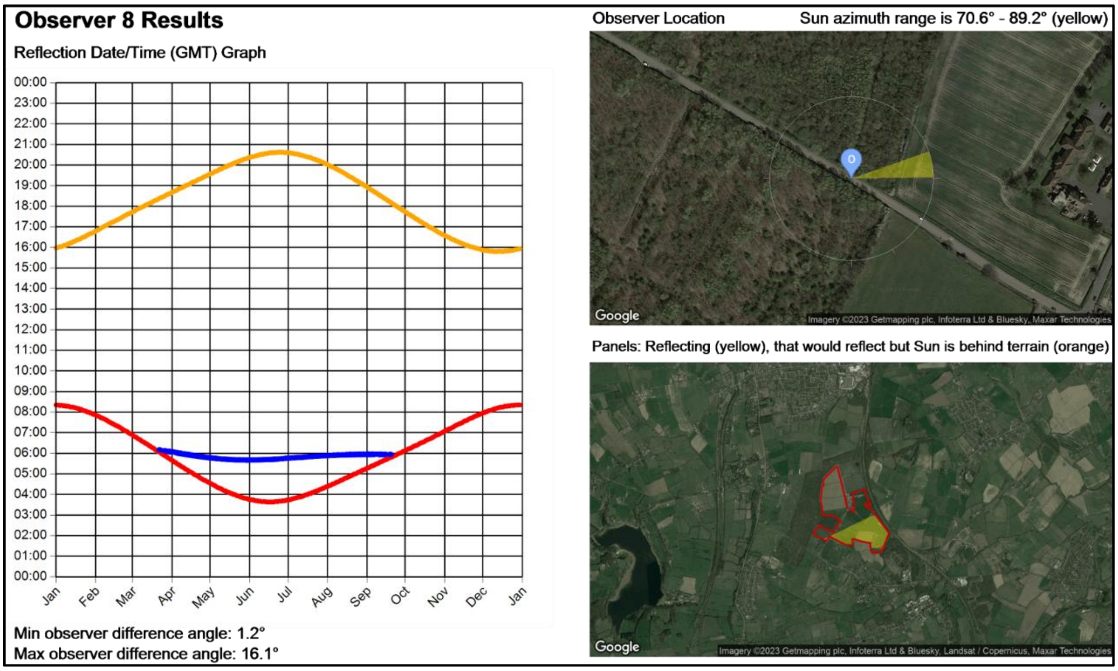


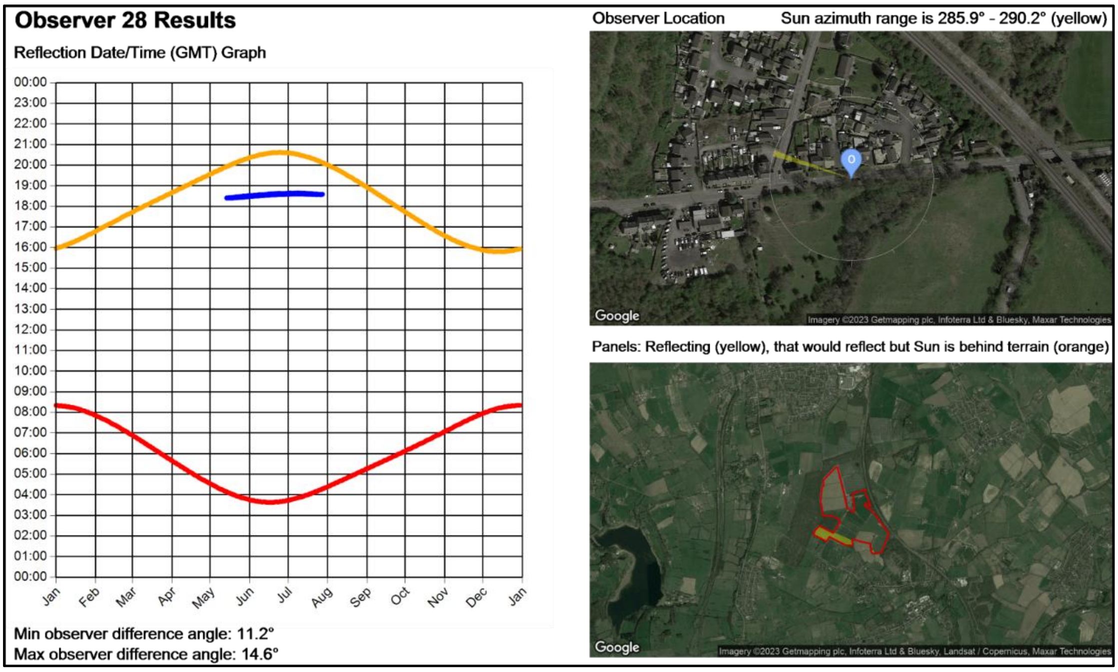
Observer 1 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 76.3° - 89.4° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Min observer difference angle: 0.1°
Max observer difference angle: 12.1°



Observer 3 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 71.8° - 90.8° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Min observer difference angle: 0.7°
Max observer difference angle: 18°

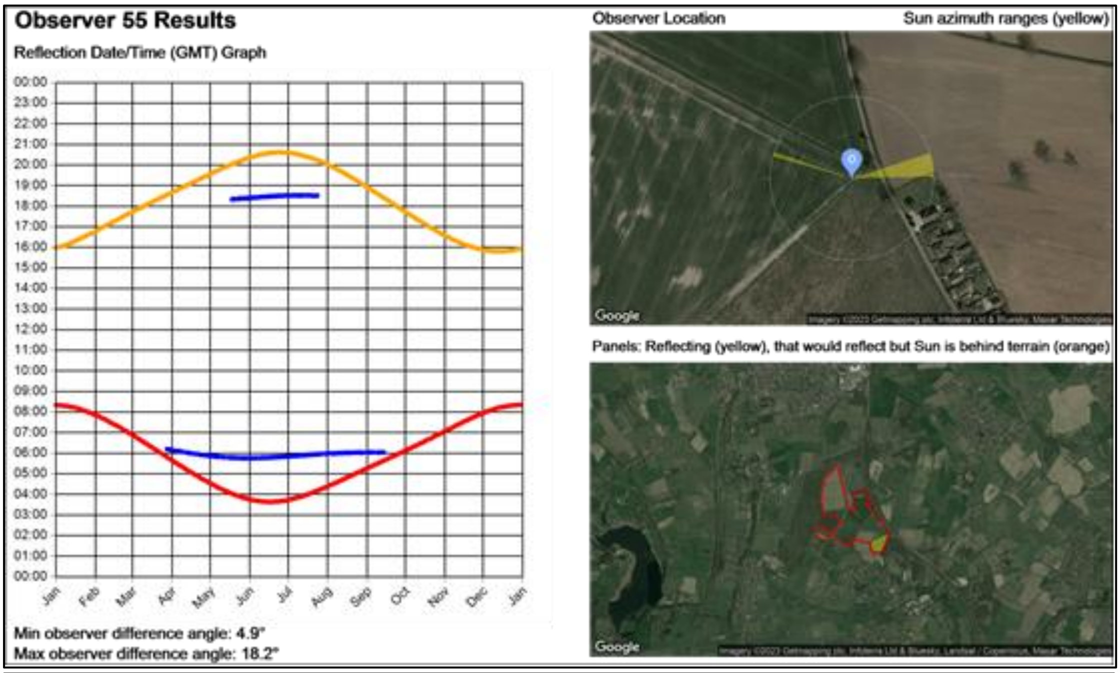
Morton Road/Stretton Road/B6014

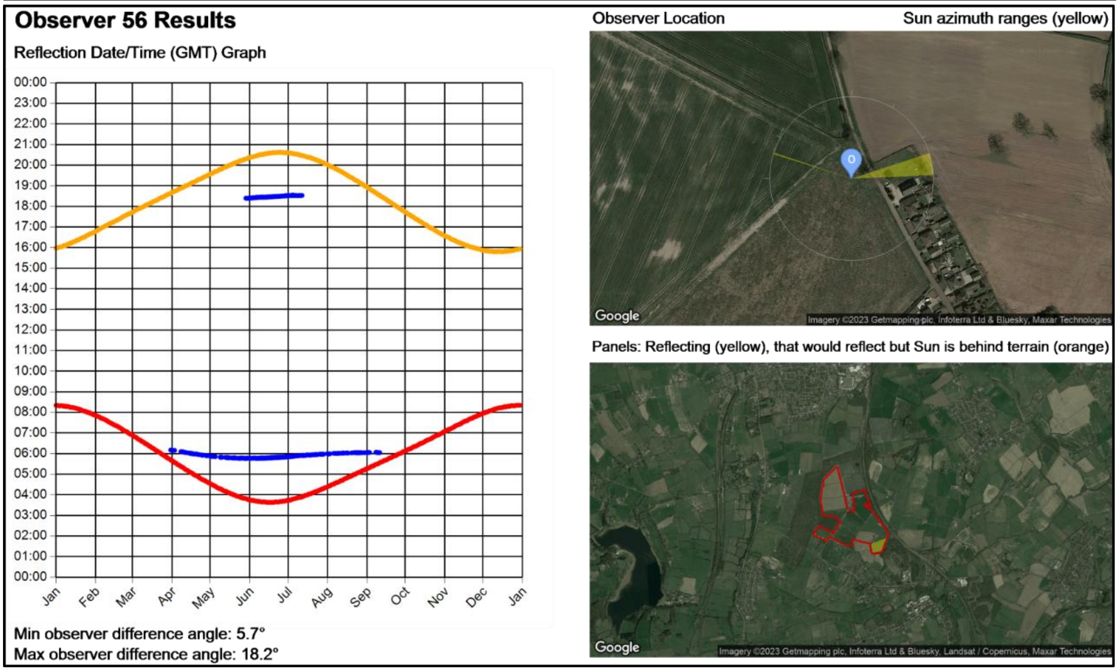




Dwelling Receptors

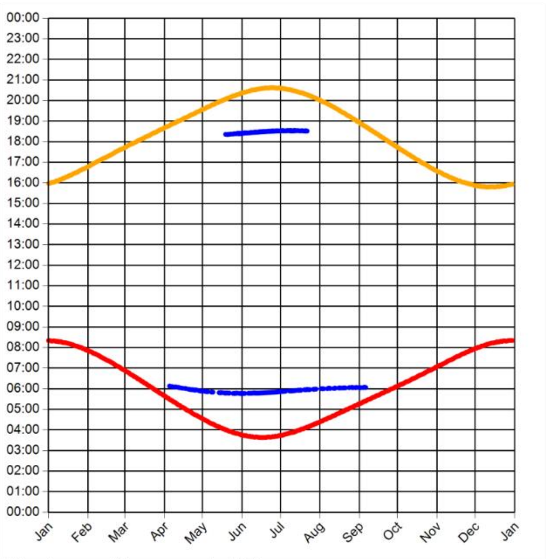
Results of dwelling receptors for which a moderate impact is predicted have been shown.





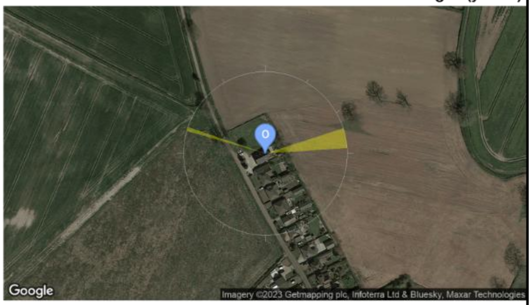
Observer 58 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 7.3°
Max observer difference angle: 18.2°

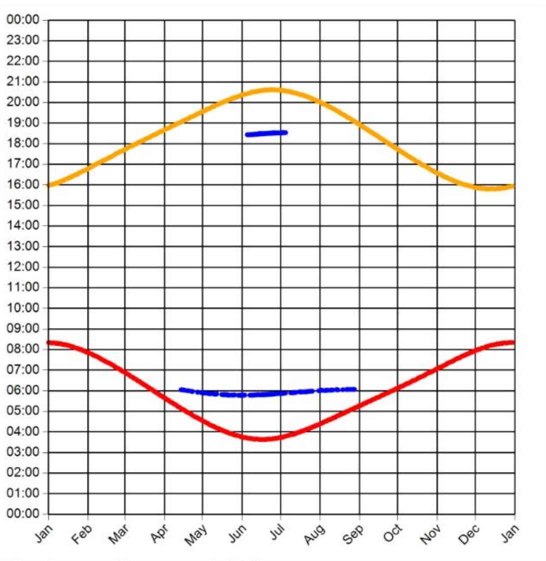
Observer Location | Sun azimuth ranges (yellow)



Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

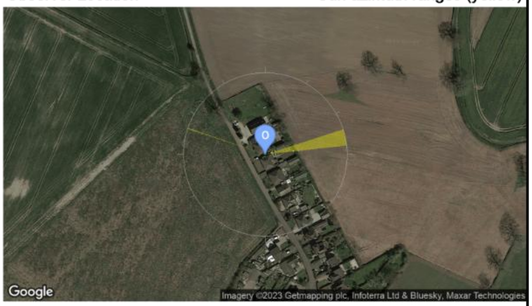
Observer 59 Results

Reflection Date/Time (GMT) Graph

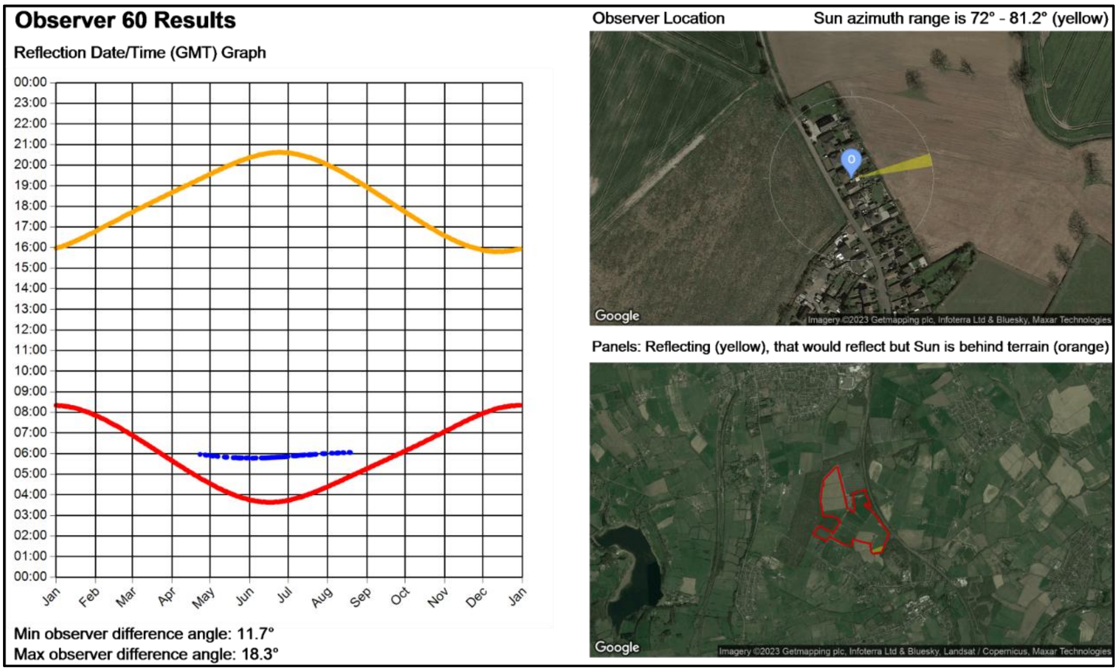


Min observer difference angle: 9.7°
Max observer difference angle: 18.6°

Observer Location | Sun azimuth ranges (yellow)



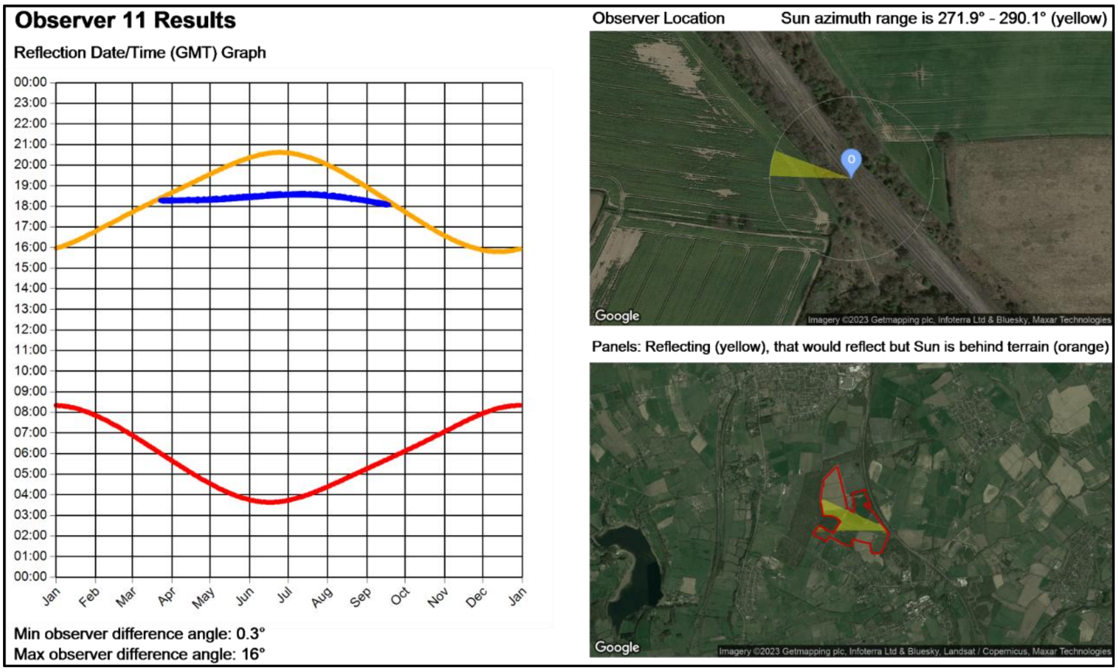
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

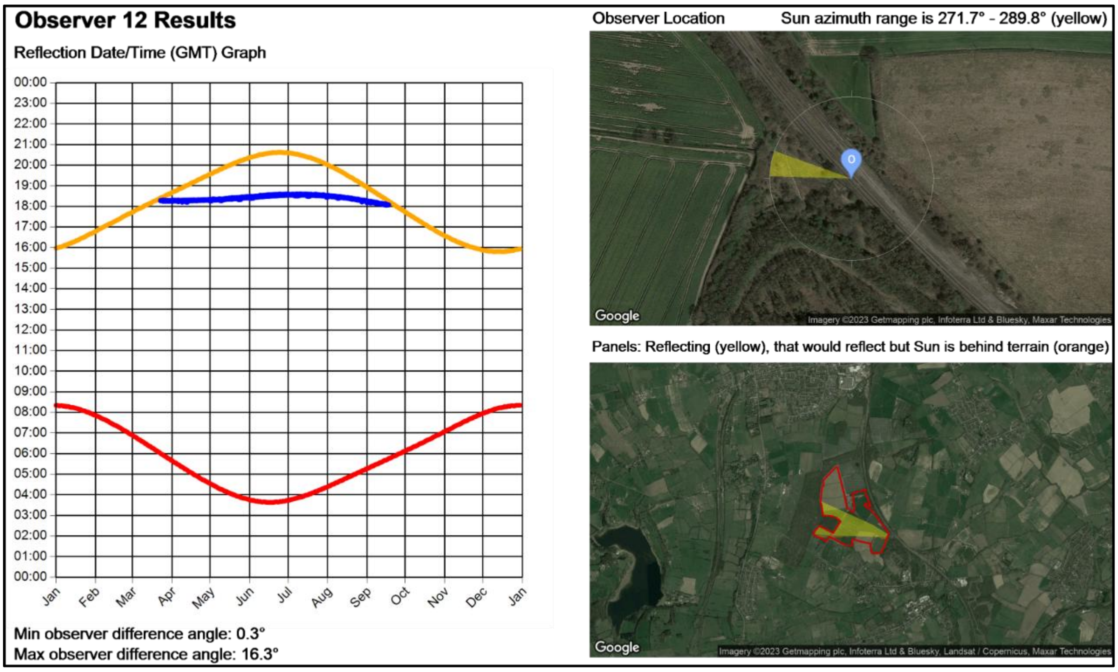


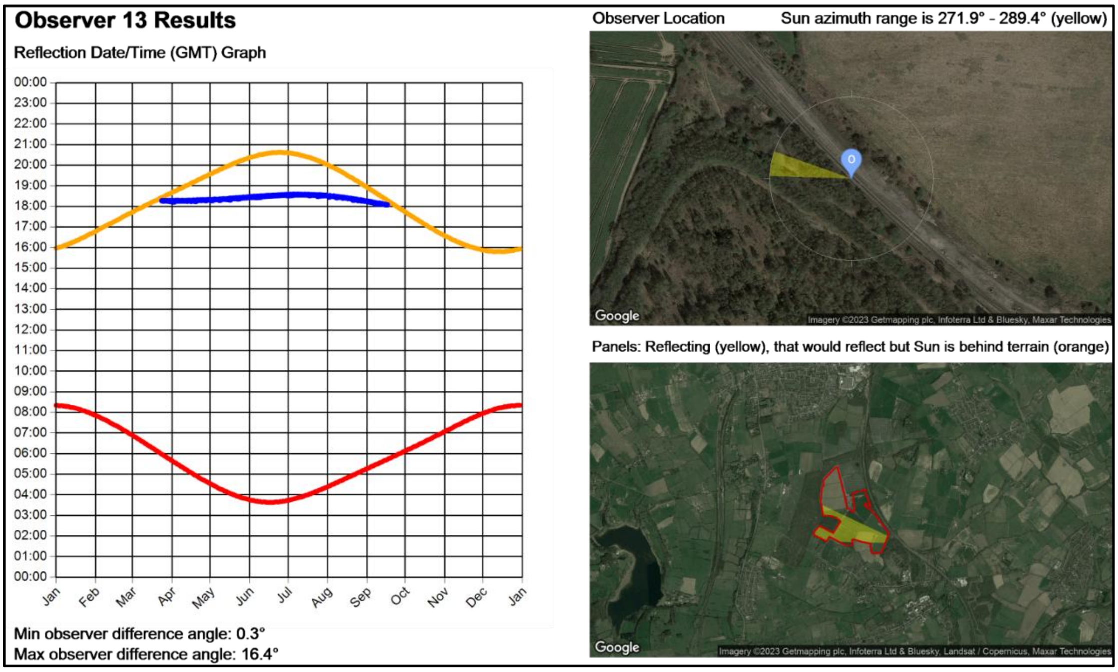
Observer 60 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 11.7°
Max observer difference angle: 18.3°
Observer Location
Sun azimuth range is 72° - 81.2° (yellow)
Google
Imagery ©2023 Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2023 Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies

Railway Receptors

Selective results are presented to show a range of results.






Observer 13 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.3°
Max observer difference angle: 16.4°
Observer Location
Sun azimuth range is 271.9° - 289.4° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

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