Craig Y Perthi Solar Farm Resubmission

Environmental Statement

Appendix 3.1 Glint and Glare Study

Prepared for

RWE Renewables UK

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PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

RWE Renewables

Craig Y Perthi

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ADMINISTRATION PAGE

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Issue	Date	Detail of Changes
1	November 2022	Initial issue
2	December 2022	Inclusion of landscape plan
3	May 2023	Layout change
4	August 2023	Updated technical modelling
5	March 2024	Administrative amendments
6	June 2026	Assessment of updated layout

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the potential effects of glint and glare from a solar photovoltaic (PV) development located near Underwood, Newport, Wales. The assessment pertains to the potential impact upon surrounding residential amenity, road safety, and railway operations and infrastructure.

Overall Conclusions

No significant impacts are predicted upon road safety, residential amenity and railway operations and infrastructure in the surrounding area. No further mitigation is recommended.

Guidance and Studies

Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the fourth edition originally published in 2022[1]. The guidance document sets out the methodology for assessing road safety, residential amenity, and railway operations and infrastructure with respect to solar reflections from solar panels.

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

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[2].

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

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

Assessment Conclusions – Train Drivers and Signal Sighting

Solar reflections are geometrically possible towards 3.3km of assessed railway track.

Reflections are predicted to occur within a train driver's primary field-of-view (30° either side of the direction of travel) along the assessed railway track. Some locations on these sections will require sight of a signal, but reflections are not predicted to occur directly behind a signal relative to a train driver, therefore signal sighting will not be significantly impacted.

The solar reflections are not predicted to cause significant visual discomfort and therefore a distraction for a train driver. Workload of train drivers is not predicted to change compared to the existing condition.

Overall, no significant impacts are predicted. Whilst a solar reflection from the development could be experienced by train drivers, solar reflections from the development are not expected to affect the safety of railway operations. Mitigation is not recommended.

Assessment Conclusions – Railway Signals

Solar reflections are geometrically possible towards all 10 of the modelled railway signals.

For signals NT 1043, NT 1046 and NT 1248, solar reflections are predicted to occur from outside 90° either side of the signal orientation. As a result, no reflections are predicted to reach the signal and the risk of phantom aspect illusion is low. No significant impacts are predicted, and no mitigation is recommended.

For the remaining seven signals, reflections occur from in front of the signal. The signal hood and vegetation screening is predicted to obstruct the majority of reflections. Additionally, all reflections occur from at least 300m away and/or 5° from the direction the signal faces. No significant impacts are predicted, and no mitigation is recommended.

Assessment Conclusions – Road Safety

The table below summarises the predicted impact upon the assessed road receptors.

Number of road receptors assessed	23 (approximately 2,000m)
Number of road receptors where a solar reflection is geometrically possible	15
Number of road receptors predicted to experience no impact due to significant screening or mitigating factors	12
Number of road receptors predicted to experience a low impact due to significant screening or mitigating factors	3

Summary of assessment results for road receptors

Assessment Conclusions – Residential Amenity

The table below summarises the predicted impact upon the assessed dwelling receptors.

Number of dwelling receptors assessed	95
Number of dwelling receptors where a solar reflection is geometrically possible	93
Number of dwelling receptors predicted to experience no impact due to significant screening or mitigating factors	86
Number of dwelling receptors predicted to experience a low impact due to significant screening or mitigating factors	7

Summary of assessment results for dwelling receptors

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ABOUT PAGER POWER

Pager Power is a specialist technical consultancy based in the United Kingdom and has been providing independent expertise on planning issues for solar, wind, and building developments for over 20 years.

Established in 1997, the company initially specialised in assessing the impact of wind turbines on radar systems. Pager Power has since expanded into a multidisciplinary technical planning consultancy that offers a comprehensive range of services and has supported renewable and building projects in more than 60 countries.

Pager Power's core competencies now include:

- Aviation and Radar;
- Daylight, Sunlight and Overshadowing;
- Glint and Glare;
- Shadow Flicker;
- Telecommunications.

Using proprietary modelling software, each study is tailored to the individual project, ensuring that results are relevant, defensible, and aligned with current national and international standards. The company also provides planning support and stakeholder consultation across all service areas, helping clients to understand constraints, explore potential mitigation options, and forge a path forward for their projects.

Pager Power's work helps our clients identify potential risks, inform project design, and support the decision-making process, and can provide support at any stage of a project, from initial feasibility through to completion. Pager Power's assessments – recognised for their objectivity, accuracy, and technical integrity – are designed to withstand legal scrutiny, and trusted by developers and stakeholders alike.

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the potential effects of glint and glare from a solar photovoltaic (PV) development located near Underwood, Newport, Wales. The assessment pertains to the potential impact upon surrounding residential amenity, road safety, and railway operations and infrastructure.

This report contains the following:

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

1.2 Pager Power's Experience

Pager Power has undertaken over 1,800 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:

- 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.

These definitions are aligned with those presented within the National Policy Statement for Renewable Energy Infrastructure (EN-3)[3] and the Federal Aviation Administration in the USA.

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

[3] Published by the Department for Energy Security and Net Zero in December 2025.

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Location Plan

Figure 1 below shows the site location plan[4].

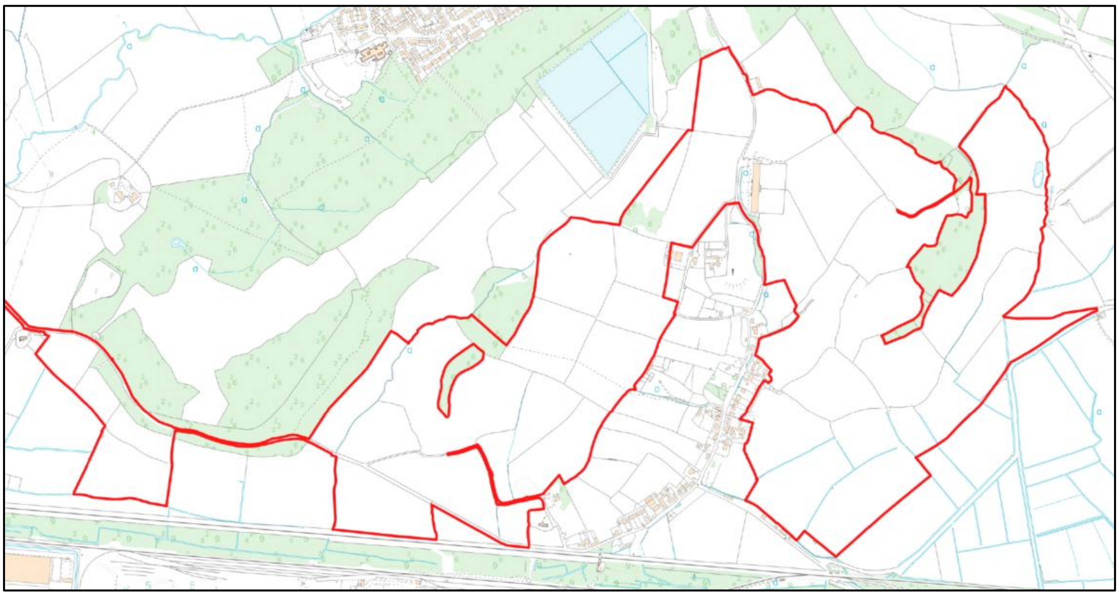

Figure 1 *Site location plan*

2.1 Proposed Development Landscape Plan

Figure 2 on the following page shows the proposed landscape plan[5]. The blue polygons denote the solar panel locations.

[4] Source: Figure 1 - Location Plan.pdf (Cropped).

[5] Source: Figure 2 - Indicative Landscape Masterplan.pdf (Cropped).

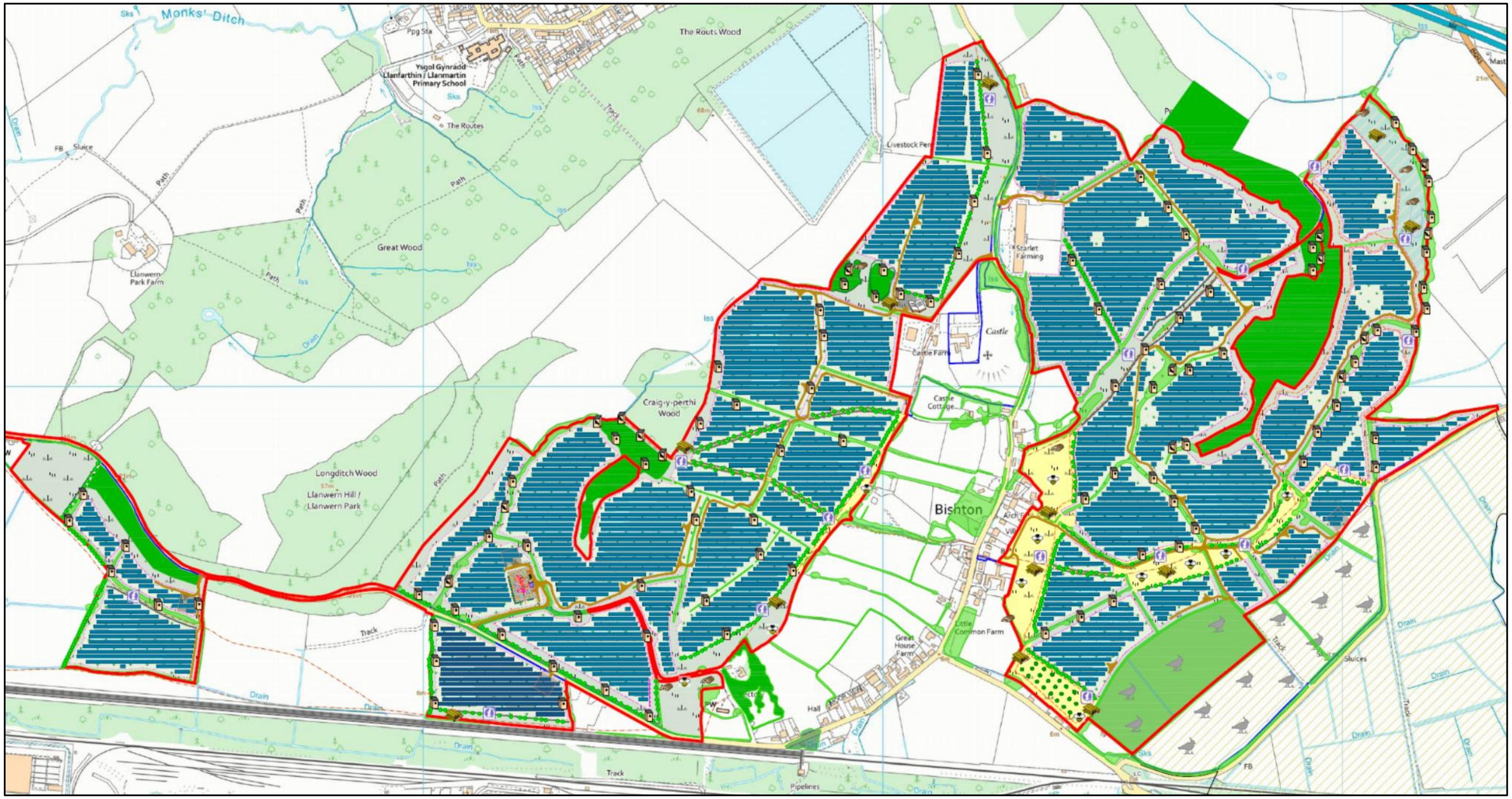

Figure 2 *Proposed landscape plan*

2.2 Proposed Development Reflector Areas

The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G. The assessed panel areas (blue polygons) are shown in Figure 3 below, overlaid onto aerial imagery.

Figure 3 *Modelled reflector areas*

A resolution of 20m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 20m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results, increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution.

2.3 Photovoltaic Panel Mounting Arrangements and Orientation

The solar panel dimensions as assessed within this report are as follows:

- The maximum height of the solar panels is 3m above ground level (agl) and the minimum height of the solar panels is 0.8m agl - assessed at a panel midpoint of 1.9m agl;
- Tilt: 18 degrees above the horizontal;
- Orientation: 180 degrees (south facing).

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Pager Power's Methodology

3.3.1 Pager Power's Methodology

The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance and studies. The methodology for a glint and glare assessments 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 Appendices E and F.

4 RAILWAY ASSESSMENT METHODOLOGY

4.1 Overview

A railway stakeholder, such as Network Rail, may request further information regarding the potential effects of glint and glare from reflective surfaces when a development is located adjacent to a railway line (typically 50-100m from its infrastructure). The request may depend on the scale, percentage of reflective surfaces and the complexity of the nearby railway, for example.

The following section presents details regarding the most common concerns relating to glint and glare.

4.2 Disability Glare for Railway Considerations

Glare can also be categorised as causing visual discomfort whereby an observer would instinctively look away, or cause disability, and objects become difficult to see. The guidance produced by the Commission Internationale de L'Eclairage (CIE) describes disability glare as:

> *'Disability glare is glare that impairs vision. It is caused by scattering of light inside the eye…The veiling luminance of scattered light will have a significant effect on visibility when intense light sources are present in the peripheral visual field and contrast of objects is seen to be low.'*
>
> *'Disability glare is most often of importance at night when contrast sensitivity is low and there may well be one or more bright light sources near to the line of sight, such as car headlights, streetlights, or floodlights. But even in daylight conditions disability glare may be of practical significance: think of traffic lights when the sun is close to them, or the difficulty viewing paintings hanging next to windows.'*

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

4.3 Guidance and Studies

Appendix A presents a review of planning and rail guidance, and Appendix B presents independent studies with regard to glint and glare issues. The following key findings are relevant:

- Studies have measured the intensity of solar reflections from various naturally occurring and manmade surfaces such as solar panels and glass;
- Specular reflections from glass and solar panels are possible, with the incoming light reflected in a particular direction relative to the angle of incidence;
- The results show that the solar reflections from glass are similar to those from solar panels and are slightly more intense than those from still water but significantly less than those from steel.

4.4 Common Concerns and Signal Overview

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

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

With respect to point 1, a reflective façade could produce solar reflections towards a train driver. If this reflection occurs where a railway signal, crossing etc., is present, where the driver's workload is particularly high, or in a scenario where contrast sensitivity is low, the solar reflection may affect operations. This is deemed to be the most concern with respect to solar reflections.

Following on 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 on the following page:

> *'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.*[6]*'*

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

- An LED railway signal produces a more intense light making them more visible to approaching trains when compared to the traditional filament bulb technology[7].

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

4.5 Methodology and Consultation

The railway glint and glare assessment methodology has been based on Pager Power's experience within the UK following previous consultation with Network Rail.

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[6] Source: Glossary of Signalling Terms, Railway Group Guidance Note GK/GN0802. Issue One. Date April 2004.
[7] Source: Wayside LED Signals – Why it's Harder than it Looks, Bill Petit.

Details of the Sun's movements at the development location are presented in Appendix C and details of the modelling approach itself are presented in Appendix E.

The general methodology for this glint and glare assessment is as follows:

1. Identify the receptors of concern. In this instance, the concern is reflections of the Sun from the reflecting panels towards surrounding railway receptors (potential signal and train driver locations) within 500 metres of the development;
2. Choose appropriate receptor locations;
3. Define the reflectors for the development and choose an appropriate assessment resolution;
4. Undertake geometric calculations[8] to determine whether a solar reflection may occur from a defined reflector area, and if so, when it will occur;
5. If a reflection can occur, determine whether the modelled reflectors will be visible from the identified receptor locations;
6. Consider the above together with the solar reflection's location of origin with respect to the location of the Sun in the sky, its angle above the horizontal and the time of day at which a solar reflection could occur;
7. If a scenario is possible which presents the potential for a significant solar reflection, calculate the intensity of the solar reflection;
8. Determine whether the solar reflection is likely to be a significant hazard or nuisance, factoring in all of the above;
9. Consider mitigation, if appropriate.

4.6 Railway Specific Criteria

The specific parameters for a railway glint and glare assessment are presented below:

- Whether the solar reflection originates within a train driver's primary field-of-view, defined as 30 degrees either side of the railway line with respect to the direction of travel;
- The contrast of sensitivity, considering a low sensitivity is where disability glare is more likely to occur;
- The reflecting area compared to the façade as a whole, with a significant area considered more than 50%;
- Solar reflections occurring towards a significant section of railway line where, for example:
    - A point of multiple lines with switch points;
    - At a station;

[8] Within the model, the development reflector area is defined, as well as the relevant receptor locations. The result is a chart that states whether a reflection can occur considering the location of the Sun throughout a given year and the duration of the solar reflection towards the receptor.

    - Signals being present;
    - Road or pedestrian crossings being present.
- The duration of the solar reflection;
- If the development in keeping with those around it and near to the assessed railway line.

4.7 Assumptions and Limitations

Key assumptions and limitations regarding the analysis in this report are listed below:

- Screening at the site boundary or anywhere between the railway line and the development is not included within the modelling output – which considers only the relative heights and geometric relationship between the Sun and the modelled reflectors;
- The assessment assumes that a view of the entire reflector area is possible from the receptor location when in reality this may not occur. A solar reflection can only be experienced by a receptor where the source of the reflection is visible;
- The modelling is output is therefore conservative and further interpretation of the results is required to provide a more accurate result and determine any impact.

Further assumptions and limitations are presented in Appendix E.

5 IDENTIFICATION OF RECEPTORS

5.1 Overview

The following sections present the relevant receptors assessed within this report. Terrain data has been interpolated based on Ordnance Survey (OS) 50 Digital Terrain Model (DTM) data. The receptor details for all receptors are presented in Appendix G.

5.2 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.

The above parameters and industry experience over a significant number of glint and glare assessments undertaken show that a 1km assessment area from the proposed development is considered appropriate for glint and glare effects on road users and dwellings, and a 500m assessment area for railway infrastructure.

Potential receptors within the associated assessment area are identified based on mapping and aerial photography of the region. The initial judgement is made based on high-level consideration of aerial photography and mapping i.e. receptors are excluded if it is clear from the outset that no visibility would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible. 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[9].

Figure 4 on the follow page shows the 1km assessment area (red) for roads users and dwellings and the 500m assessment area (cyan) for railway.

[9] For fixed, south-facing panels at this latitude.

Figure 4 *Assessment areas, 1km (red) and 500m (cyan)*

5.3 Train Driver Receptors

5.3.1 Overview

The analysis has considered train driver receptors that:

- Are within the 500-metre assessment area;
- Have a potential view of the development.

5.3.2 Identified Receptors

One section of track, approximately 3,300m, has been identified within the 500m assessment area. Receptors are placed approximately 100m apart, with an additional height of 2.75m above rail level, which is used to model the eye-level[10] of train drivers based on previous consultation with Network Rail.

Figure 5 on the following page shows the section of railway and the modelled train driver receptors.

[10] This fixed height for the train driver receptors is for modelling purposes. Small changes to the modelling height by a few metres is not expected to significantly change the modelling results.

Figure 5 *Rail driver receptors*

5.4 Railway Signals

5.4.1 Railway Signal Overview

The analysis has considered railway signals that are within the 500m assessment area and have a potential view of the reflecting panels.

Railway signals, including assets of Network Rail, are identified from the available imagery, including AIVR imagery. This report can be updated following further signals and assets identified by Network Rail.

The height[11] above ground level (agl) for a trackside signal is 3.3m[12].

5.4.2 Identified Railway Signals

Table 1 below shows the details of the identified signals.

Railway Signal receptor	Signal Type	Direction Signal Is Facing
NT 1042	Trackside	West
NT 1043		East
NT 1044		West
NT 1045		East
NT 1246		West
NT 1247		East
NT1046		West
NT 1047		East
NT1248		West
NT1249		East

Table 1 *Signal identification*

Figures 6 to 9 on the following pages shows the location of the signal receptors in relation to the proposed development. The white arrows denote the direction the signals are facing.

[11] Consultation undertaken with Network Rail in the UK.

[12] This fixed height for the railway signals is for modelling purposes. Small changes to the modelled signal height, within a few metres, is not expected to significantly change the modelling results. The coordinate location of a signal relative to the reflector area is a significant factor.

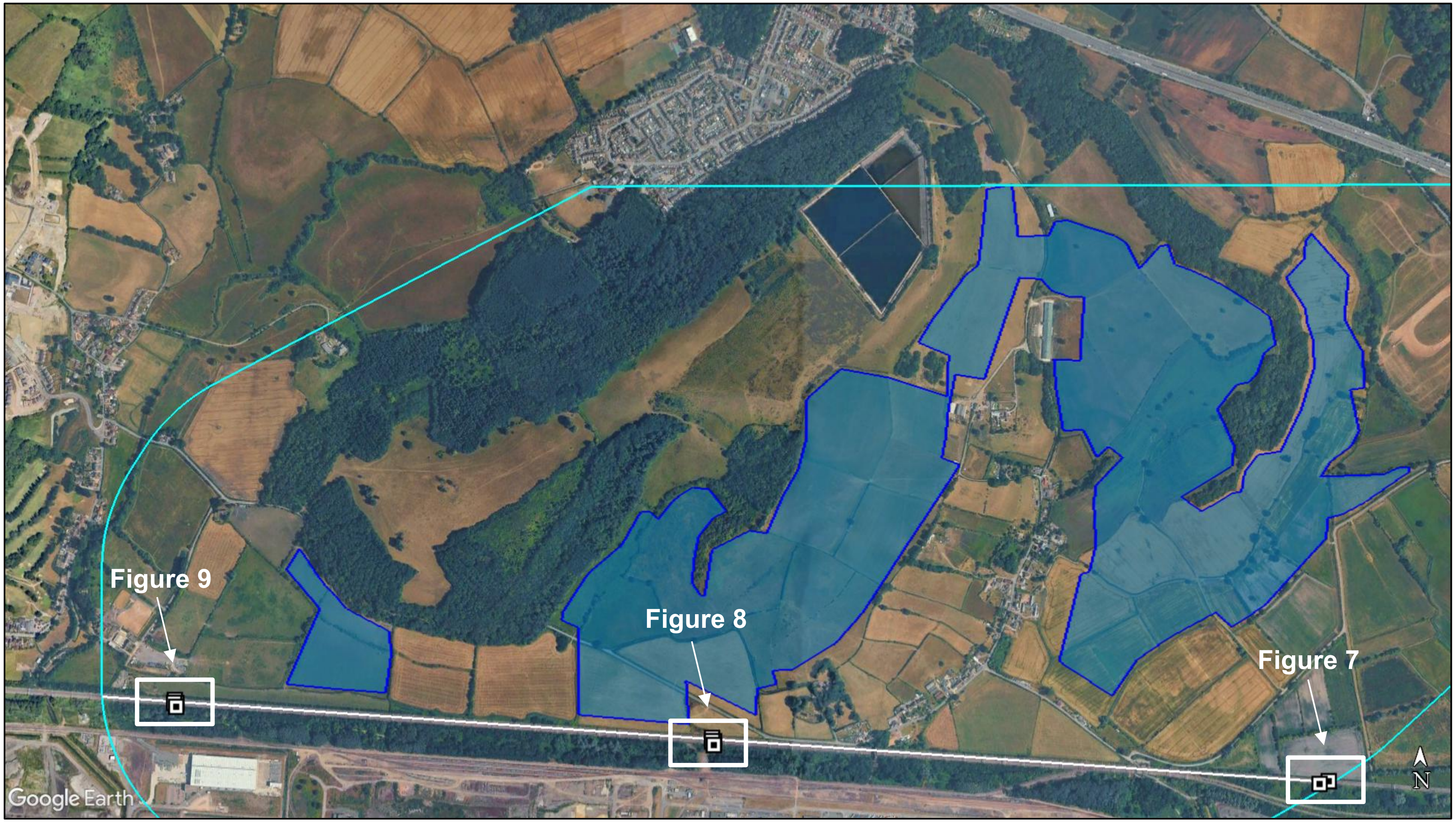

Figure 6 *Rail signal receptors overview*

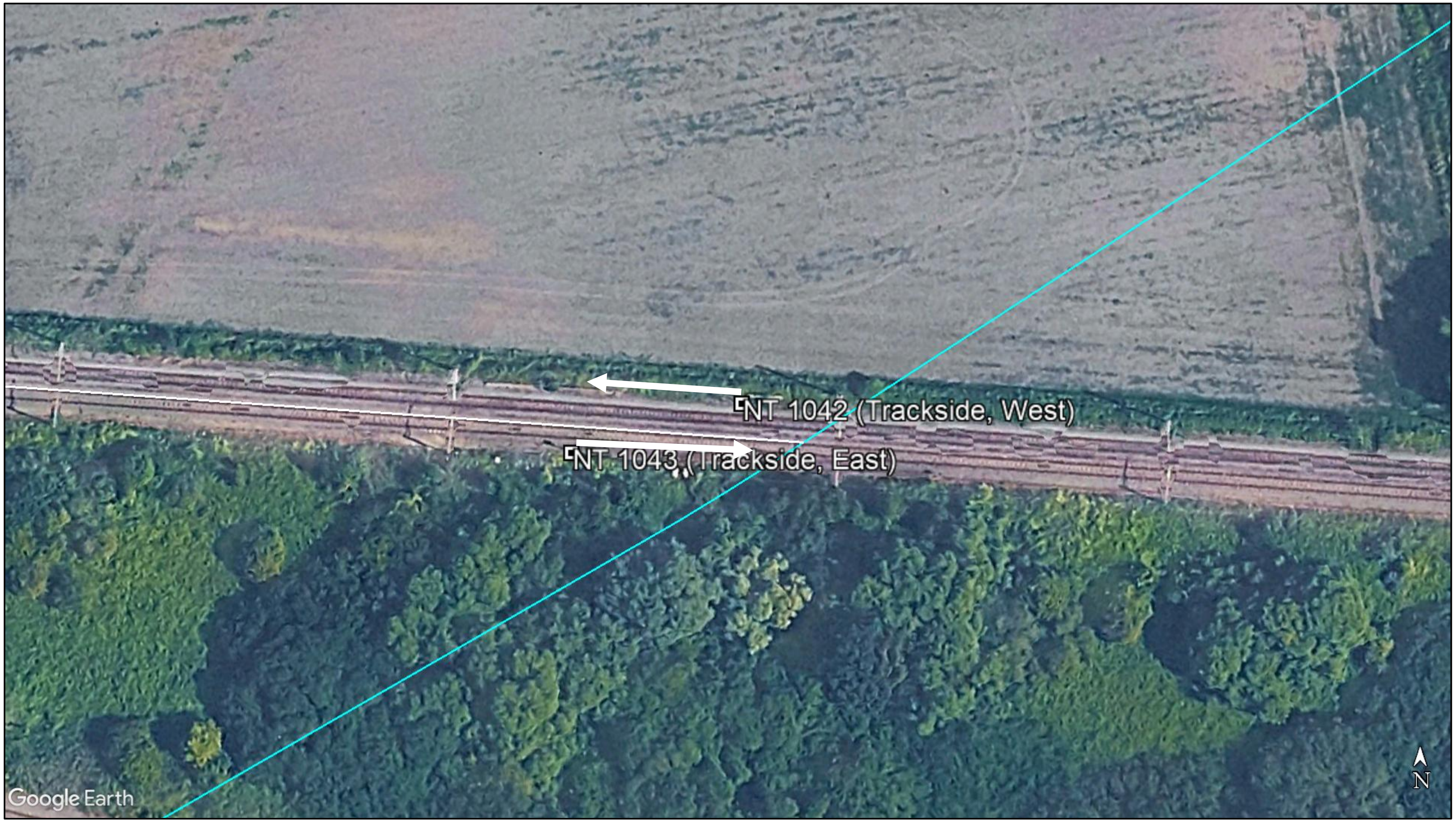

Figure 7 *Rail signal receptors NT 1042 and NT 1043*

Figure 8 *Railway signal receptors NT 1044, NT 1246, NT 1045 and NT 1247*

Figure 9 *Railway signal receptors NT 1046, NT 1047, NT 1248 and NT 1249*

5.5 Dwelling Receptors

5.5.1 Overview

The analysis has considered dwellings that:

- Are within the one-kilometre assessment area;
- Have a potential view of the panels.

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

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.

5.5.2 Identified Receptors

95 dwelling receptors have been identified within the assessment area, which are shown in Figure 10 on the following page. 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. Small changes to this height are not significant, and views above the ground floor considered are considered where appropriate within the analysis following geometric modelling.

Figure 10 *Assessed dwelling receptors – aerial image*

5.6 Road Receptors

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

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

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

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

5.6.2 Identified Receptors

A 0.8km section of the M4 (receptors 1-10), and a 1.2km section of the B4245 (receptors 11-23) have been identified within the assessment area, shown in Figure 11 on the following page.

A height of 1.5 metres above ground level has been taken as typical eye level for a road user[13]. The distance between road receptors is circa 100m.

All other roads within the assessment area have either been determined to be local roads, or that view of the proposed development are not predicted from them, and thus have not been taken forward for technical modelling

[13] Views of an elevated driver are considered within the results discussion where appropriate.

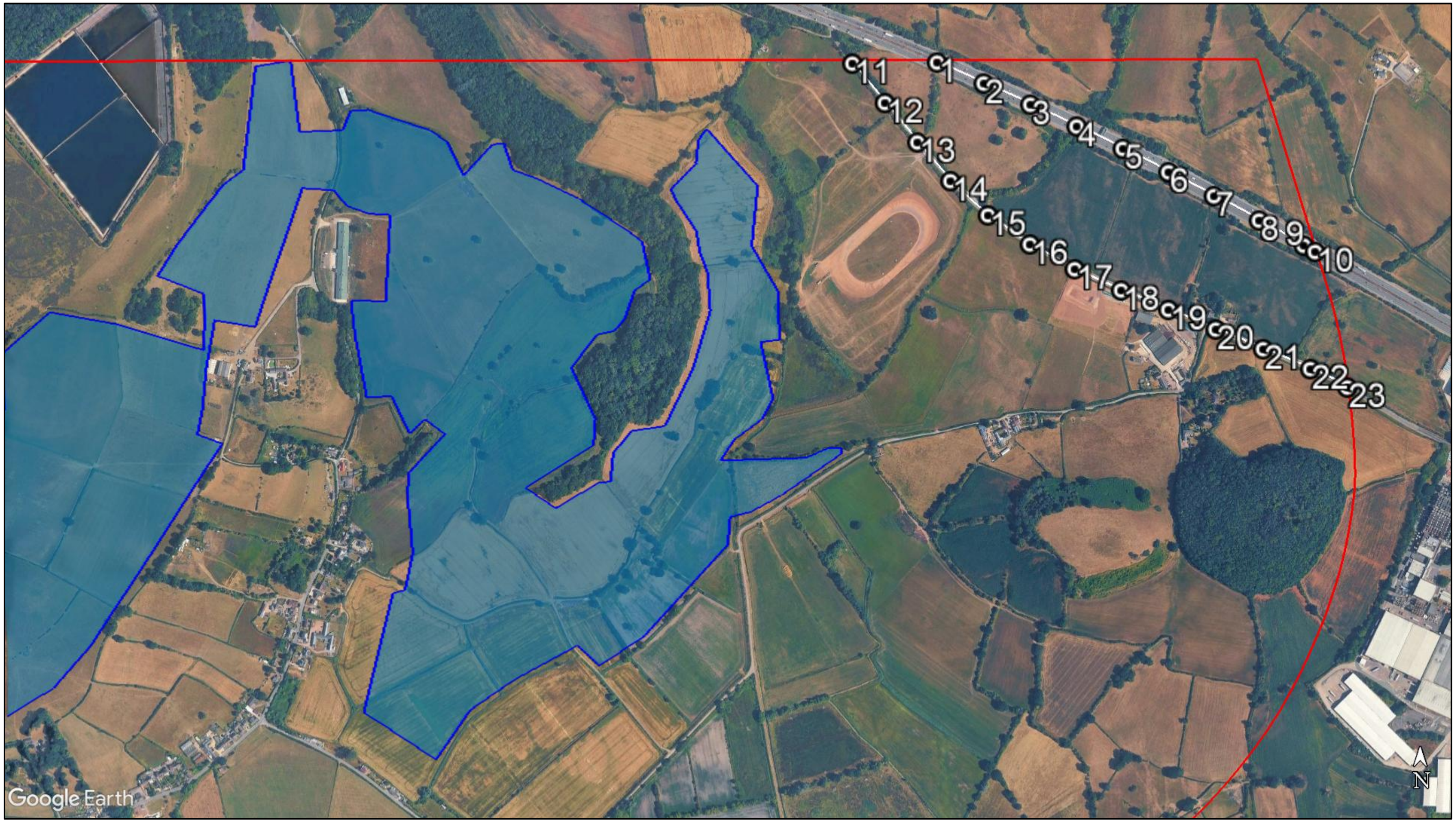

Figure 11 *Assessed road receptors – aerial image*

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

The following subsections present 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 Assessment Results – Train Driver Receptors

6.2.1 Key Considerations

The process for quantifying the impact significance concerning railway safety is outlined in Appendix D. 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 complexity of the railway at the position of a train driver experiencing a solar reflection;
    - This assessment is based on the presence of a signal, station, level crossing, or switching point within the reflection zone.

Where reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

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

Where reflections are predicted to be experienced from inside of a train driver's primary field-of-view, expert assessment of the following relevant factors is required to determine the impact significance and mitigation requirement:

- Whether the solar reflection originates from directly in front of a train driver. Solar reflections that are directly in front of a train driver are more hazardous;
- The separation distance to the reflecting surface. 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 a signal, station, level crossing, or switching point is located within the reflection zone;
    - These are considered as a factor when assessing the complexity of the affected railway. It is considered that drivers are more likely to be distracted where the

track is complex, and their attention could be drawn away from important operations to safely drive the train.

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 further mitigating factors, the impact significance is high, and mitigation is required.

6.2.2 Geometric Modelling Results

Table 2 on the following pages presents:

- Geometric modelling results (prior to consideration of screening);
- Desk-based review of identified screening;
- Consideration of mitigating factors present, where appropriate;
- Predicted impact significance.

Reference is made to a train driver's primary field-of-view (FOV), which is defined as 30 degrees either side of the direction of travel.

Train Driver Receptor	Geometric Modelling Results (screening not considered)	Relevant Factors	Identified Screening (desk-based review)	Impact Classification (<u>Without vegetation</u> Screening)	Impact Classification (<u>With</u> vegetation Screening)
1 – 3	Solar reflections are geometrically possible **<u>inside</u>** a train driver's primary FOV	Train drivers will require sight of signal NT 1046 and NT 1248. Glare is not predicted to occur directly behind the signals Signal sighting is not predicted to be significantly impacted Reflections would occur from at least 300m away from the receptors	Existing and proposed vegetation is predicted to significantly obstruct reflections	Low impact	No impact
4 – 17	Solar reflections are geometrically possible **<u>inside</u>** a train driver's primary FOV	Train drivers will require sight of signals NT 1047 and NT 1249 (westerly) and signals NT 1044 and NT 1246 (easterly). Glare is not predicted to occur directly behind the signals Signal sighting is not predicted to be significantly impacted	Existing and proposed vegetation is predicted to partially obstruct reflections Residual views are considered possible	Low impact	Low impact

Train Driver Receptor	Geometric Modelling Results (screening not considered)	Relevant Factors	Identified Screening (desk-based review)	Impact Classification (Without vegetation Screening)	Impact Classification (With vegetation Screening)
18 – 21	Solar reflections are geometrically possible **inside** a train driver's primary FOV	Train drivers will require sight of signals NT 1045 and NT 1247. Glare is not predicted to occur directly behind the signals Signal sighting is not predicted to be significantly impacted	Existing and proposed vegetation is predicted to partially obstruct reflections Residual views are considered possible	Low impact	Low impact
22 – 25	Solar reflections are geometrically possible **inside** a train driver's primary FOV	Train drivers will require sight of signals NT 1045 and NT 1247 (westerly) and signal NT 1042 (easterly). Glare is not predicted to occur directly behind the signals Signal sighting is not predicted to be significantly impacted Reflections would occur from at least 300m away from the receptors	Intervening terrain, existing vegetation and proposed vegetation is predicted to significantly obstruct reflections	Low impact	No impact

Train Driver Receptor	Geometric Modelling Results (screening not considered)	Relevant Factors	Identified Screening (desk-based review)	Impact Classification (Without vegetation Screening)	Impact Classification (With vegetation Screening)
26 – 34	Solar reflections are geometrically possible **inside** a train driver's primary FOV	Train drivers will require sight of signal NT 1042. Glare is not predicted to occur directly behind the signals Signal sighting is not predicted to be significantly impacted Reflections would occur from at least 600m away from the receptors	Intervening terrain, existing vegetation and proposed vegetation is predicted to significantly obstruct reflections	Low impact	No impact
35	Solar reflections are geometrically possible **inside** a train driver's primary FOV	Train drivers will require sight of signal NT 1043. Glare is not predicted to occur directly behind the signal Signal sighting is not predicted to be significantly impacted Reflections would occur from at least 600m away from the receptors	Intervening terrain, existing vegetation and proposed vegetation is predicted to significantly obstruct reflections	Low impact	No impact

Table 2 *Impact classification - train drivers*

6.2.3 Desk-Based Review of Imagery – Train Drivers

The desk-based imagery is shown in Figures 12 to 17 on pages 41 to 46. The cumulative reflecting panel areas are indicated by regions of yellow. Identified screening in the form of existing vegetation, proposed vegetation and buildings are highlighted in pink, green and blue, respectively. AIVR imagery is used to show a ground-based view of screening at specific locations, from a train driver's perspective, with a blue cone and white arrow to illustrate the location and direction. High-level Zones of Theoretical Visibility (ZTV Viewshed)[14] generated by Google Earth have been used to show the intervening terrain in green.

[14] The green highlighted extents show the areas of terrain from the relevant receptor point that is visible to an observer.

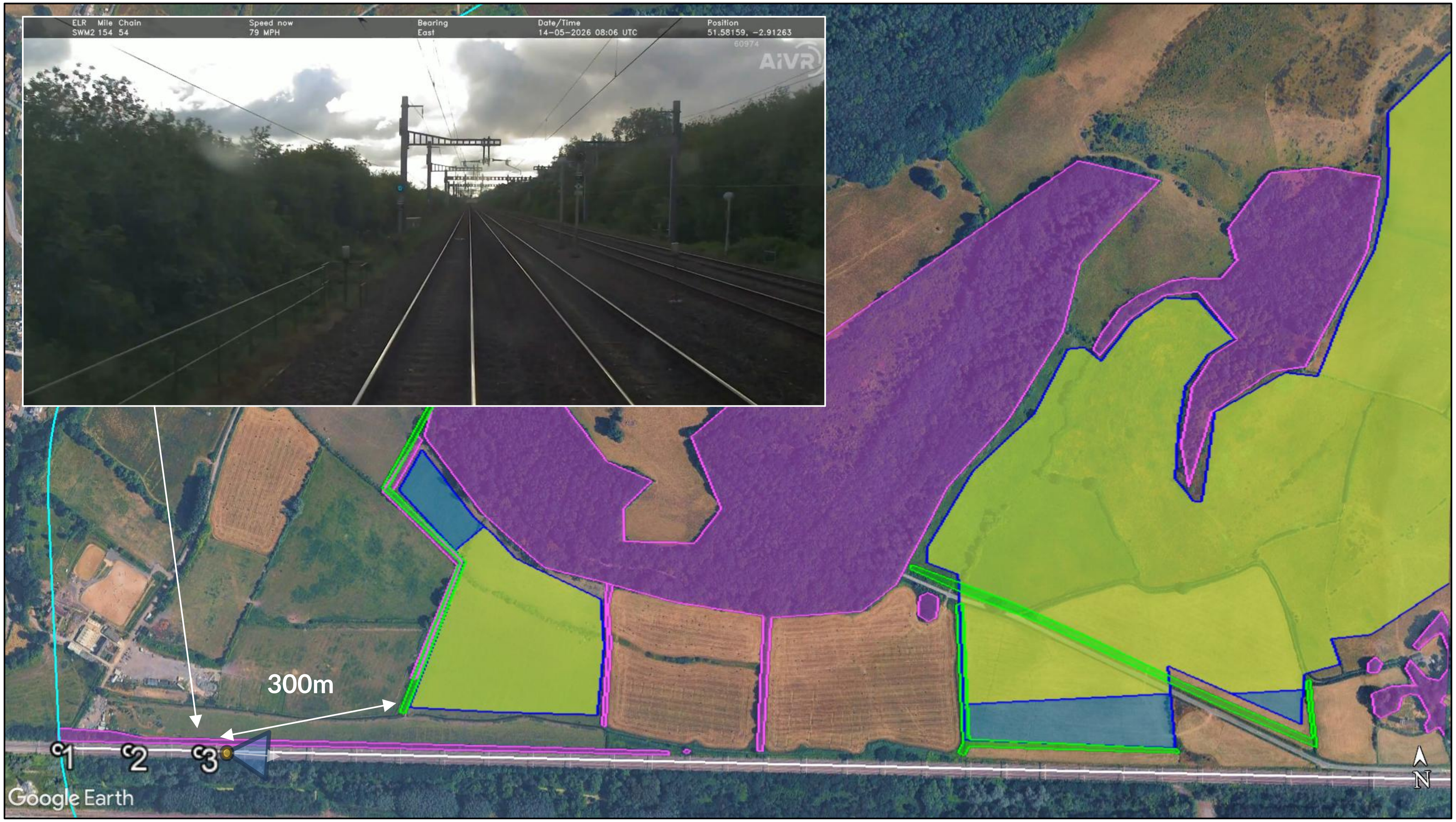

Figure 12 *Screening relevant to train driver receptors 1 to 3*

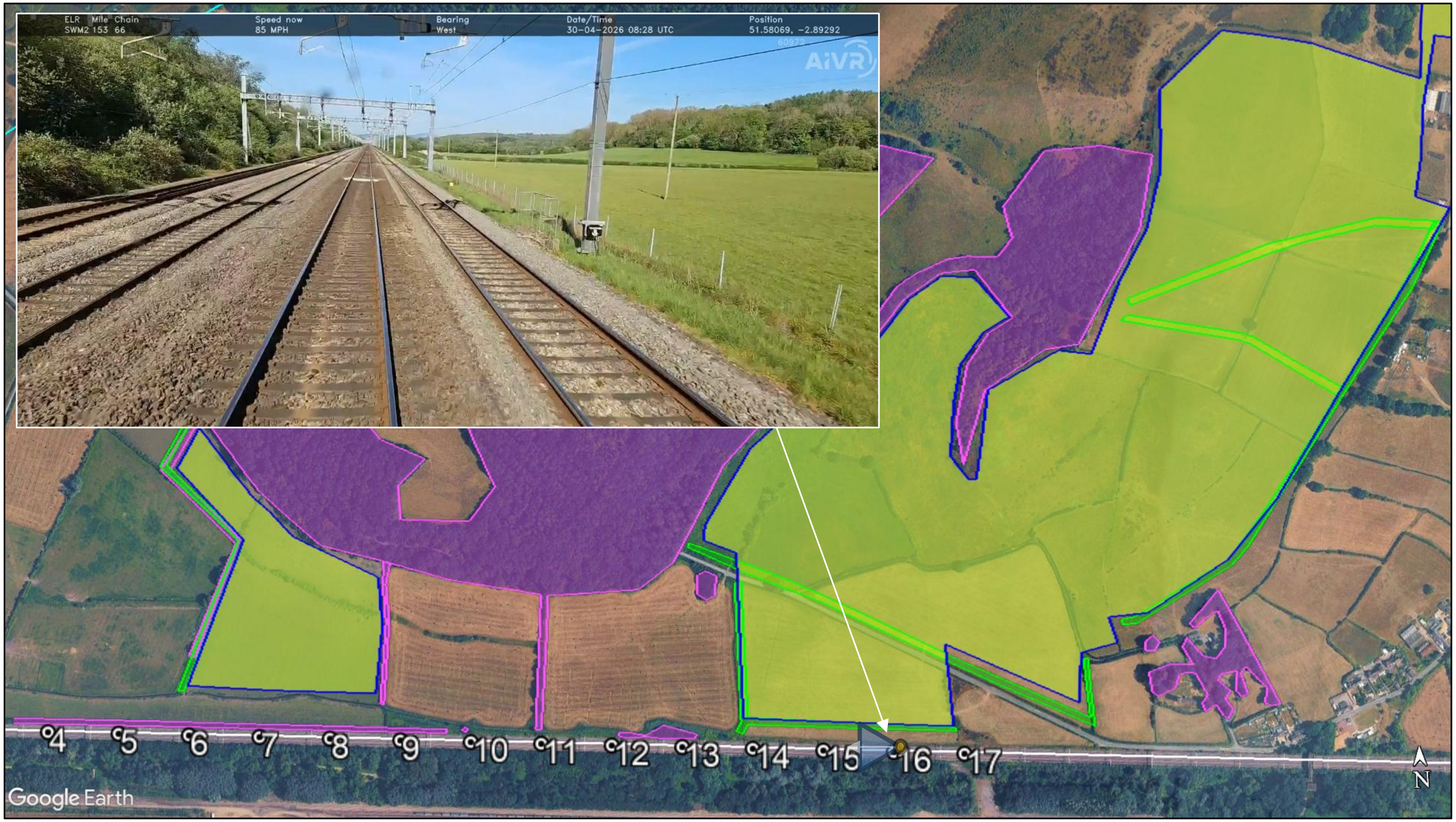

Figure 13 *Screening relevant to train driver receptors 4 to 17*

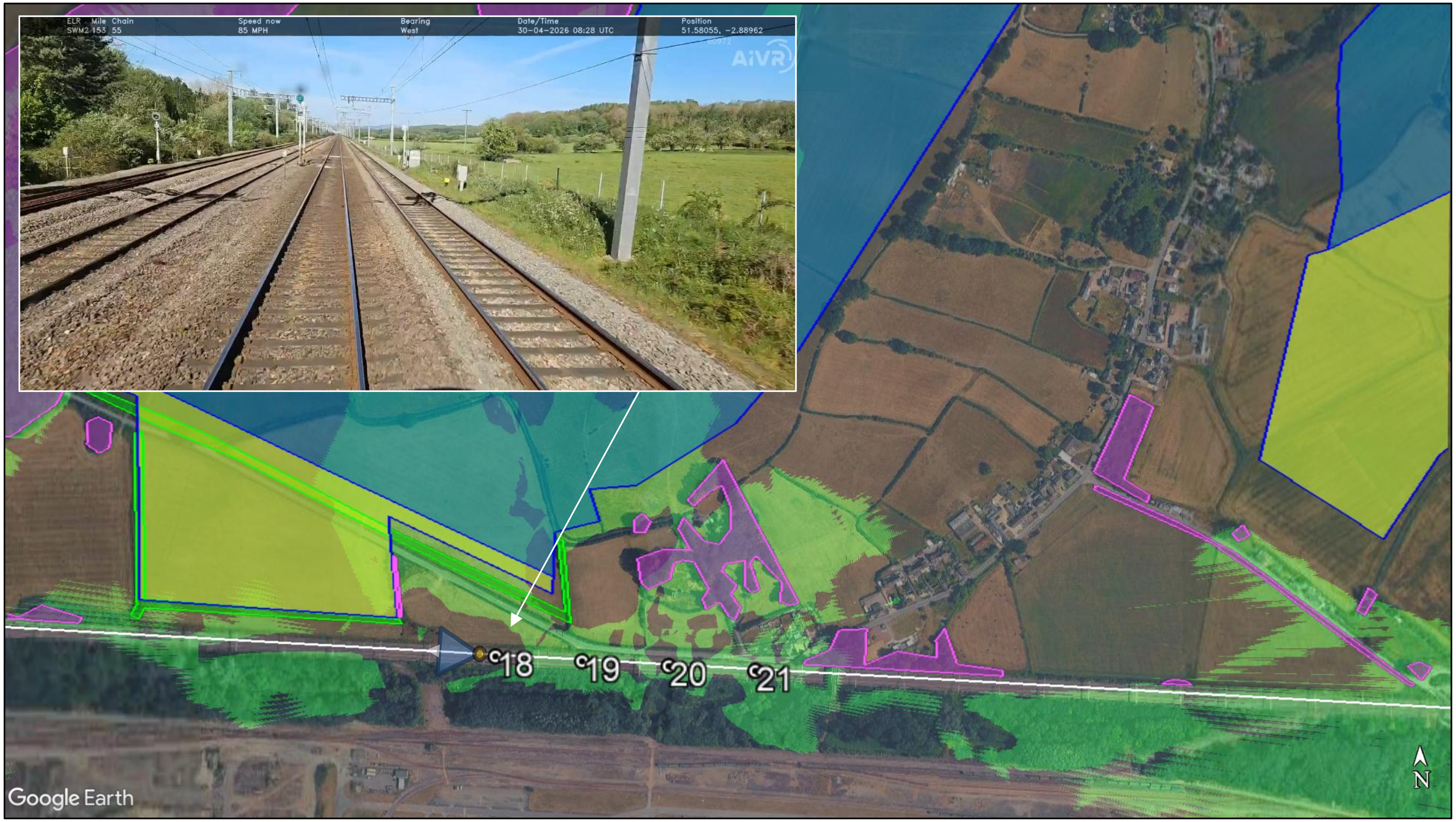

Figure 14 *Screening relevant to train driver receptors 18 to 21, with representative ZTV viewshed from receptor 19*

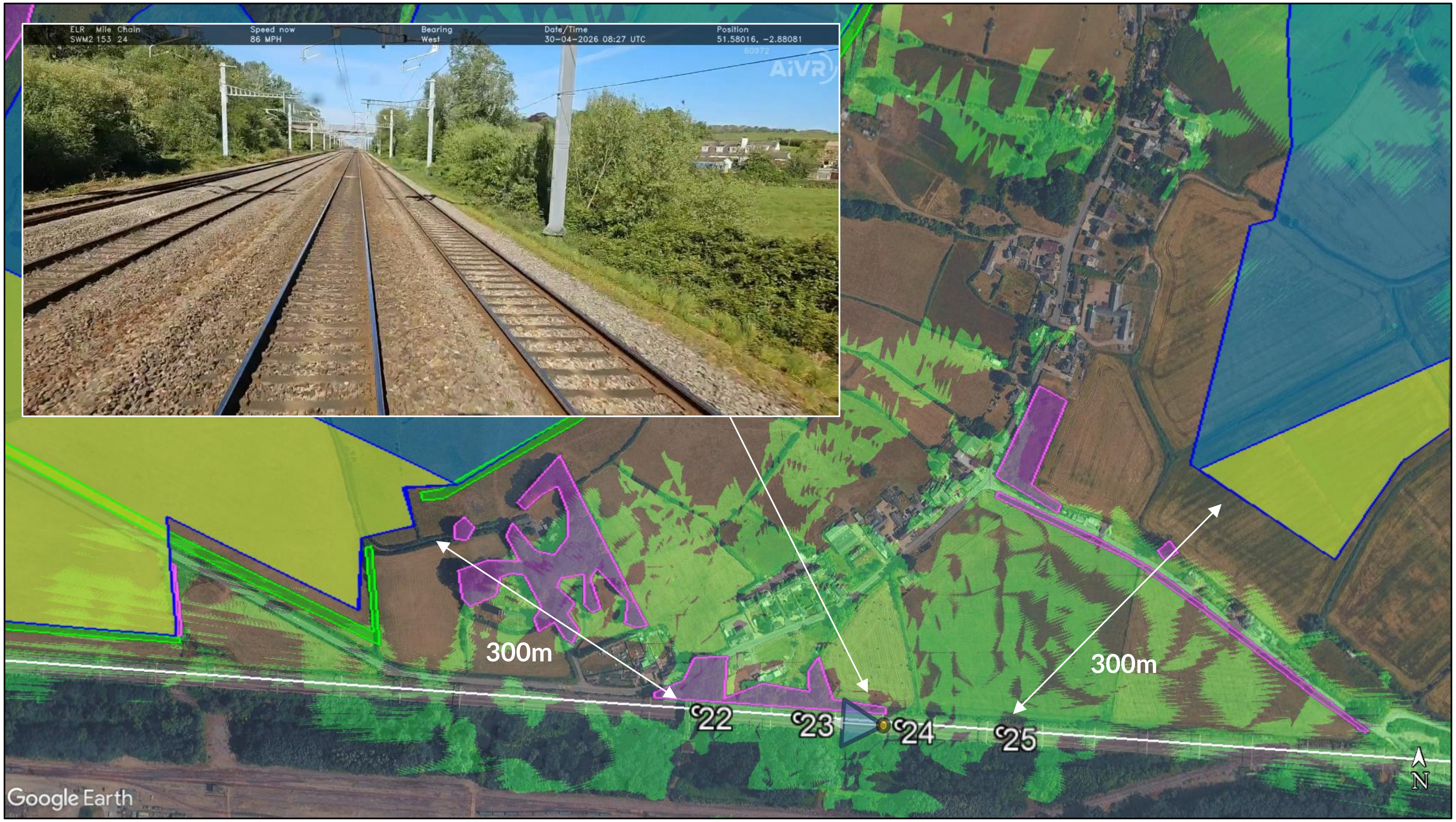

Figure 15 *Screening relevant to train driver receptors 22 to 25, with representative ZTV viewshed from receptor 24*

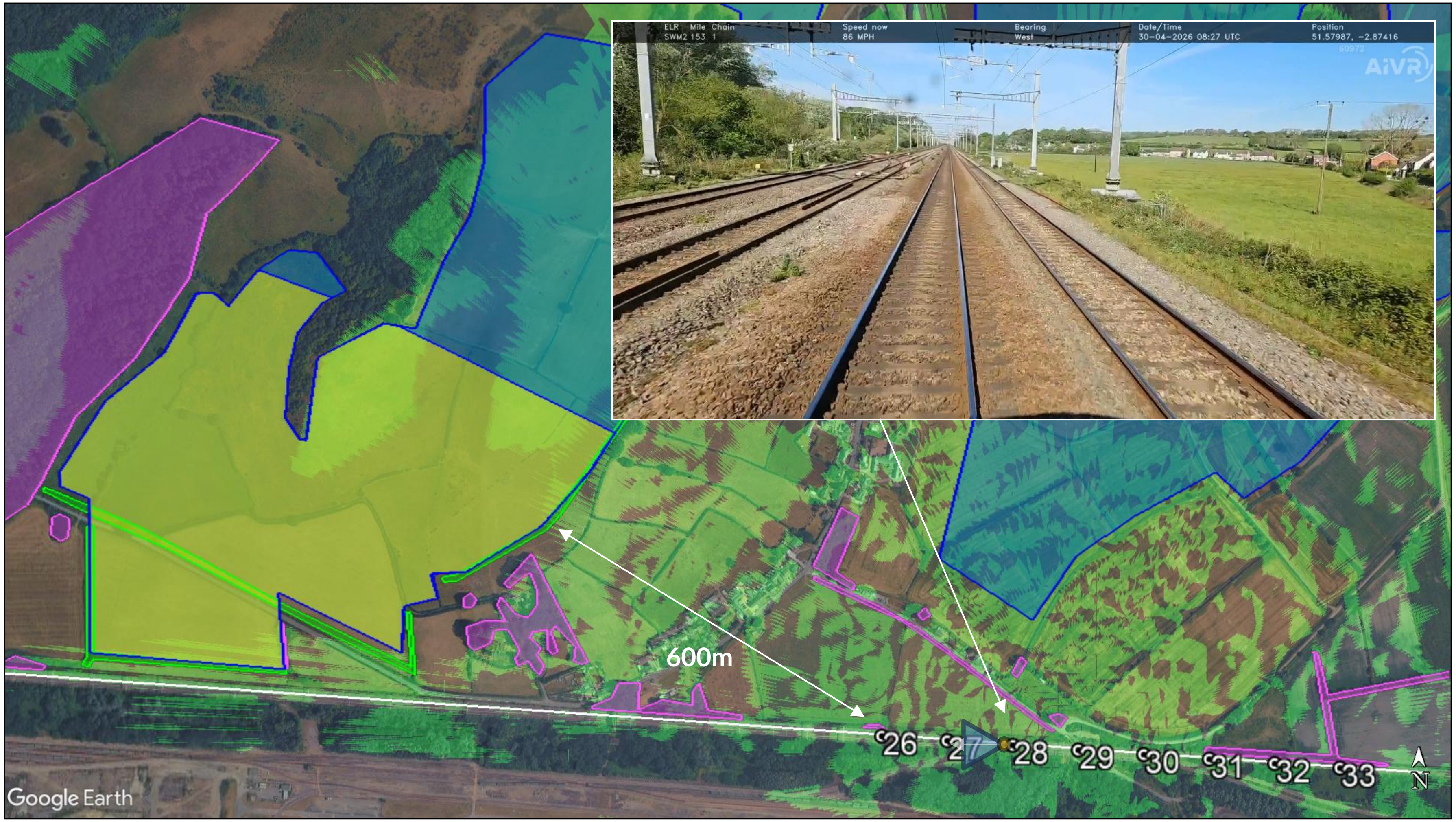

Figure 16 *Screening relevant to train driver receptors 26 to 33, with representative ZTV viewshed from receptor 29*

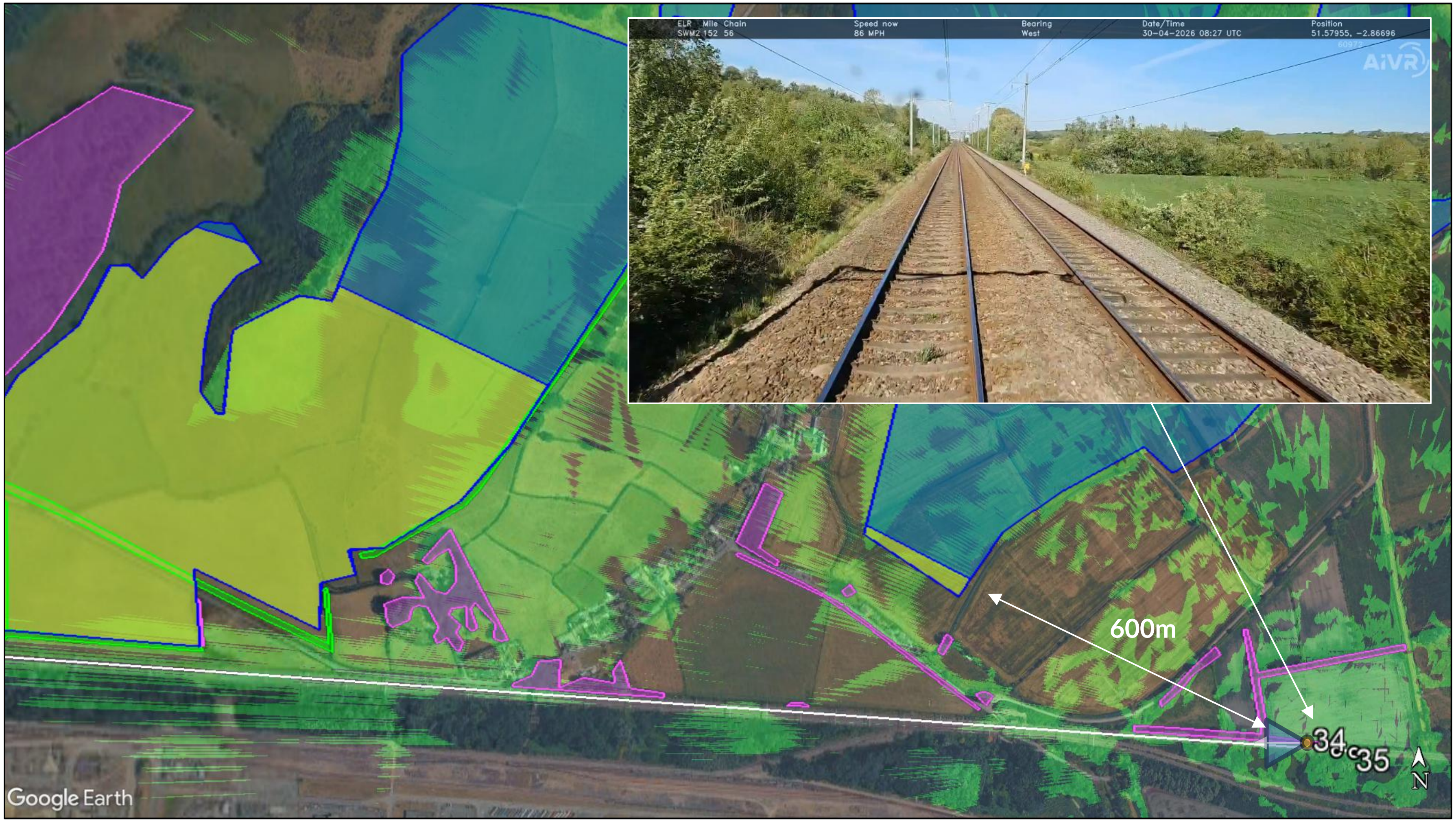

Figure 17 *Screening relevant to train driver receptors 34 and 35, with representative ZTV viewshed from receptor 34*

6.3 Assessment Results – Railway Signal Receptors

6.3.1 Key Considerations

The process for quantifying impact significance is defined in the report appendices. The key considerations for railway signals are:

- Whether a reflection is predicted to reach the signal lens or not;
- Whether the railway signal appears to be LED or incandescent;
- Whether the solar reflections illuminates the signal directly.

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 180 degrees of the direction of the signal 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 reach the signal from within 180 degrees of the direction of the signal, expert assessment of the following relevant factors is required to determine the impact significance:

- Whether the railway signal appears to be LED or incandescent;
- Whether the solar reflection originates from directly in front of the signal;
- Whether the railway signal has a hood fitted or not;
- The separation distance to the reflecting area. Larger separation distances reduce the likelihood of phantom aspect illusion.

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

Where reflections originate from directly in front of an incandescent signal and there are no mitigating factors, the impact significance is high, and mitigation is required.

6.3.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards all 10 of the modelled railway signals. Table 3 on the following pages summarises the predicted impact at these receptors.

Railway Signal	Geometric Modelling Results (screening not considered)	Relevant Factors	Identified Screening (desk-based review)	Impact Classification (Without vegetation Screening)	Impact Classification (With vegetation Screening)
NT 1042	Solar reflections are geometrically possible **within** 90° either side of the direction of the signal	Any reflections would occur from at least 600m away These signals are LED and have been observed to be fitted with signal hoods, which both decrease the likelihood of phantom aspect illusion	Intervening terrain, existing vegetation and proposed vegetation is predicted to significantly obstruct reflections	Low impact	No impact
NT 1043, NT 1248, NT 1046	Solar reflections are geometrically possible **outside** of 90° either side of the direction of the signal	Any reflections would occur from outside the direction that the signal faces and would therefore be very unlikely to cause phantom aspect illusion	Intervening terrain, existing vegetation and proposed vegetation is predicted to significantly obstruct reflections	No impact	No impact

Railway Signal	Geometric Modelling Results (screening not considered)	Relevant Factors	Identified Screening (desk-based review)	Impact Classification (Without vegetation Screening)	Impact Classification (With vegetation Screening)
NT 1247, NT 1045	Solar reflections are geometrically possible **within** 90° either side of the direction of the signal	Reflections within 90° either side of the direction of the signal occur at least 10° from the direction the signal faces, and from at least 900m away All other reflections would occur from outside the direction that the signal faces and would therefore be very unlikely to cause phantom aspect illusion These signals are LED and have been observed to be fitted with signal hoods, which both decrease the likelihood of phantom aspect illusion	Existing and proposed vegetation is predicted to partially obstruct reflections Residual views are considered possible	Low impact	Low impact
NT 1246, NT 1044	Solar reflections are geometrically possible **within** 90° either side of the direction of the signal	Reflections within 90° either side of the direction of the signal occur at least 5° from the direction the signal faces, or from at least 800m away All other reflections would occur from outside the direction that the signal faces and would therefore be very unlikely to cause phantom aspect illusion These signals are LED and have been observed to be fitted with signal hoods, which both decrease the likelihood of phantom aspect illusion	Existing and proposed vegetation is predicted to partially obstruct reflections Residual views are considered possible	Low impact	Low impact

Railway Signal	Geometric Modelling Results (screening not considered)	Relevant Factors	Identified Screening (desk-based review)	Impact Classification (Without vegetation Screening)	Impact Classification (With vegetation Screening)
NT 1249, NT 1047	Solar reflections are geometrically possible **within** 90° either side of the direction of the signal	Any reflections would occur from at least 300m away These signals are LED and have been observed to be fitted with signal hoods, which both decrease the likelihood of phantom aspect illusion	Existing and proposed vegetation is predicted to significantly obstruct reflections	Low impact	No impact

Table 3 *Impact classification - railway signals*

6.3.3 Desk-Based Review of Imagery – Railway Signal Receptors

The desk-based imagery is shown in Figures 18 to 20 on the following pages. The cumulative reflecting panel areas are indicated by regions of yellow. Identified screening in the form of existing vegetation, proposed vegetation and buildings are highlighted in pink, green and blue, respectively. High-level Zones of Theoretical Visibility (ZTV Viewshed)[15] generated by Google Earth have been used to show the intervening terrain in green.

[15] The green highlighted extents show the areas of terrain from the relevant receptor point that is visible to an observer.

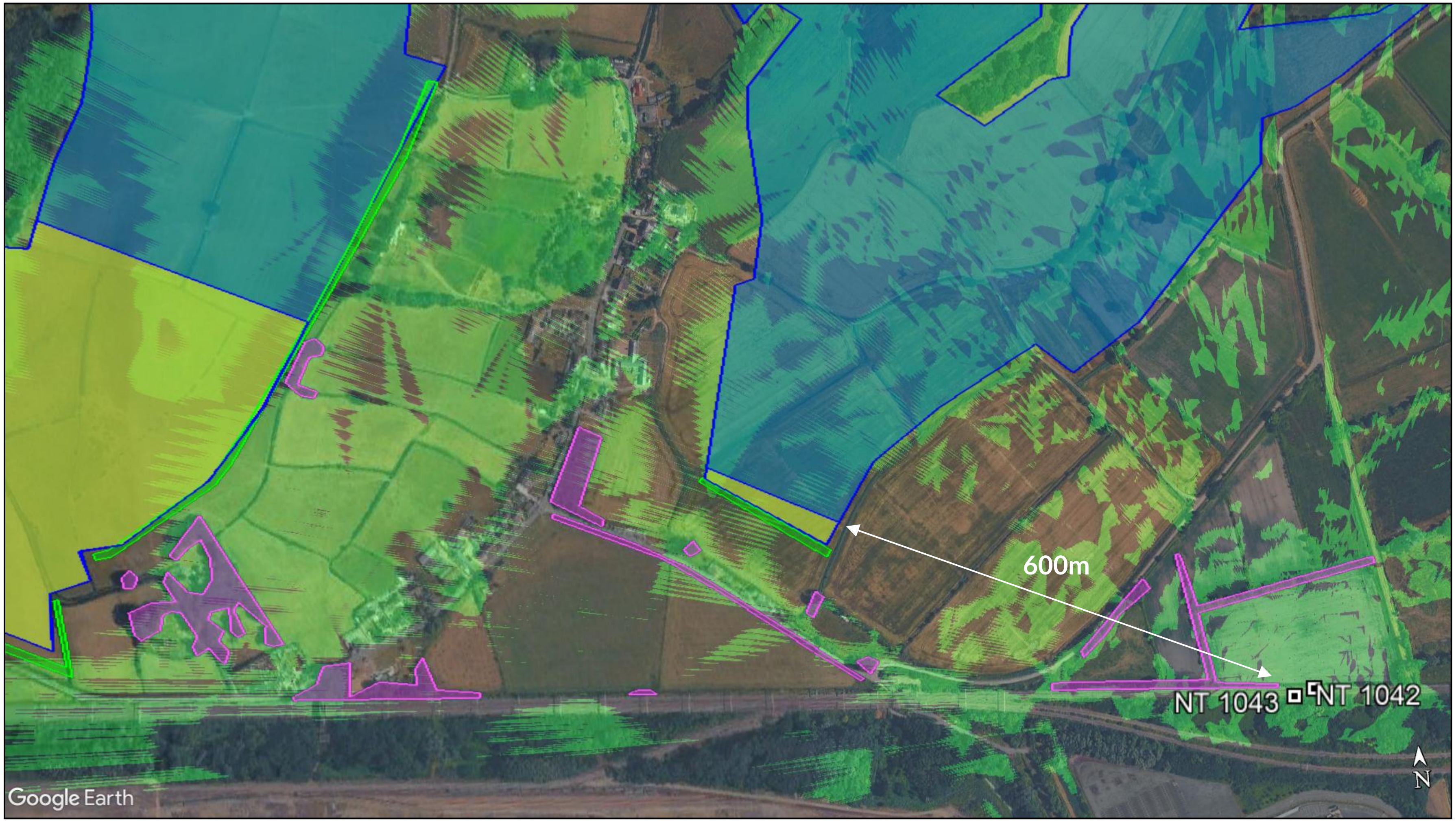

Figure 18 *Screening relevant to railway signals NT 1042 and NT 1043, with representative ZTV viewshed from receptor NT 1043*

Figure 19 *Screening relevant to railway signals NT 1044, NT 1045, NT 1246 and NT 1247*

Figure 20 *Screening relevant to railway signals NT 1046, NT 1047, NT 1248 and NT 1249*

6.4 Assessment results – Road Receptors

6.4.1 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 primary 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.

6.4.2 Geometric Modelling Results

Table 4 on the following pages presents the geometric modelling results and predicted impact upon each receptor. Reference is made to a road user's primary field-of-view (FOV), which is defined as 50 degrees either side of the direction of travel.

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Considering screening[16], do reflections remain inside the primary FOV	Mitigating Factors	Predicted Impact Classification
1 – 5, 11 - 13	Solar reflections **are not** geometrically possible	N/A	N/A	N/A	No impact
6 - 10	Solar reflections **are** geometrically possible and occur **inside** a road user's primary FOV	Intervening terrain, existing vegetation and proposed vegetation are predicted to significantly obstruct reflections Views are not predicted in practice	N/A	N/A	No impact
14, 18 - 19	Solar reflections **are** geometrically possible and occur **inside** a road user's primary FOV	Existing and proposed vegetation are predicted to significantly obstruct reflections Views are not predicted in practice	N/A	N/A	No impact

[16] Assessment scenario may include an initial conservative qualitative consideration of screening. The reflecting area of the solar development may be partially screened such that it does not meet the key criteria i.e. whether the solar reflection occurs within a road users' main field of view.

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Considering screening[16], do reflections remain inside the primary FOV	Mitigating Factors	Predicted Impact Classification
15 - 17	Solar reflections **are** geometrically possible and occur **inside** a road user's primary FOV	Existing and proposed vegetation are predicted to partially obstruct reflections Residual views are considered possible	Reflections occur **inside** a road user's primary FOV	Reflections coincide with direct sunlight Reflections are predicted to occur from at least 450m away	Low impact
20 - 23	Solar reflections **are** geometrically possible and occur **inside** a road user's primary FOV	Existing buildings, existing vegetation and proposed vegetation are predicted to significantly obstruct reflections Views are not predicted in practice	N/A	N/A	No impact

Table 4 *Impact classification - road receptors*

6.4.3 Desk-Based Review of Imagery – Road Receptors

The desk-based imagery is shown in Figures 21 to 24 on the following pages. The cumulative reflecting panel areas are indicated by regions of yellow. Identified screening in the form of existing vegetation, proposed vegetation and buildings are highlighted in pink, green and blue, respectively. Streetview images are used to show a ground-based view of screening at specific locations, with a white arrow and blue cone to illustrate the location and direction. High-level Zones of Theoretical Visibility (ZTV Viewshed)[17] generated by Google Earth have been used to show the intervening terrain in green.

[17] The green highlighted extents show the areas of terrain from the relevant receptor point that is visible to an observer.

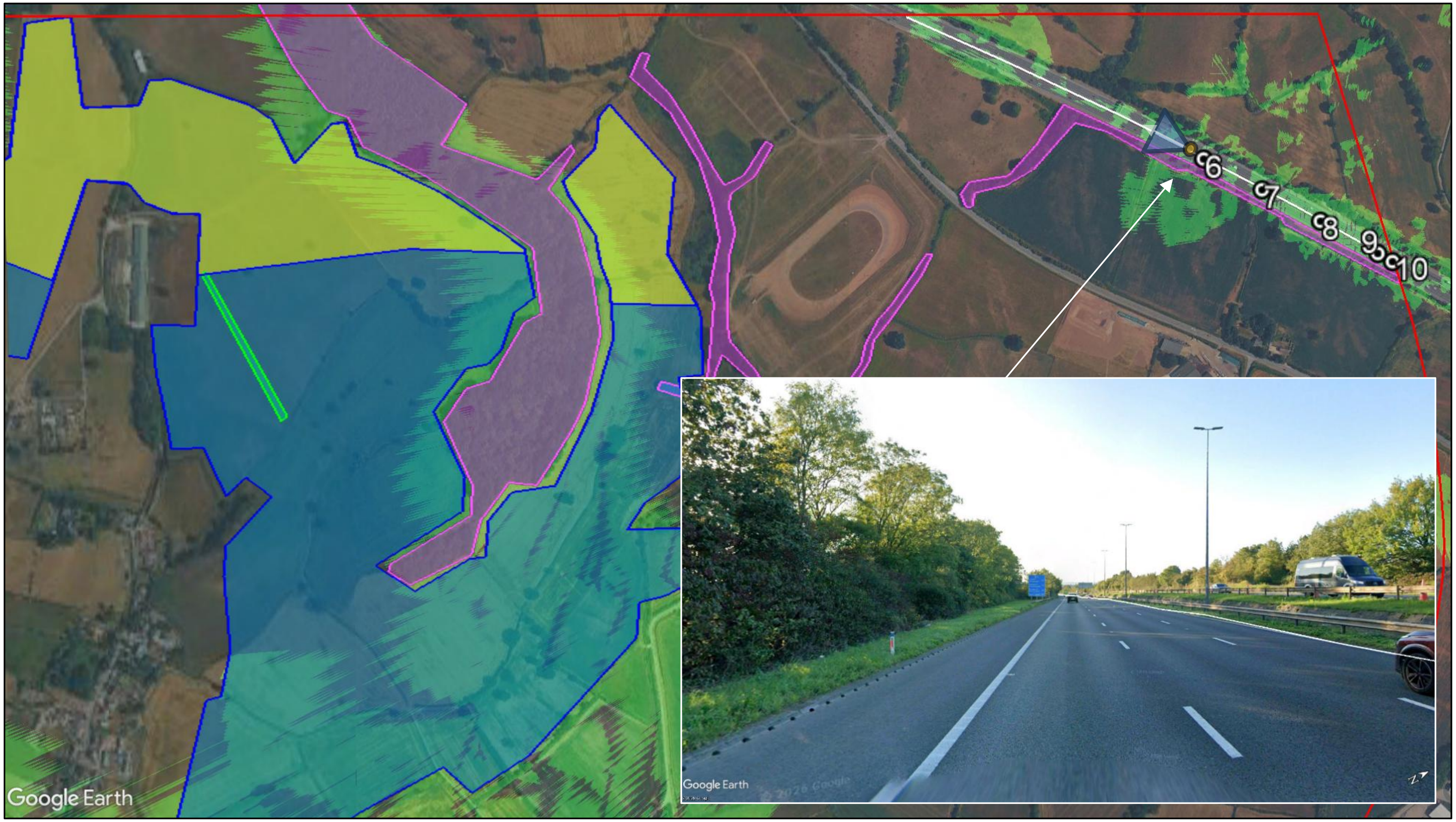

Figure 21 *Screening relevant to road receptors 6 to 10, with representative ZTV viewshed from receptor 7*

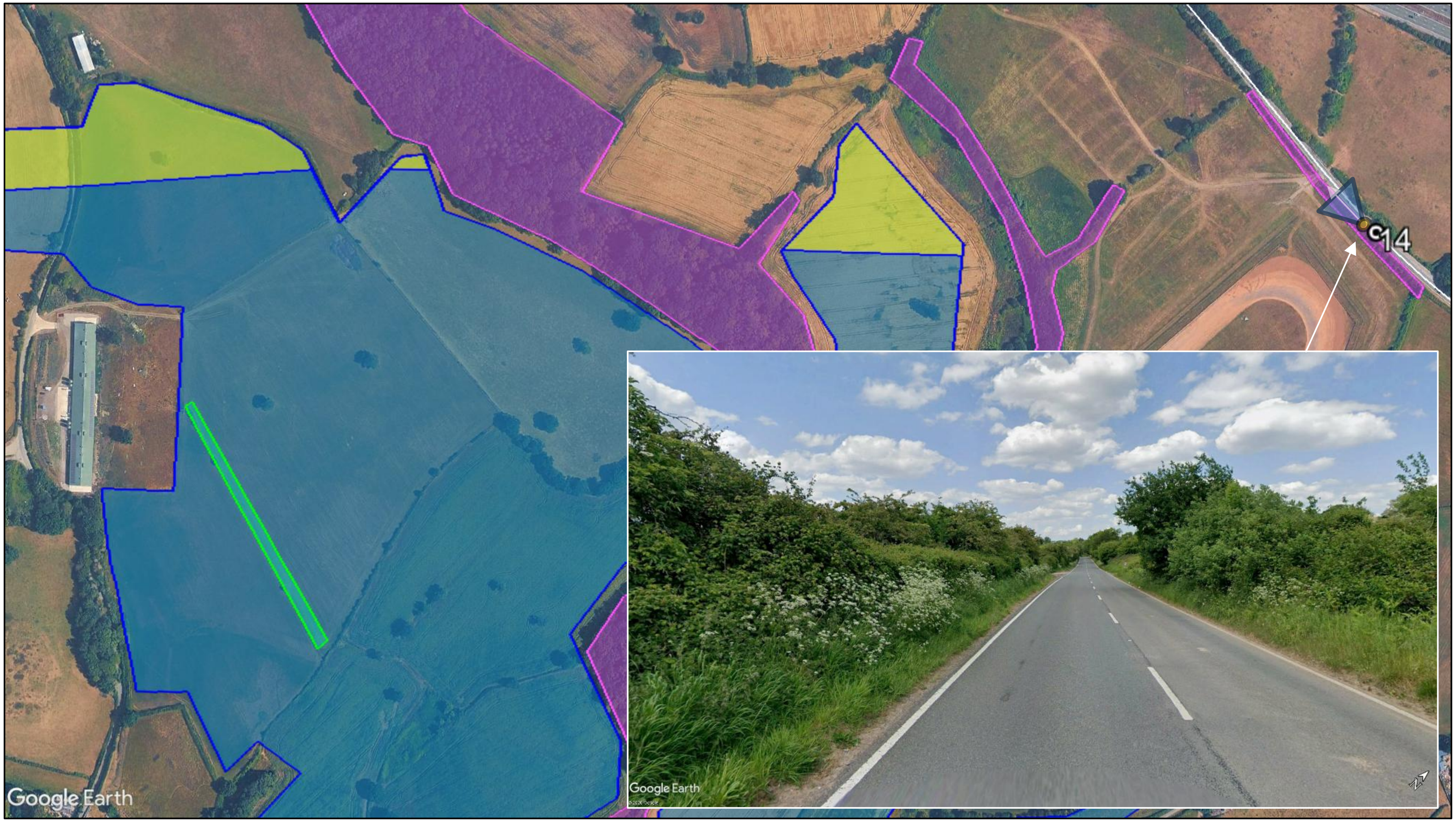

Figure 22 *Screening relevant to road receptor 14*

Figure 23 *Screening relevant to road receptors 15 to 17*

Figure 24 *Screening relevant to road receptors 18 to 23*

6.5 Assessment Results – Dwelling Receptors

6.5.1 Key Considerations

The key considerations for residential dwellings are:

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

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

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

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

- 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 visibility is likely from all storeys – the ground floor is typically considered the main living space and has a greater significance with respect to residential amenity;
- Whether the dwelling appears to have windows facing the reflecting area – factors that restrict potential views of a reflecting area reduce the level of impact.

Following consideration of these mitigating 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.

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

6.5.2 Geometric Modelling Results

Table 5 on the following pages presents the geometric modelling results and predicted impact upon each receptor.

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Duration of reflections (with consideration of screening)[18]	Mitigating Factors	Predicted Impact Classification
1 - 2, 4 - 8	Solar reflections are geometrically possible for: **More** than three months **Less** than 60 minutes	Existing and proposed vegetation and/or existing buildings are predicted to partially obstruct views of reflecting panels Views are considered possible in practice	**Less** than three months **Less** than 60 minutes	N/A	Low impact
3, 15 – 24, 31 – 35, 94 - 95	Solar reflections are geometrically possible for: **More** than three months **Less** than 60 minutes	Existing and proposed vegetation are predicted to significantly obstruct views of reflecting panels Views are not predicted in practice	None	N/A	No impact
9 – 14, 25 – 30, 36 – 52, 73 - 88	Solar reflections are geometrically possible for: **More** than three months **Less** than 60 minutes	Existing and proposed vegetation, intervening terrain and/or existing buildings are predicted to significantly obstruct views of reflecting panels Views are not predicted in practice	None	N/A	No impact

[18] Assessment scenario may include an initial conservative qualitative consideration of screening in determining the duration of predicated effects in practice. The reflecting area of the solar development may be partially screened such that it does not meet the two key criteria i.e. 1) The solar reflection occurs for more than 3 months per year. 2) and/or for more than 60 minutes on any given day.

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Duration of reflections (with consideration of screening)[18]	Mitigating Factors	Predicted Impact Classification
53 – 72, 89 - 91	Solar reflections are geometrically possible for: **Less** than three months **Less** than 60 minutes	Existing and proposed vegetation, intervening terrain and/or existing buildings are predicted to significantly obstruct views of reflecting panels Views are not predicted in practice	None	N/A	No impact
92 - 93	Solar reflections **are not** geometrically possible	N/A	N/A	N/A	No impact

Table 5 *Impact classification - dwelling receptors*

6.5.3 Desk-Based Review of Available Imagery – Dwelling receptors

The desk-based imagery is shown in Figures 25 to 37 on the following pages. The cumulative reflecting panel areas are indicated by regions of yellow. Identified screening in the form of existing vegetation, proposed vegetation and buildings are highlighted in pink, green and blue, respectively. High-level Zones of Theoretical Visibility (ZTV Viewshed)[19] generated by Google Earth have been used to show the intervening terrain in green.

[19] The green highlighted extents show the areas of terrain from the relevant receptor point that is visible to an observer.

Figure 25 *Screening relevant to dwelling receptors 1 to 6*

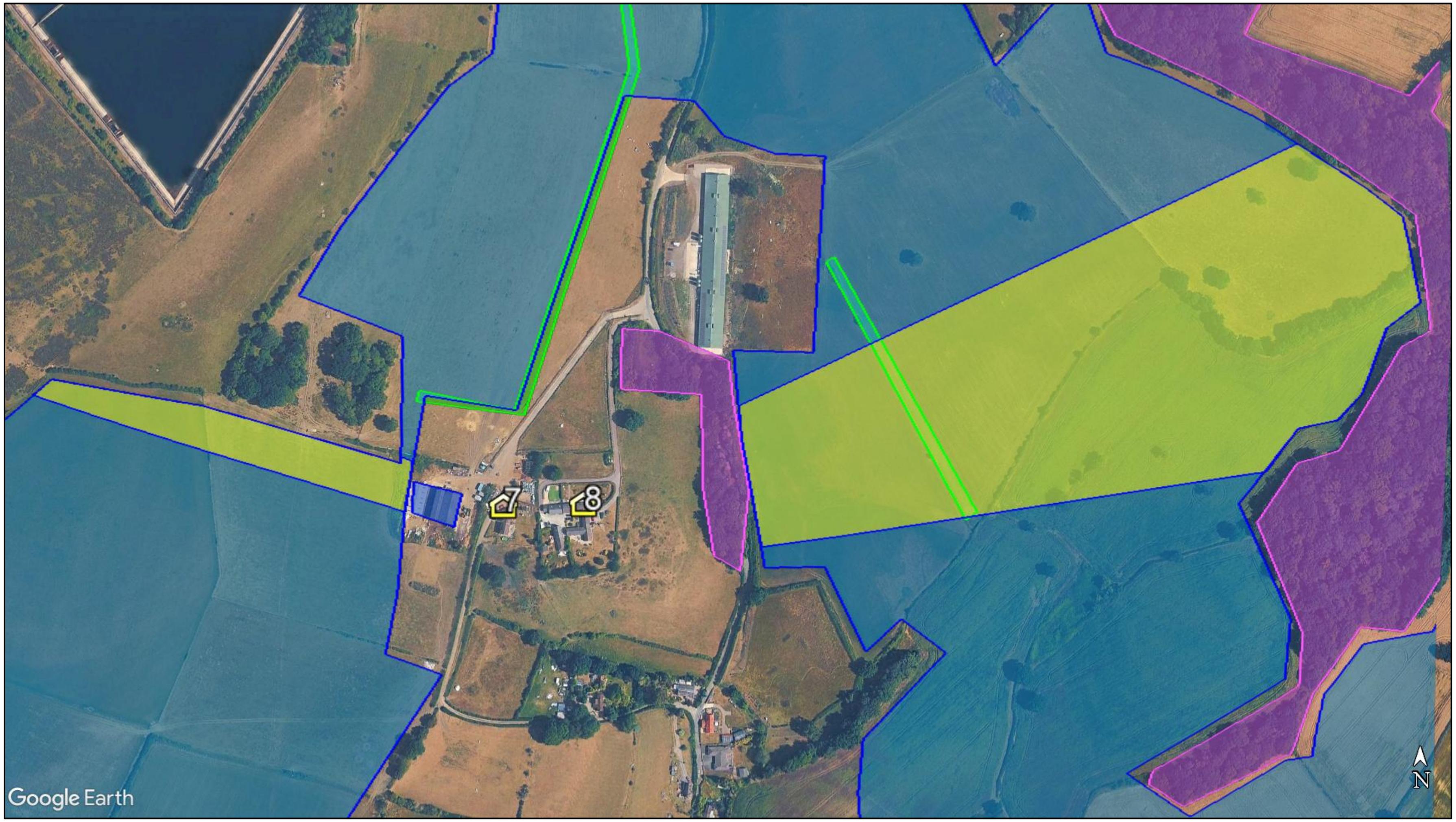

Figure 26 *Screening relevant to dwelling receptors 7 and 8*

Figure 27 *Screening relevant to dwelling receptors 9 to 14, with representative ZTV viewshed from receptor 14*

Figure 28 *Screening relevant to dwelling receptors 15 to 24*

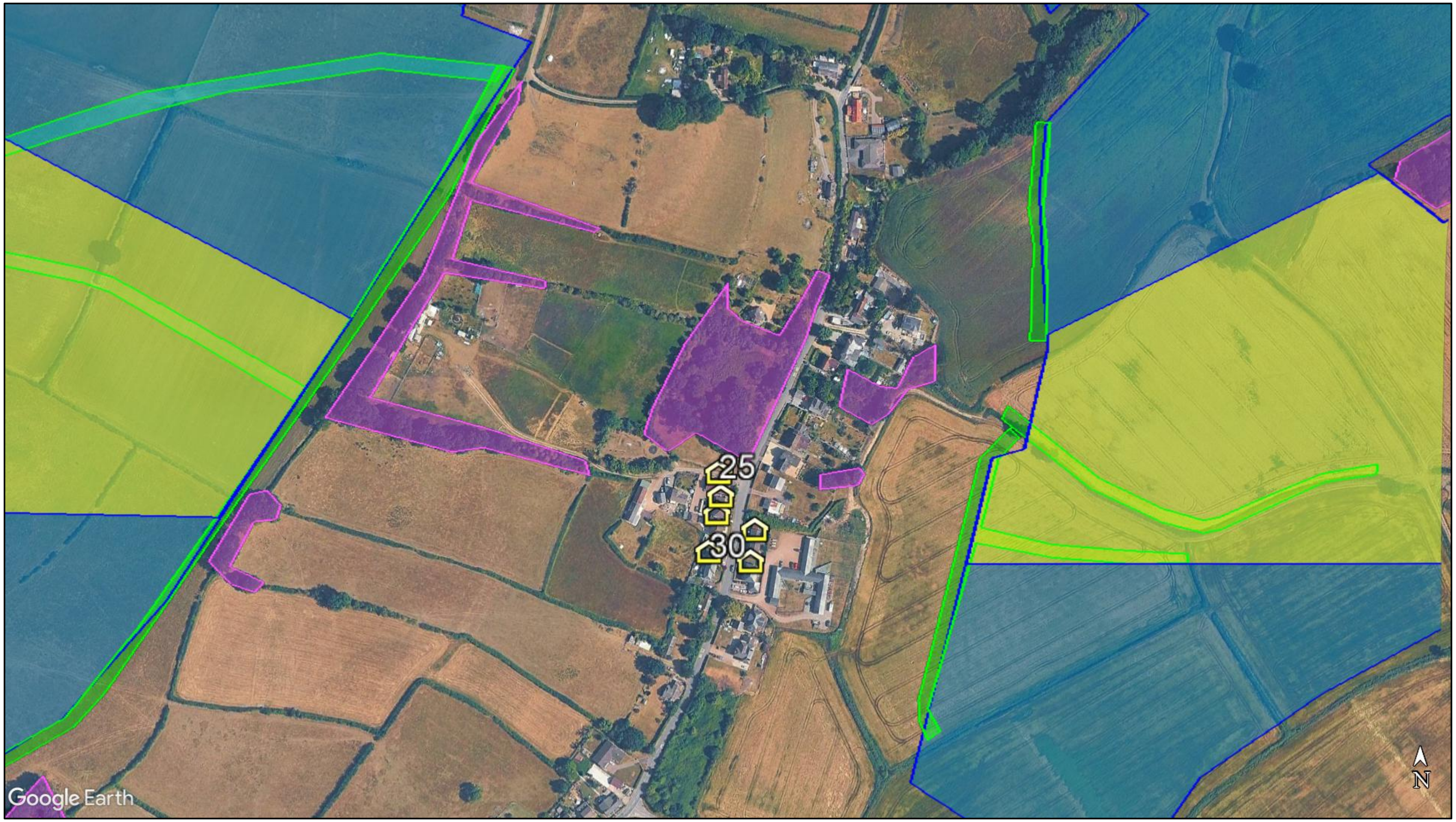

Figure 29 *Screening relevant to dwelling receptors 25 to 30*

Figure 30 *Screening relevant to dwelling receptors 31 to 35*

Figure 31 *Screening relevant to dwelling receptors 36 to 48, with representative ZTV viewshed from receptor 36*

Figure 32 *Screening relevant to dwelling receptor 49, with representative ZTV viewshed*

Figure 33 *Screening relevant to dwelling receptors 50 to 52*

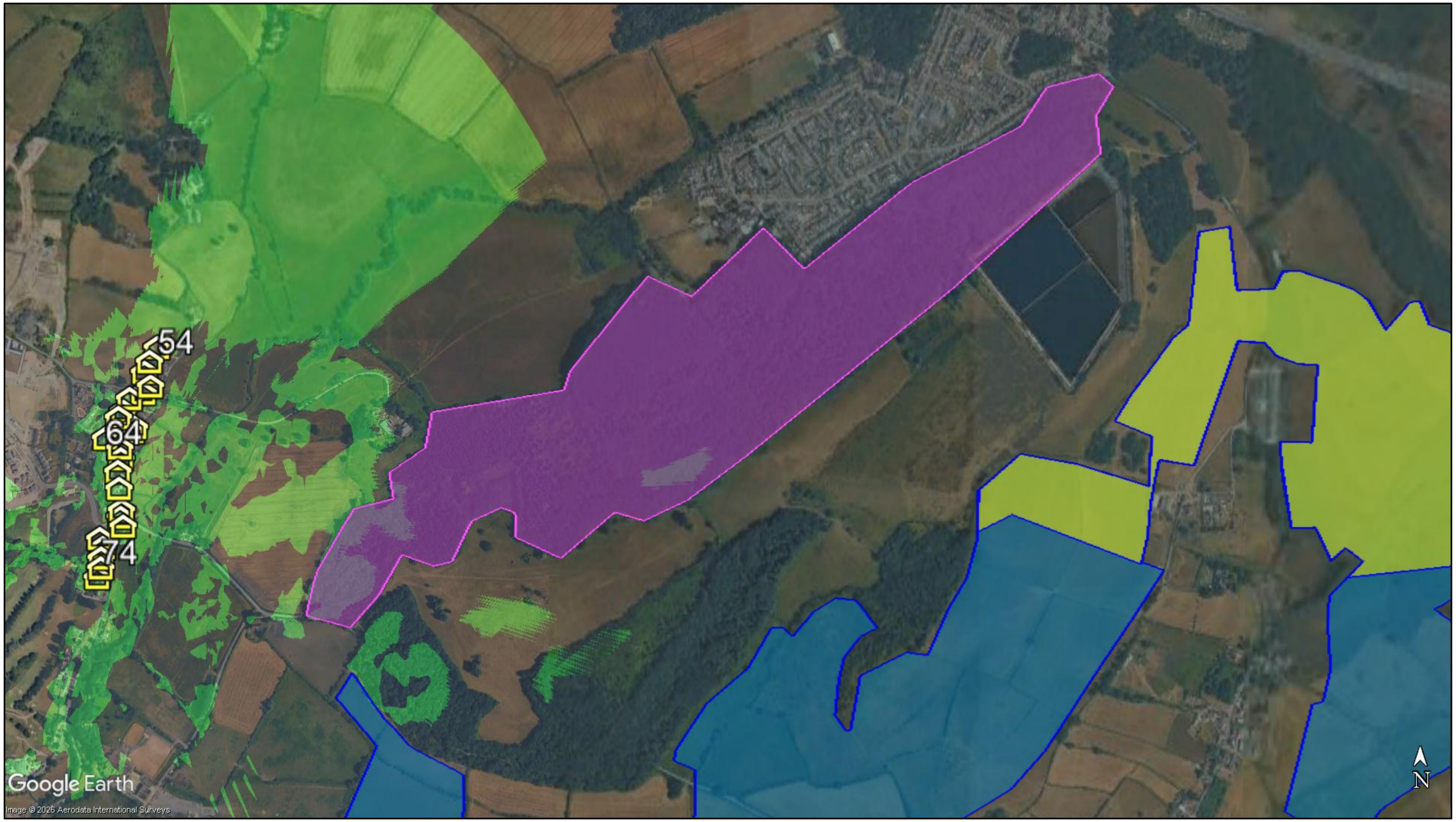

Figure 34 *Screening relevant to dwelling receptors 54 to 74, with representative ZTV viewshed from receptor 70*

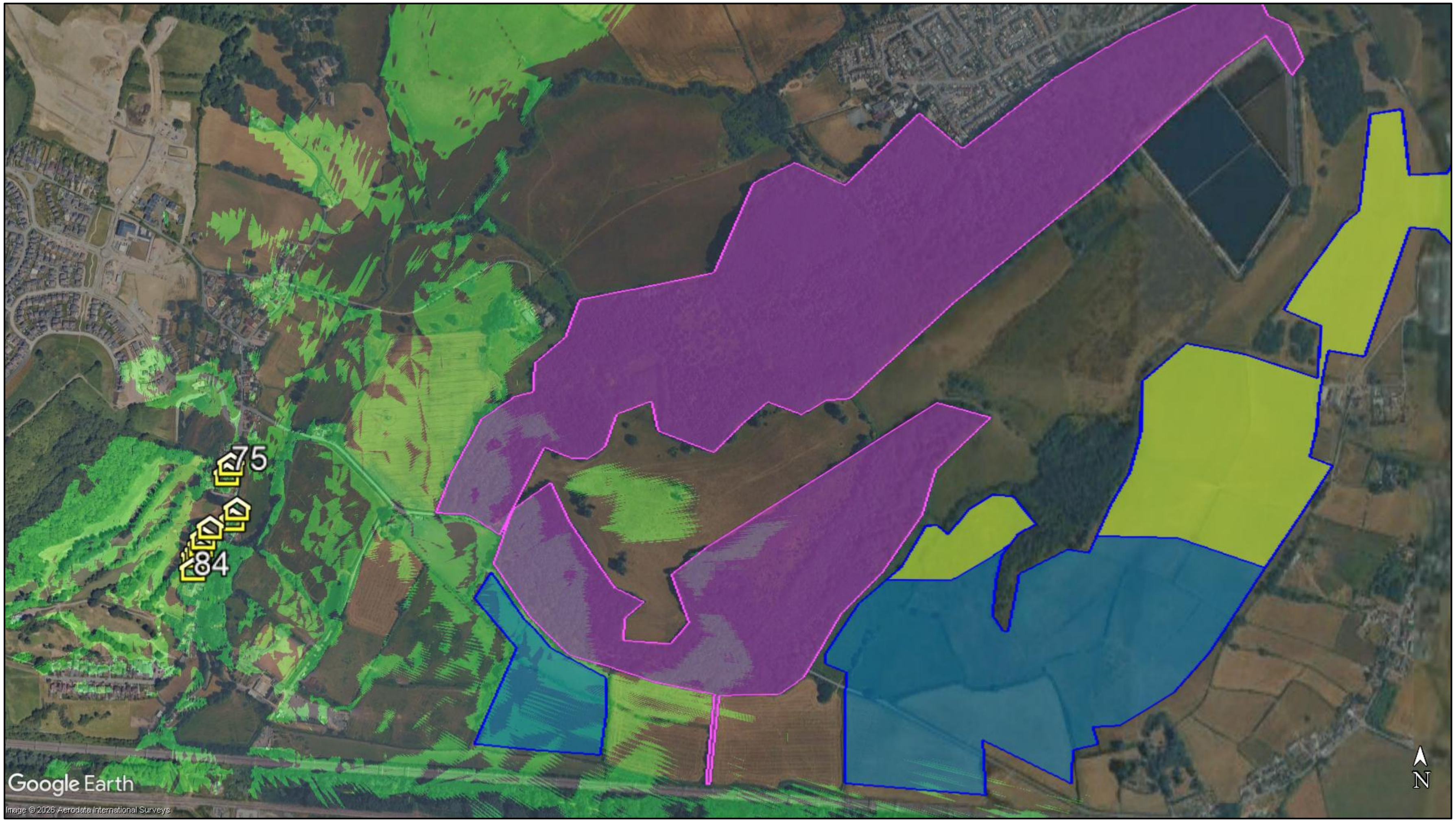

Figure 35 Screening relevant to dwelling receptors 75 to 84, with representative ZTV viewshed from receptor 80

Figure 36 Screening relevant to dwelling receptors 85 to 87 and 94 to 95

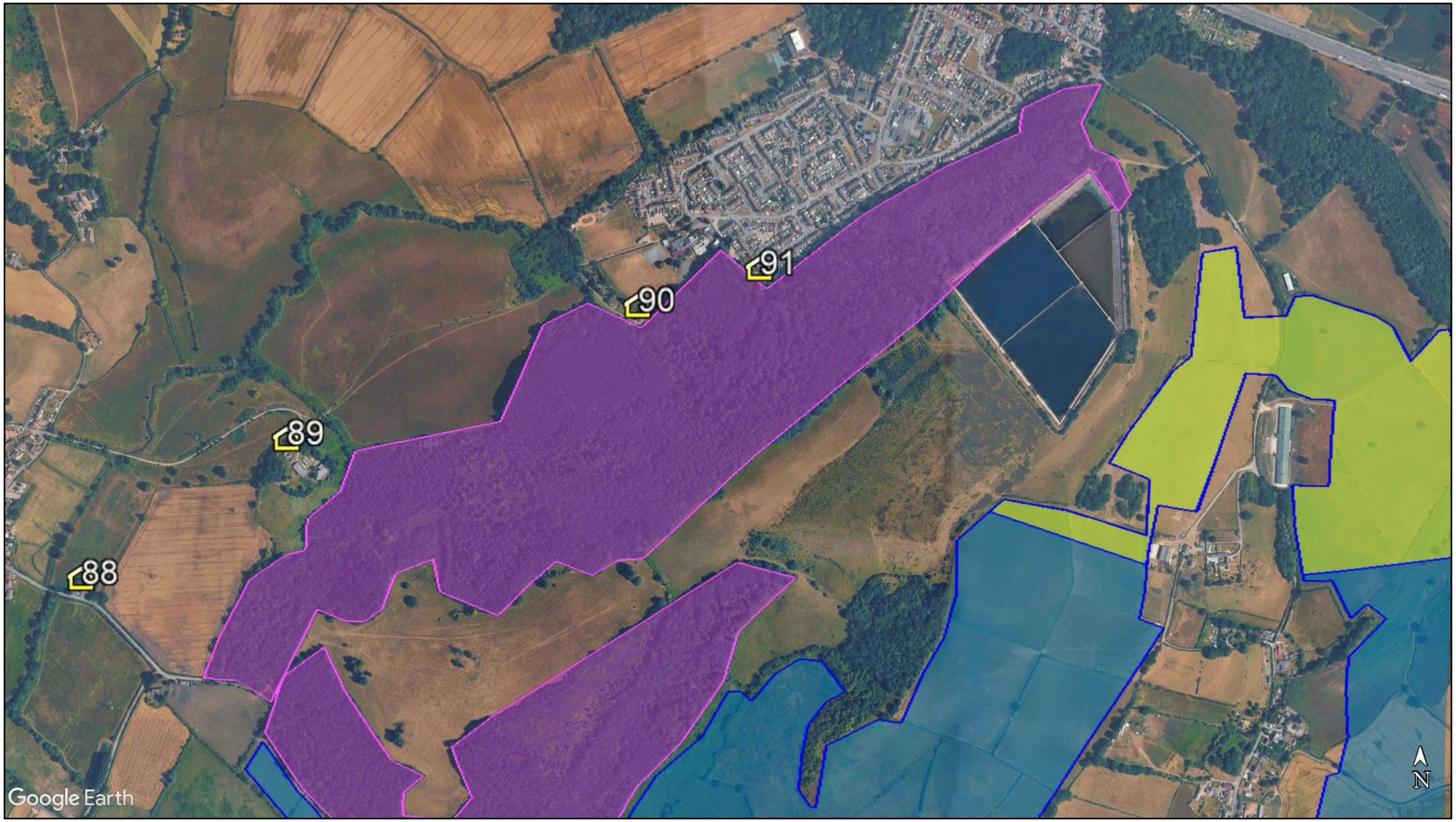

Figure 37 *Screening relevant to dwelling receptors 88 to 91*

7 CONCLUSIONS

7.1 Assessment Conclusions – Train Drivers and Signal Sighting

Solar reflections are geometrically possible towards 3.3km of assessed railway track.

Reflections are predicted to occur within a train driver's primary field-of-view (30° either side of the direction of travel) along the assessed railway track. Some locations on these sections will require sight of a signal, but reflections are not predicted to occur directly behind a signal relative to a train driver, therefore signal sighting will not be significantly impacted.

The solar reflections are not predicted to cause significant visual discomfort and therefore a distraction for a train driver. Workload of train drivers is not predicted to change compared to the existing condition.

Overall, no significant impacts are predicted. Whilst a solar reflection from the development could be experienced by train drivers, solar reflections from the development are not expected to affect the safety of railway operations. Mitigation is not recommended.

7.2 Assessment Conclusions – Railway Signals

Solar reflections are geometrically possible towards all 10 of the modelled railway signals.

For signals NT 1043, NT 1046 and NT 1248, solar reflections are predicted to occur from outside 90° either side of the signal orientation. As a result, no reflections are predicted to reach the signal and the risk of phantom aspect illusion is low. No significant impacts are predicted, and no mitigation is recommended.

For the remaining seven signals, reflections occur from in front of the signal. The signal hood and vegetation screening is predicted to obstruct the majority of reflections. Additionally, all reflections occur from at least 300m away and/or 5° from the direction the signal faces. No significant impacts are predicted, and no mitigation is recommended.

7.3 Assessment Conclusions – Road Safety

Table 6 below summarises the predicted impact upon the assessed road receptors.

Number of road receptors assessed	23 (approximately 2,000m)
Number of road receptors where a solar reflection is geometrically possible	15
Number of road receptors predicted to experience no impact due to significant screening or mitigating factors	12
Number of road receptors predicted to experience a low impact due to significant screening or mitigating factors	3

Table 6 *Summary of assessment for road receptors*

7.4 Assessment Conclusions – Residential Amenity

Table 7 below summarises the predicted impact upon the assessed dwelling receptors.

Number of dwelling receptors assessed	95
Number of dwelling receptors where a solar reflection is geometrically possible	93
Number of dwelling receptors predicted to experience no impact due to significant screening or mitigating factors	86
Number of dwelling receptors predicted to experience a low impact due to significant screening or mitigating factors	7

Table 7 *Summary of assessment for dwelling receptors*

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 and is limited to the UK; however, it is relevant from a technical and planning perspective. The section is intended to give an overview of the important parameters and considerations that have informed this assessment.

UK Planning Policy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[20] (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.

National Policy Statement for Renewable Energy Infrastructure (2025)

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[21] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 2.10.94-98 state:

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

[21] National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: December 2025, accessed on:28/01/2026.

'2.10.94 Solar panels are specifically designed to absorb, not reflect, irradiation.[22] 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.

2.10.95 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.

2.10.96 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.

2.10.97 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.

2.10.98 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 2.10.126-128 state:

'2.10.126 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.

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

2.10.128 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 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 2.10.158-159 state:

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[22] *'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.'*

2.10.158 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).

2.10.159 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.

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare is provided for 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[23] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

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 Ireland, 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 below. These relate specifically to the sighting distance for railway signals.

Reflections and Glare

The extract below is taken from Section A5 – Reflections and glare (pages 64-65) of the 'Signal Sighting Assessment Requirements'[24] which details the requirement for assessing glare towards railway signals.

Reflections and glare

[23] Pager Power Glint and Glare Guidance, Fourth Edition (4.0), August 2022.

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

Rationale

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

Guidance

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

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

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

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

a) *Disability glare, caused by scattering of light in the eye, can make it difficult to read a lit display.*
b) *Discomfort glare, which is often associated with disability glare. While being unpleasant, it does not affect the signal reading time directly, but may lead to distraction and fatigue.*

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 below is taken from Appendix F - Guidance on Field of Vision (pages 98-101) of the 'Signal Sighting Assessment Requirements'25 which details the visibility of signals, train drivers' field of vision and the implications with regard to signal positioning.

Asset visibility

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

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

a) Position in the observer's visual field.

b) Contrast with its background.

c) Luminance properties.

d) The observer's adaptation to the illumination level of the environment.

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

Field of vision

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

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

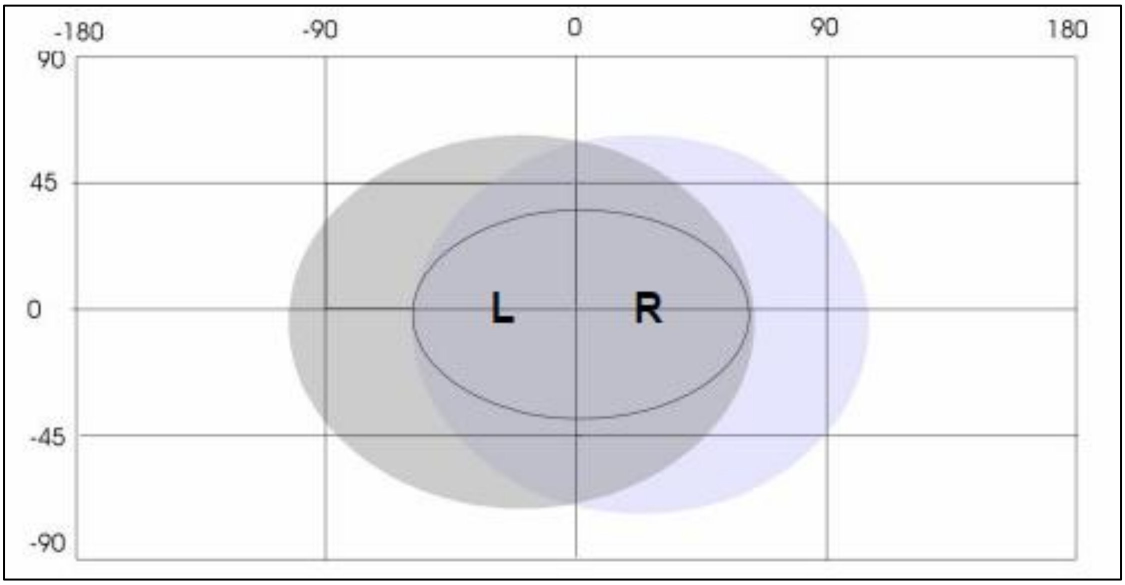


Figure G 21 - Field of view

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.

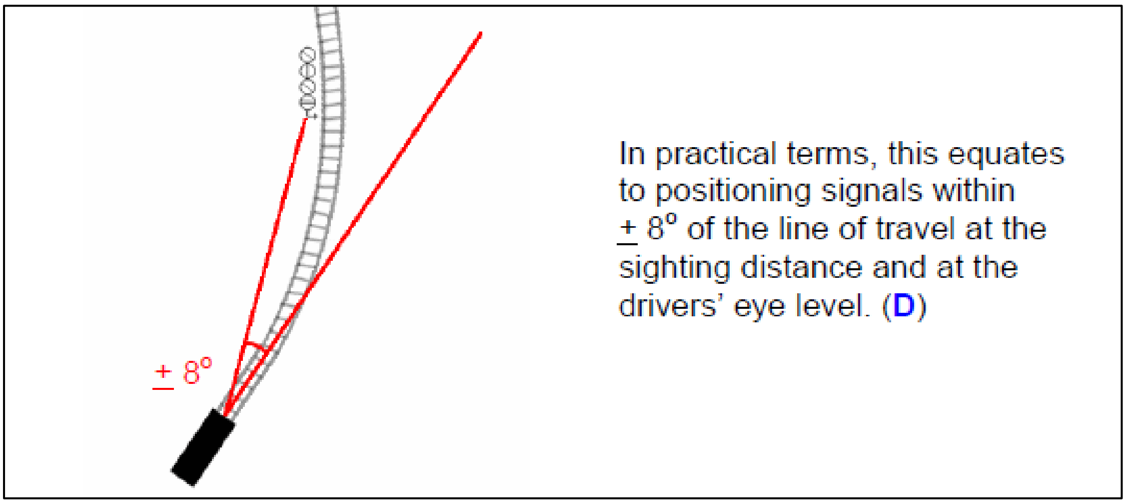


Figure G 22 - Signal positioning

'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° cone at 15.44 m in front of the driver*
16	*2.25*	-
17	*2.39*	-
18	*2.53*	*A stop aspect positioned 5.1 m above rail level and 0.9 m from the left hand rail is within the 8° cone at 17.93 m in front of the driver*
19	*2.67*	-
20	*2.81*	-
21	*2.95*	-
22	*3.09*	-
23	*3.23*	-
24	*3.37*	-
25	*3.51*	*A stop aspect positioned 3.3 m above rail level and 2.1 m from the right hand rail is within the 8° cone at 25.46 m in front of the driver*

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

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

Determining the Assessed Minimum Reading Time

The extracts below are taken from the RIS-0737-CCS-1 of the 'Signal Sighting Assessment Requirements', which details the required minimum reading time for a train driver when approaching a signal.

The following abbreviations are defined within the 'Definitions and Abbreviations':

'Baseline response time

The minimum time value that can be used by the SSC to specify the MRT for a particular signalling asset type.

Supplementary response time

The assessed amount of extra time that the SSC adds to the BRT to determine the MRT value for a specific lineside signalling asset.'

The following extract is taken from page 114 of the RIS-0737-CCS-1:

'Minimum response time (MRT)

The assessed minimum time needed by a driver (or other authorised user) to respond to the information presented by a specific lineside signalling asset, taking account of the following human tasks:

a) Read the display or display combination.

a) Interpret the display or display combination

b) Assimilate all of the available information

c) Decide what action to take (if any), and when it needs to be taken

d) Take the action, where necessary, before the train passes the asset.

MRT = BRT + SRT'

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[26];
- 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.

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

Many LED signal manufacturers[27,28,29] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

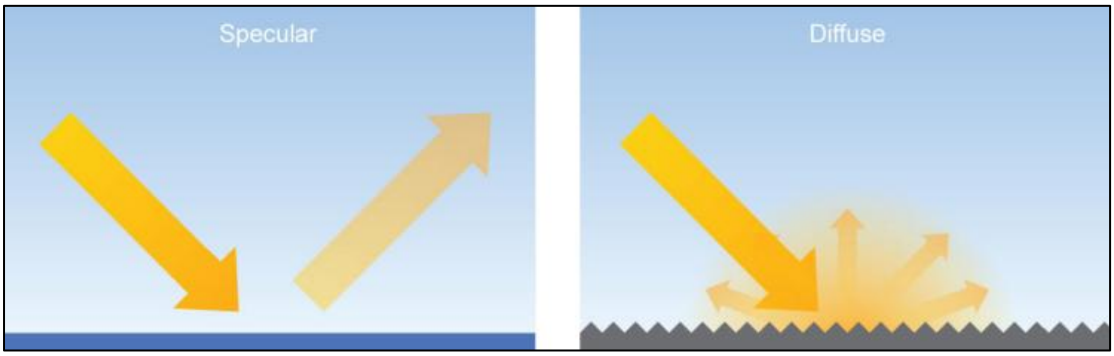
Overview

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

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

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[30], 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

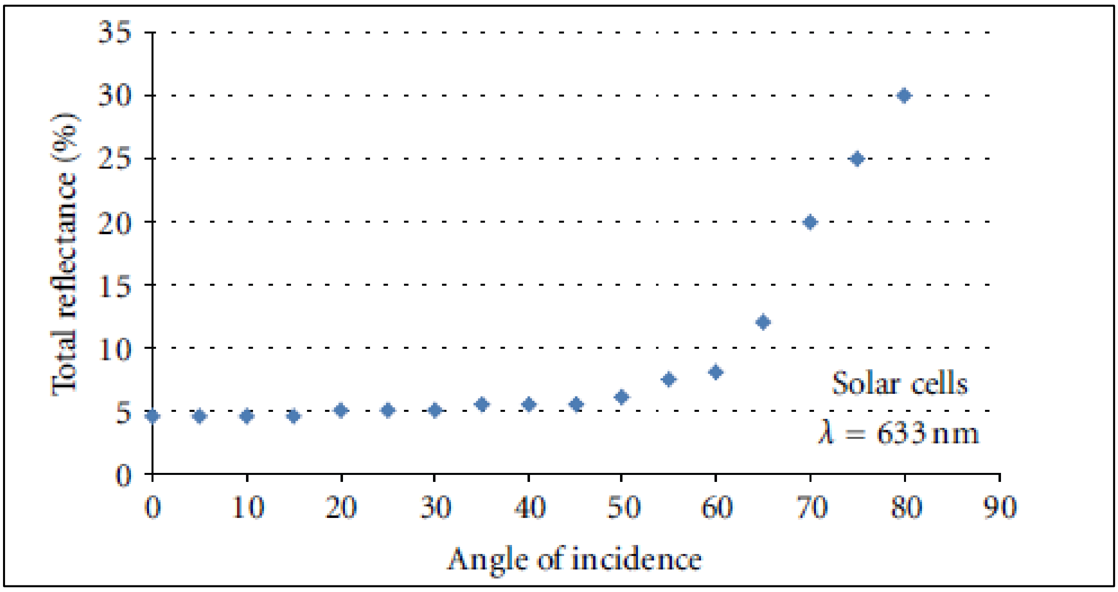
[30] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

Solar Reflection Studies

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

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

Evan Riley and Scott Olson published in 2011 their study titled: *A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems*[31]". They researched the potential glare that a pilot could experience from a 25-degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

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

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

FAA Guidance – "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[32]

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

Surface	Approximate Percentage of Light Reflected[33]
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).

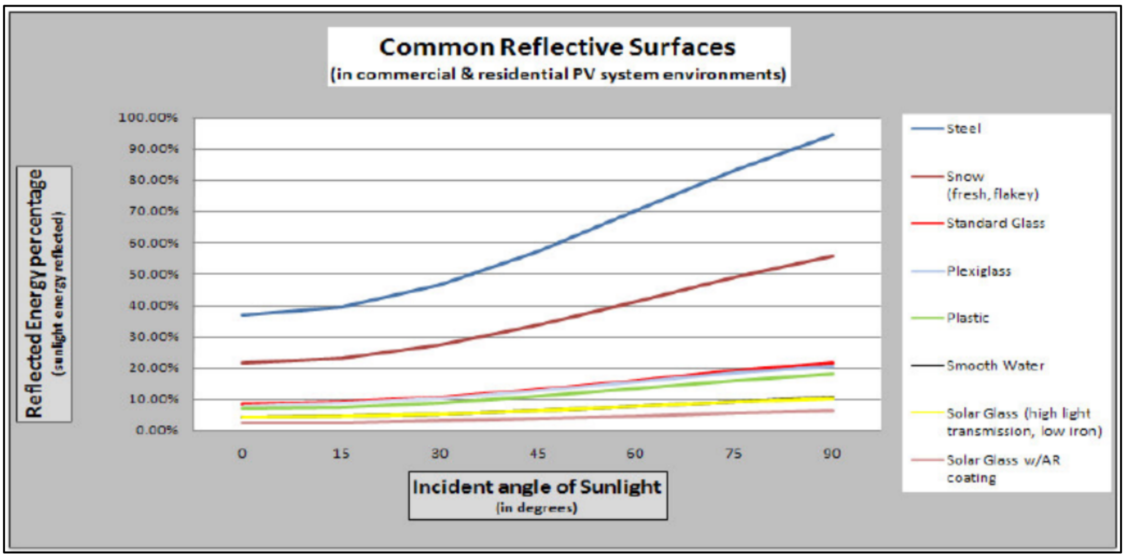
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[34] 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.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

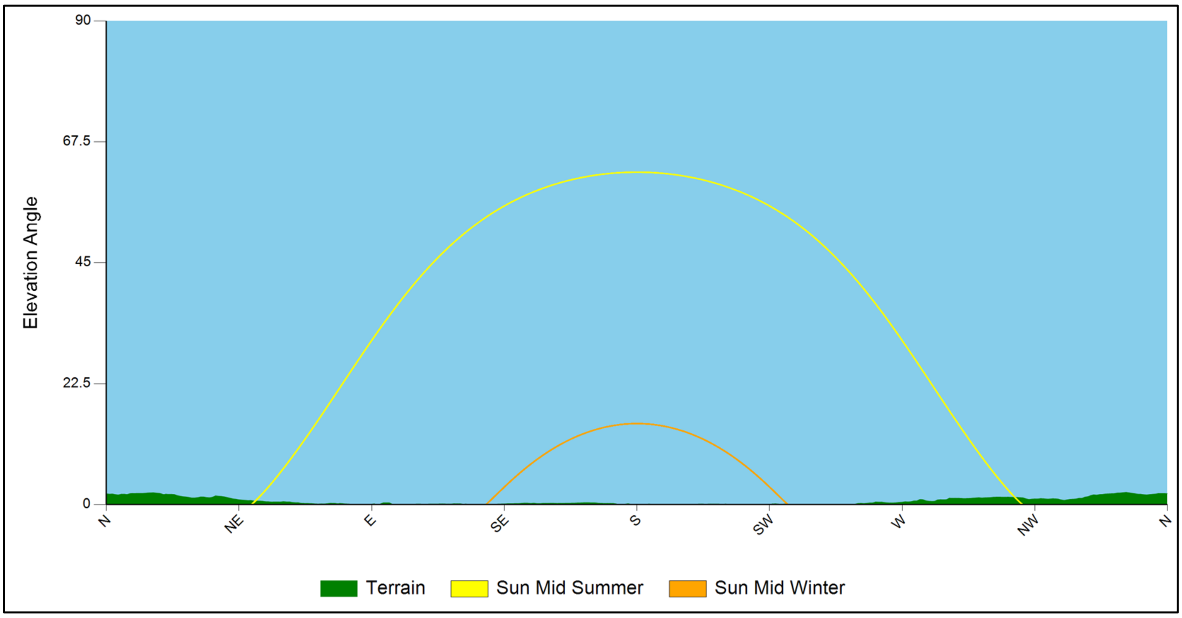
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

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



Terrain at the visible horizon and Sun paths

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

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

Impact Significance Definition

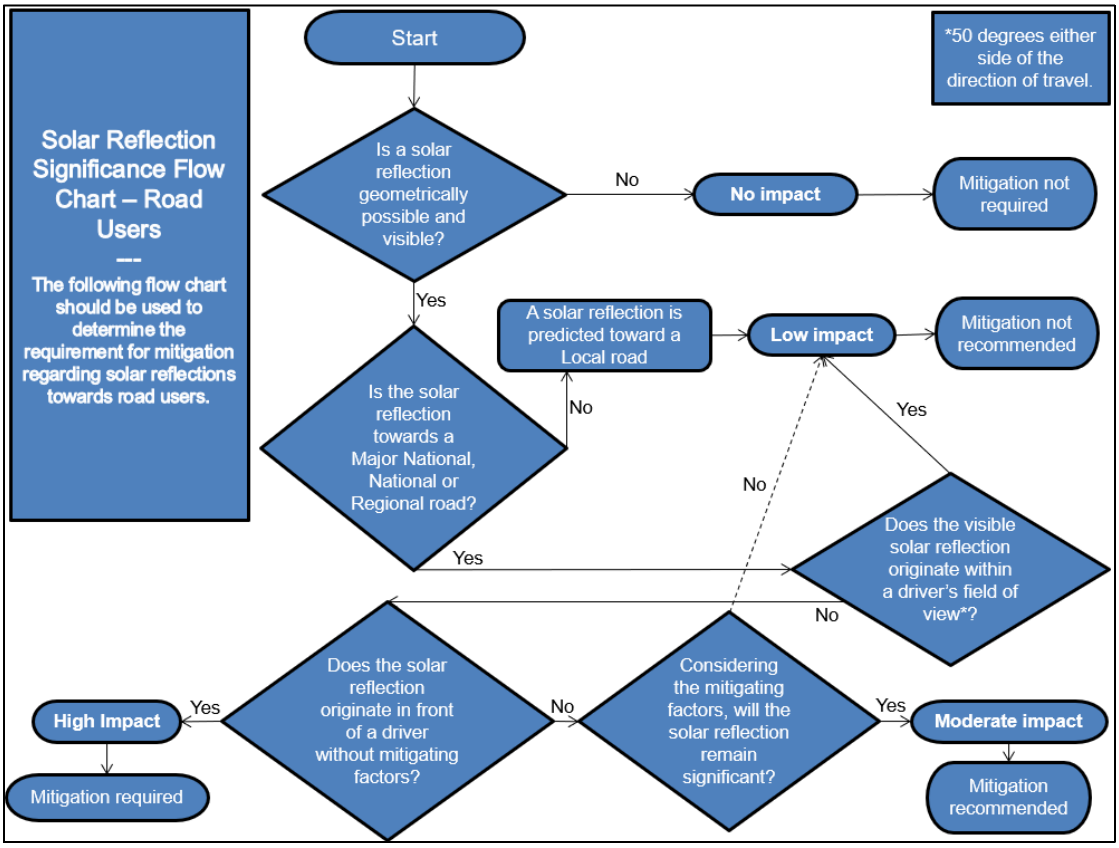
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels 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

Assessment Process for Road Receptors

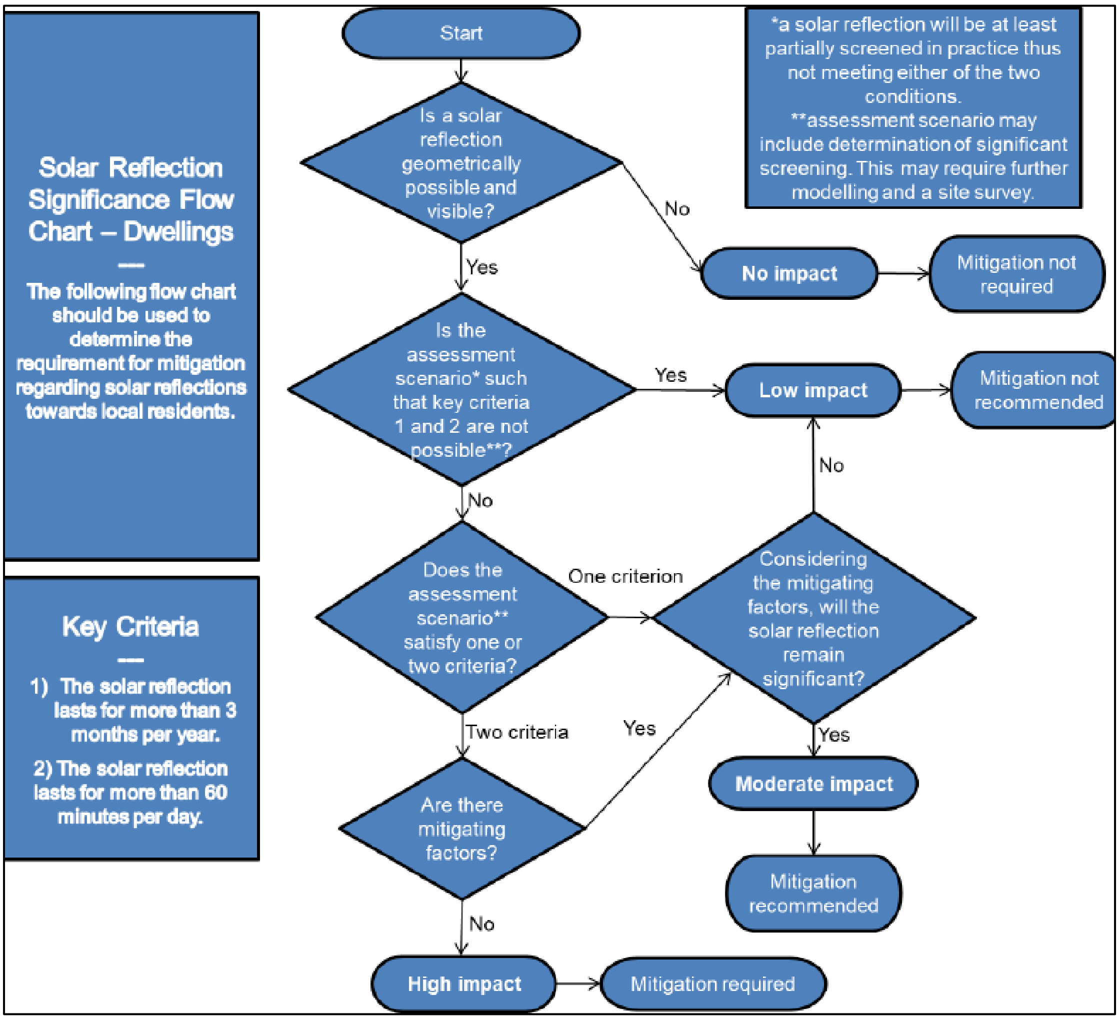
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

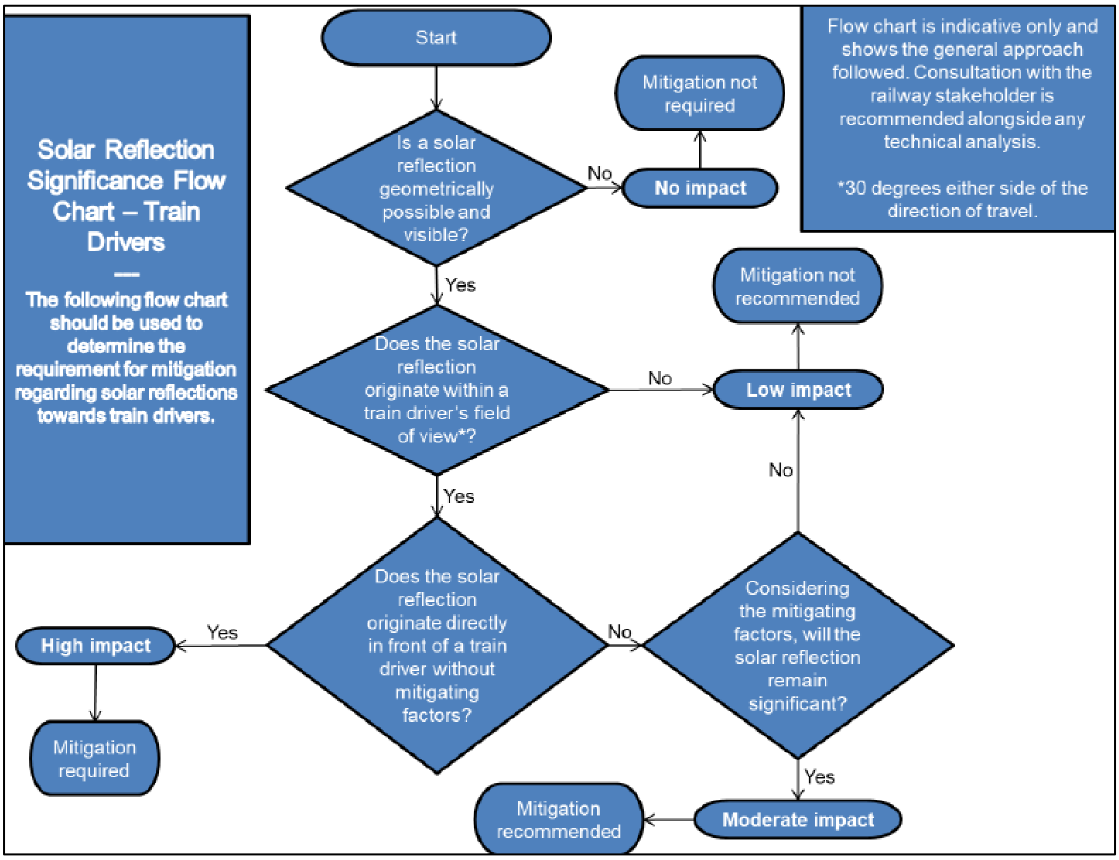
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling receptor mitigation requirement flow chart

Assessment Process for Train Driver Receptors

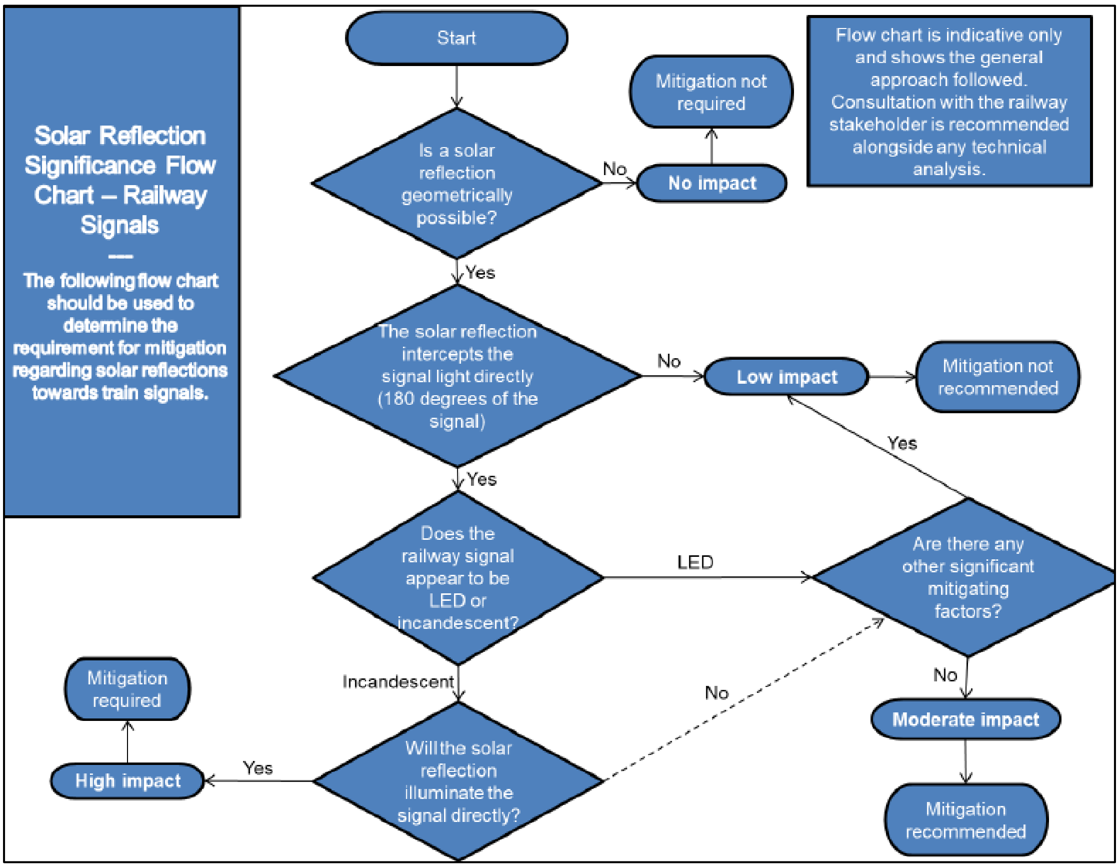
The flow chart presented below has been followed when determining the mitigation requirement for train driver receptors.



Train driver impact significance flow chart

Assessment Process for Railway Signals

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



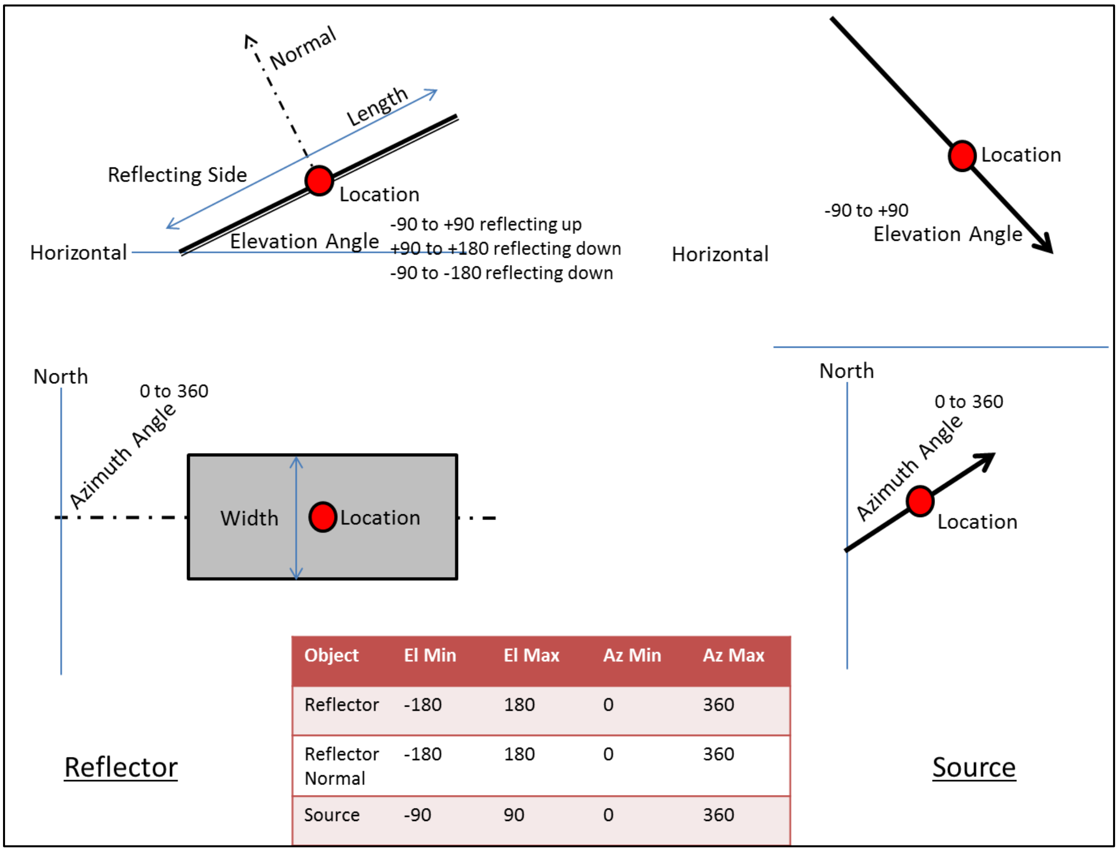
Railway signal impact significance flow chart

APPENDIX E – PAGER POWER'S REFLECTION CALCULATIONS METHODOLOGY

The calculations are three dimensional and complex, accounting for:

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

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



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

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

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

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

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

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

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)[35].

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

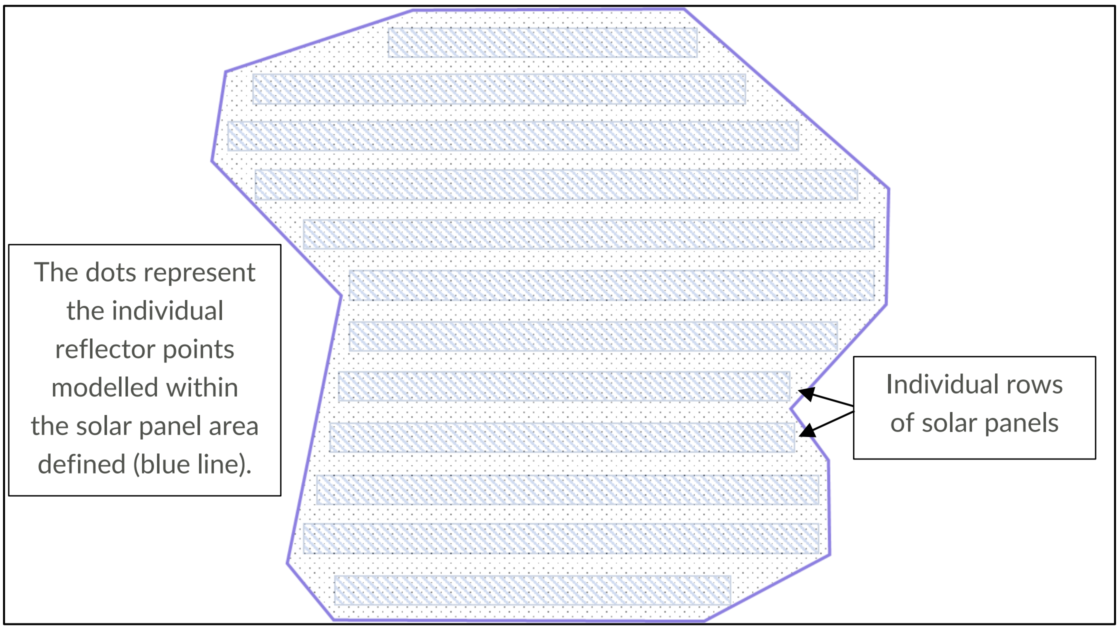
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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..

[35] 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

Dwelling Receptor Data

The table below presents the coordinate data for assessed dwelling receptors.

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
1	51.58872	-2.855038	20.42	49	51.58187	-2.886136	13.96
2	51.58835	-2.85431	21.32	50	51.58201	-2.878709	10.80
3	51.58804	-2.852813	23.01	51	51.58145	-2.877114	9.80
4	51.58741	-2.853649	24.21	52	51.58106	-2.876234	9.45
5	51.58759	-2.858772	11.80	53	51.59241	-2.911769	15.05
6	51.58765	-2.858436	12.18	54	51.59133	-2.912907	16.04
7	51.58845	-2.880258	26.85	55	51.59105	-2.913153	14.34
8	51.58847	-2.879248	22.67	56	51.59084	-2.913309	14.70
9	51.58701	-2.879078	17.90	57	51.59057	-2.913132	12.23
10	51.58710	-2.877971	14.19	58	51.59043	-2.913358	13.02
11	51.58683	-2.877675	11.80	59	51.59032	-2.913789	13.85
12	51.58657	-2.877536	11.80	60	51.59007	-2.913989	14.21
13	51.58631	-2.877963	12.19	61	51.58995	-2.914144	14.12
14	51.58609	-2.877713	11.61	62	51.58975	-2.913664	11.21
15	51.58551	-2.878741	12.85	63	51.58967	-2.913749	10.65
16	51.58573	-2.877378	10.89	64	51.58954	-2.914547	13.16
17	51.58545	-2.877068	11.05	65	51.58935	-2.914106	10.77
18	51.58528	-2.877754	10.80	66	51.58914	-2.914083	10.01

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
19	51.58519	-2.877971	10.80	67	51.58889	-2.914184	9.51
20	51.58493	-2.878078	10.80	68	51.58855	-2.914137	8.79
21	51.58471	-2.878292	10.80	69	51.58812	-2.91408	9.00
22	51.58458	-2.878416	10.80	70	51.58799	-2.914116	9.07
23	51.58442	-2.878483	10.80	71	51.58781	-2.914024	8.67
24	51.58432	-2.879954	11.67	72	51.58757	-2.914757	9.53
25	51.58440	-2.879106	10.91	73	51.58739	-2.914665	9.07
26	51.58425	-2.879086	10.80	74	51.58718	-2.914719	8.77
27	51.58414	-2.879127	10.80	75	51.58699	-2.914726	8.80
28	51.58403	-2.878731	10.80	76	51.5868	-2.914842	9.55
29	51.58383	-2.878775	10.80	77	51.58613	-2.914542	7.80
30	51.58389	-2.879208	10.80	78	51.58593	-2.914675	8.24
31	51.58354	-2.87875	10.80	79	51.58578	-2.91536	9.07
32	51.58364	-2.879246	10.80	80	51.58558	-2.915569	9.15
33	51.58335	-2.878859	10.80	81	51.58544	-2.915646	8.88
34	51.58307	-2.879576	10.80	82	51.58533	-2.915729	8.80
35	51.58266	-2.880255	10.93	83	51.58523	-2.915842	8.80
36	51.58235	-2.880253	10.80	84	51.58499	-2.915876	8.80
37	51.58227	-2.880499	10.80	85	51.58329	-2.917885	10.96
38	51.58222	-2.880711	10.96	86	51.58295	-2.917328	10.80
39	51.58205	-2.880771	10.80	87	51.58269	-2.916054	9.80

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
40	51.58192	-2.881098	10.80	88	51.58785	-2.911955	9.20
41	51.58181	-2.881509	11.03	89	51.59034	-2.905916	34.06
42	51.58136	-2.882082	10.99	90	51.59269	-2.896003	19.22
43	51.58152	-2.882528	11.69	91	51.59334	-2.892536	23.47
44	51.58141	-2.882855	11.33	92	51.59366	-2.892105	22.97
45	51.58127	-2.883289	10.93	93	51.59383	-2.89174	24.95
46	51.58064	-2.884515	10.80	94	51.58338	-2.914504	8.80
47	51.58074	-2.884852	10.91	95	51.5835	-2.913196	8.80
48	51.58062	-2.885111	10.80				

Dwelling receptor data

Road Receptor Data

The table below presents the coordinate data for assessed road receptors.

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
1	51.59397	-2.860707	33.89	13	51.59259	-2.861235	19.72
2	51.59360	-2.859386	37.64	14	51.59191	-2.860294	19.05
3	51.59323	-2.858068	34.22	15	51.59130	-2.859227	19.67
4	51.59284	-2.856758	30.01	16	51.59079	-2.85804	21.43
5	51.59245	-2.855455	37.81	17	51.59035	-2.856776	25.50
6	51.59204	-2.854168	39.15	18	51.58997	-2.85546	27.03
7	51.59162	-2.852888	39.78	19	51.58963	-2.854121	27.37
8	51.59119	-2.851614	39.92	20	51.58928	-2.852785	28.43

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
9	51.59075	-2.85035	39.01	21	51.58894	-2.851448	29.92
10	51.59064	-2.850032	38.45	22	51.58858	-2.850114	29.53
11	51.59397	-2.863092	22.36	23	51.58826	-2.849085	31.99
12	51.59328	-2.862164	20.41				

Road receptor data

Train Driver Receptor Data

An additional height of 2.75m has been added to the ground height, this has been taken as typical eye level for a train driver.

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
1	51.58162	-2.914467	10.75	19	51.58050	-2.888462	11.75
2	51.58156	-2.913022	9.75	20	51.58043	-2.887018	12.10
3	51.58150	-2.911577	9.75	21	51.58037	-2.885573	11.75
4	51.58144	-2.910133	10.75	22	51.58031	-2.884128	11.75
5	51.58137	-2.908688	10.75	23	51.58025	-2.882684	11.75
6	51.58131	-2.907243	10.75	24	51.58018	-2.881239	10.75
7	51.58125	-2.905798	11.75	25	51.58012	-2.879794	10.75
8	51.58119	-2.904354	11.75	26	51.58006	-2.878349	10.75
9	51.58112	-2.902909	11.75	27	51.58	-2.876905	10.01
10	51.58106	-2.901464	11.75	28	51.57993	-2.87546	9.75
11	51.58100	-2.90002	11.75	29	51.57987	-2.874015	9.75
12	51.58093	-2.898575	11.75	30	51.57981	-2.872571	9.75
13	51.58087	-2.89713	11.75	31	51.57974	-2.871126	9.75

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
14	51.58081	-2.895686	11.75	32	51.57968	-2.869681	9.75
15	51.58075	-2.894241	11.75	33	51.57962	-2.868237	9.75
16	51.58068	-2.892796	11.89	34	51.57956	-2.866792	9.63
17	51.58062	-2.891352	11.75	35	51.57954	-2.866407	9.64
18	51.58056	-2.889907	11.75				

Train driver receptor data

Railway Signal Receptor Data

An additional height of 3.3m has been added to the ground height, this has been taken as the typical height of a trackside signal.

No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)	No.	Latitude (°)	Longitude (°)	Assessed Height (m amsl)
1	51.57959	-2.866537	10.30	6	51.58048	-2.890546	12.30
2	51.57953	-2.866899	10.05	7	51.58157	-2.911595	10.30
3	51.58065	-2.890616	12.30	8	51.58149	-2.911531	10.30
4	51.58057	-2.890537	12.30	9	51.58150	-2.911619	10.30
5	51.58057	-2.890615	12.30	10	51.58140	-2.911536	10.30

Railway signal receptor data

Modelled Reflector Data

The table below presents the coordinate data for modelled reflector area used in the assessment.

Western Panel Area

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
1	-2.90596	51.58376	7	-2.90491	51.58378
2	-2.90727	51.58193	8	-2.90535	51.5841

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
3	-2.90551	51.58182	9	-2.90572	51.58432
4	-2.90341	51.58172	10	-2.90673	51.58521
5	-2.9032	51.5826	11	-2.90726	51.58471
6	-2.90321	51.58321			

Modelled reflector area

Eastern Panel Area

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
1	-2.89167	51.58202	68	-2.86941	51.58748
2	-2.88896	51.58119	69	-2.86993	51.58709
3	-2.8889	51.58184	70	-2.87002	51.58658
4	-2.88814	51.58194	71	-2.87036	51.58656
5	-2.88831	51.58228	72	-2.87158	51.58611
6	-2.88751	51.58231	73	-2.87242	51.58647
7	-2.88586	51.58294	74	-2.87048	51.58722
8	-2.88479	51.58369	75	-2.87042	51.58769
9	-2.88103	51.58725	76	-2.87109	51.58859
10	-2.88173	51.58741	77	-2.87037	51.58917
11	-2.88158	51.58788	78	-2.86988	51.58924
12	-2.88148	51.58856	79	-2.86959	51.58943
13	-2.88122	51.58942	80	-2.8693	51.58994
14	-2.88009	51.58931	81	-2.86886	51.59014
15	-2.87873	51.59175	82	-2.86908	51.59079

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
16	-2.87786	51.59171	83	-2.86951	51.59099
17	-2.87748	51.59144	84	-2.87089	51.59155
18	-2.87685	51.5913	85	-2.87208	51.59191
19	-2.87623	51.59127	86	-2.87275	51.59205
20	-2.87637	51.58976	87	-2.87301	51.59252
21	-2.87737	51.58978	88	-2.87331	51.5925
22	-2.87728	51.58912	89	-2.87413	51.59195
23	-2.87697	51.58807	90	-2.87461	51.59255
24	-2.87622	51.58809	91	-2.87511	51.59275
25	-2.87571	51.58743	92	-2.87685	51.59311
26	-2.87527	51.58769	93	-2.87734	51.5931
27	-2.8747	51.58742	94	-2.87759	51.59276
28	-2.87574	51.58674	95	-2.87879	51.59273
29	-2.87579	51.58632	96	-2.87904	51.59397
30	-2.87568	51.5853	97	-2.88001	51.59386
31	-2.87591	51.58465	98	-2.88035	51.59205
32	-2.87625	51.58459	99	-2.88088	51.59178
33	-2.87709	51.58248	100	-2.88218	51.5907
34	-2.87503	51.58163	101	-2.88269	51.59018
35	-2.87406	51.58251	102	-2.88148	51.58988
36	-2.8728	51.58305	103	-2.88153	51.5889
37	-2.87098	51.58366	104	-2.88386	51.58934

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
38	-2.87035	51.58331	105	-2.88569	51.58954
39	-2.86908	51.58382	106	-2.88699	51.58884
40	-2.86667	51.58545	107	-2.88701	51.58786
41	-2.8666	51.58595	108	-2.88733	51.58713
42	-2.866	51.58604	109	-2.8879	51.58652
43	-2.86512	51.58634	110	-2.88853	51.58561
44	-2.86341	51.58708	111	-2.8892	51.58568
45	-2.8634	51.58717	112	-2.89065	51.58522
46	-2.86378	51.58718	113	-2.89094	51.58411
47	-2.86442	51.587	114	-2.8911	51.58412
48	-2.86688	51.58695	115	-2.89143	51.58441
49	-2.86649	51.58732	116	-2.89132	51.58508
50	-2.86569	51.58768	117	-2.89115	51.58556
51	-2.86537	51.58806	118	-2.89063	51.58596
52	-2.86573	51.58905	119	-2.8901	51.58614
53	-2.86519	51.5891	120	-2.89076	51.58666
54	-2.86524	51.58997	121	-2.8914	51.5867
55	-2.86599	51.59076	122	-2.89209	51.58642
56	-2.86582	51.59182	123	-2.89275	51.58594
57	-2.86727	51.59283	124	-2.89308	51.58612
58	-2.8675	51.59264	125	-2.89343	51.58611
59	-2.86758	51.59221	126	-2.89416	51.58531

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
60	-2.86829	51.59175	127	-2.89548	51.58462
61	-2.86813	51.59154	128	-2.89598	51.58415
62	-2.86757	51.59101	129	-2.89648	51.58367
63	-2.86747	51.59063	130	-2.89651	51.58348
64	-2.86725	51.59028	131	-2.89586	51.5833
65	-2.86717	51.5896	132	-2.89587	51.58119
66	-2.86766	51.58859	133	-2.89156	51.58096
67	-2.86847	51.58756			

Modelled reflector area – eastern panel area

APPENDIX H – DETAILLED MODELLING RESULTS

Model Output Charts

The Pager Power charts for the receptors are shown below and on the following pages. 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 the page. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas.
- The sunrise and sunset curves throughout the year (red and yellow lines).

Full modelling results are available upon request.

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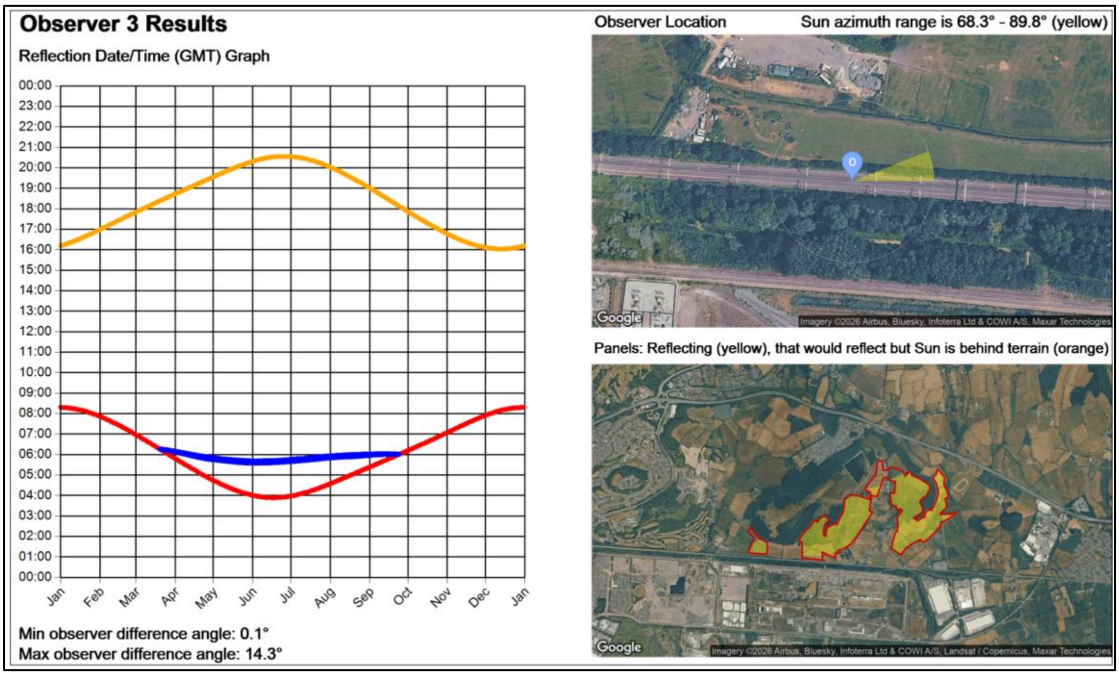
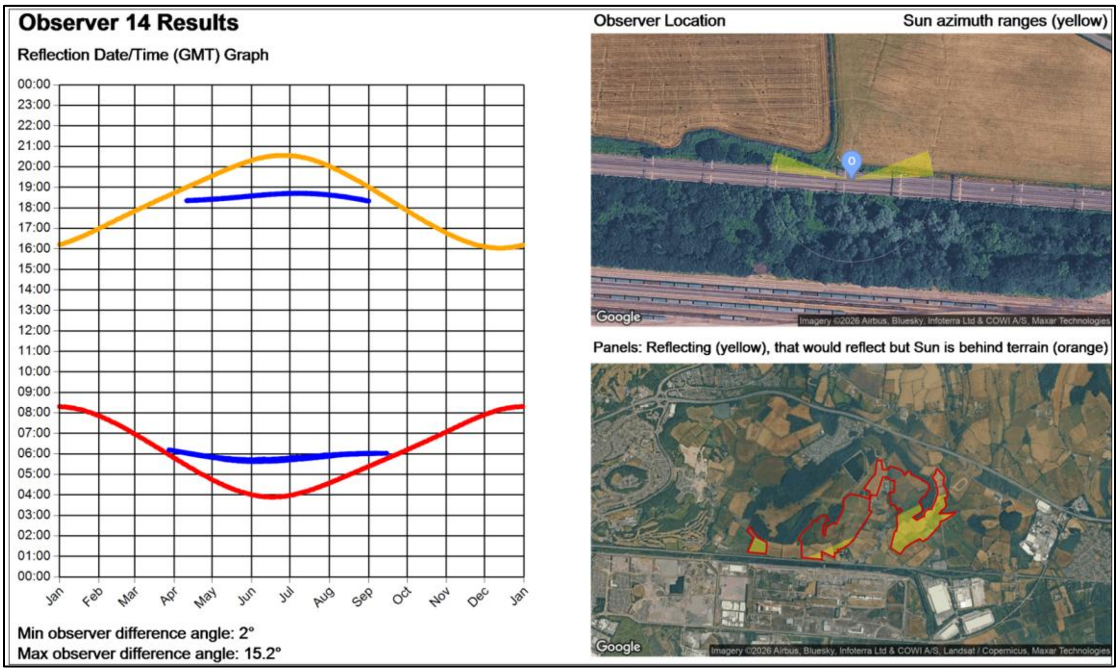
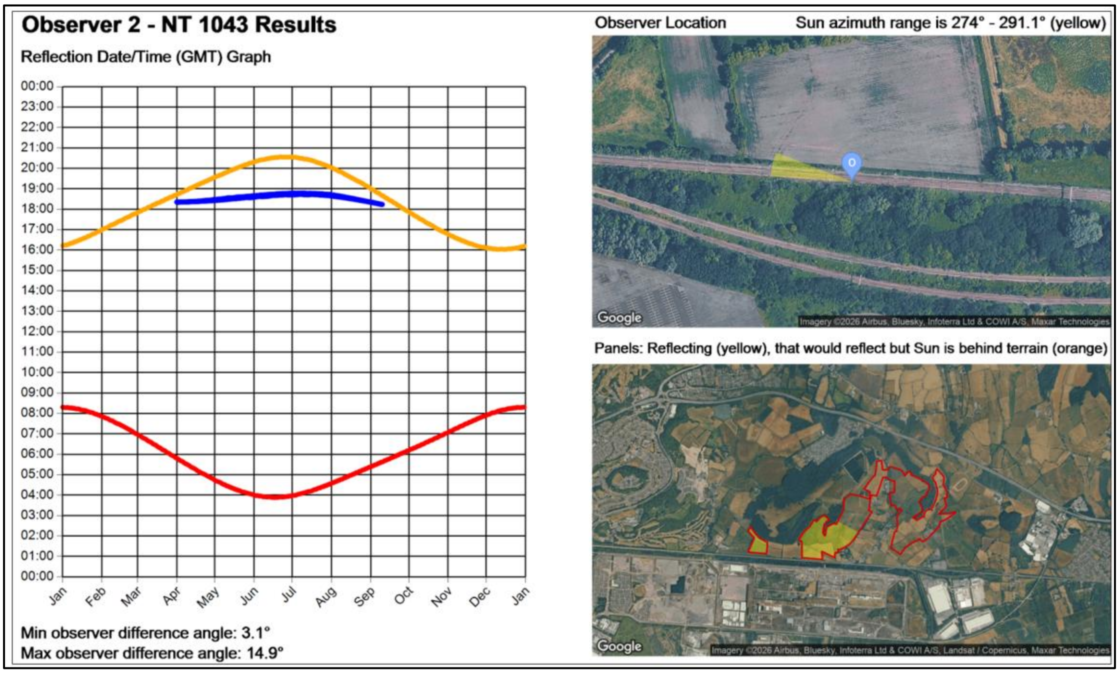
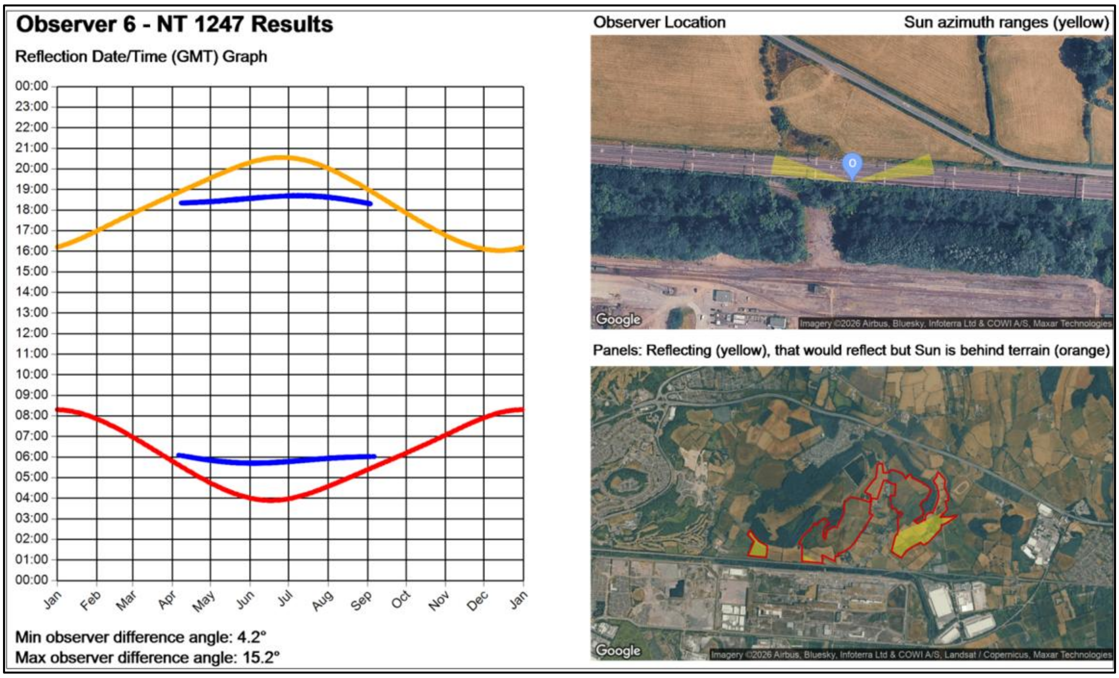
Train Driver Receptors



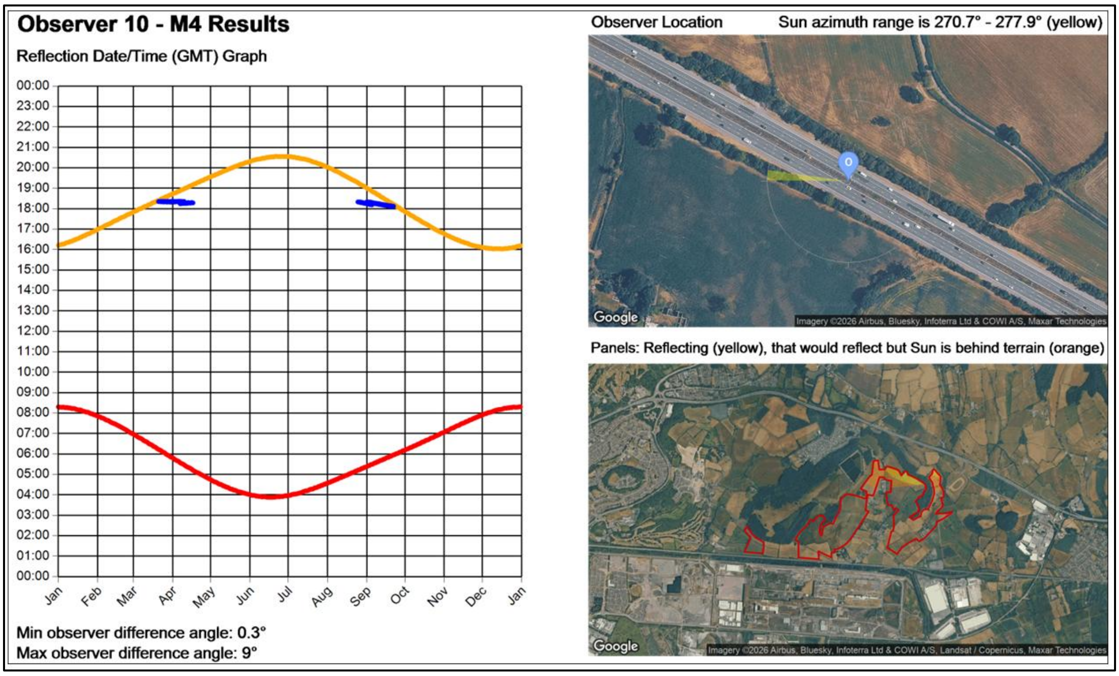


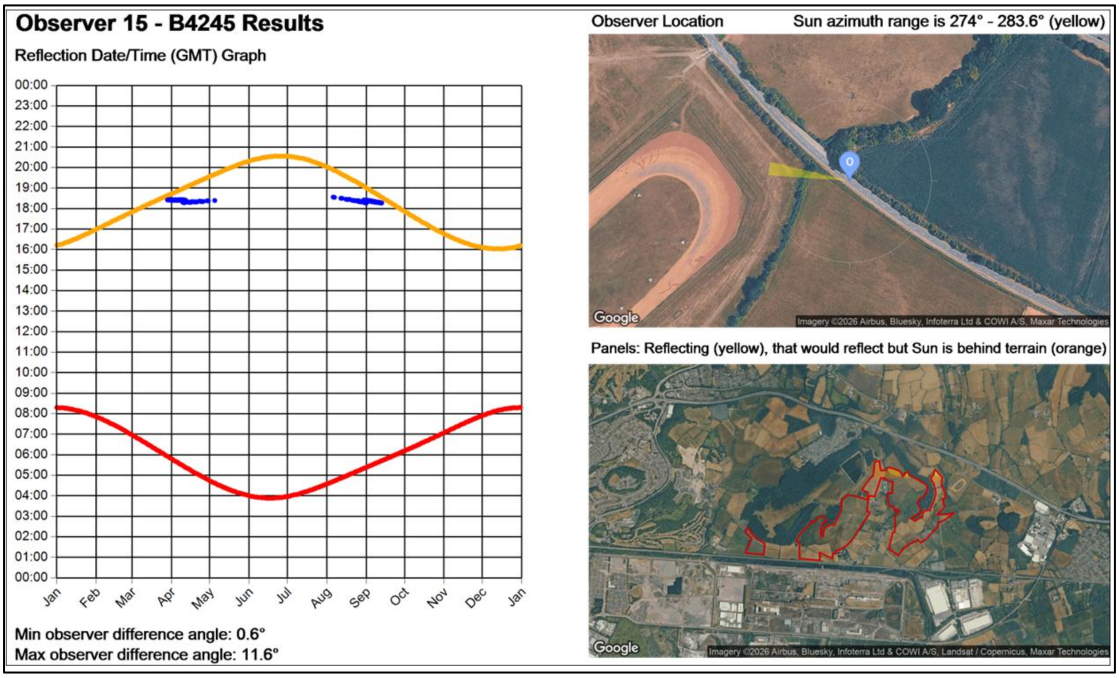
Railway Signal Receptors



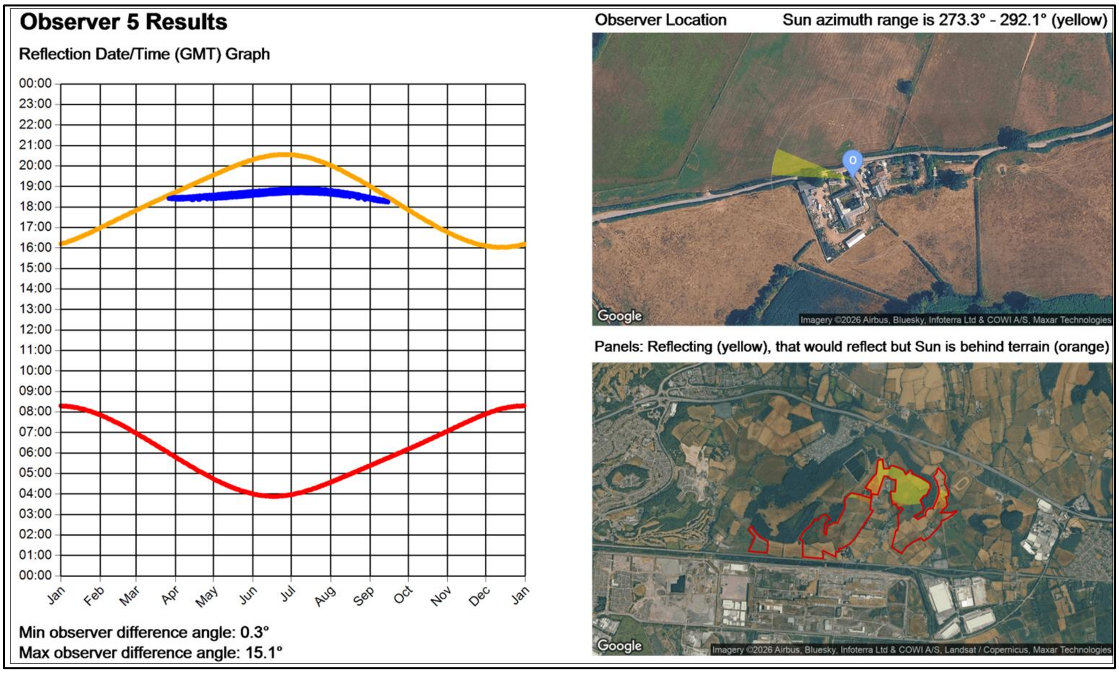


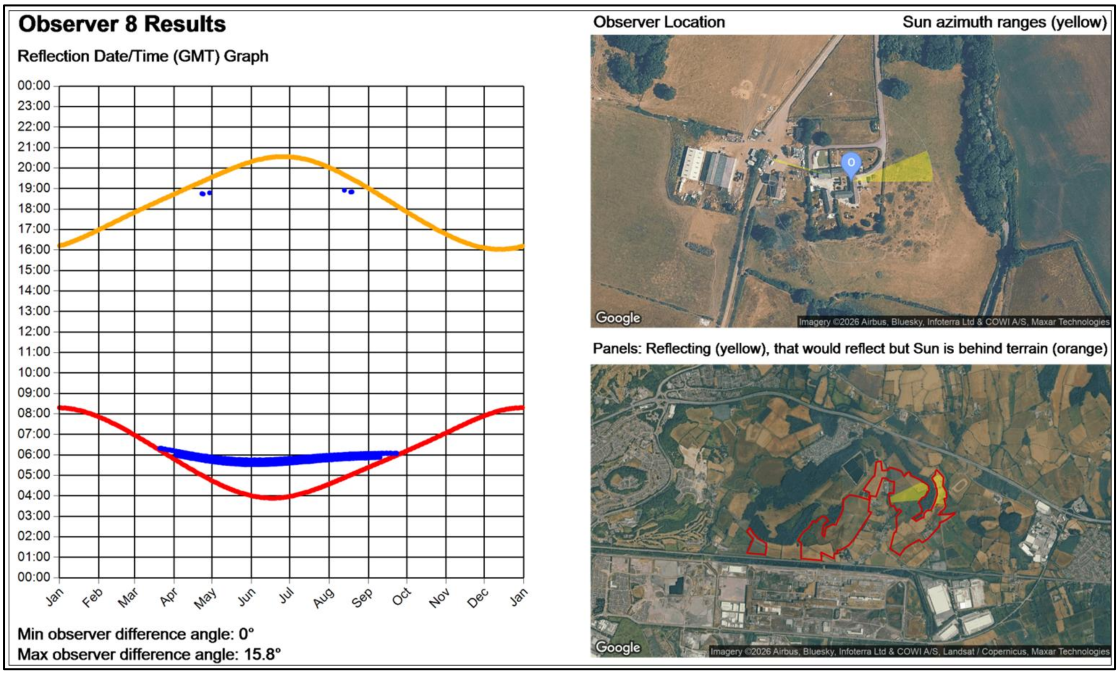
Road Receptors

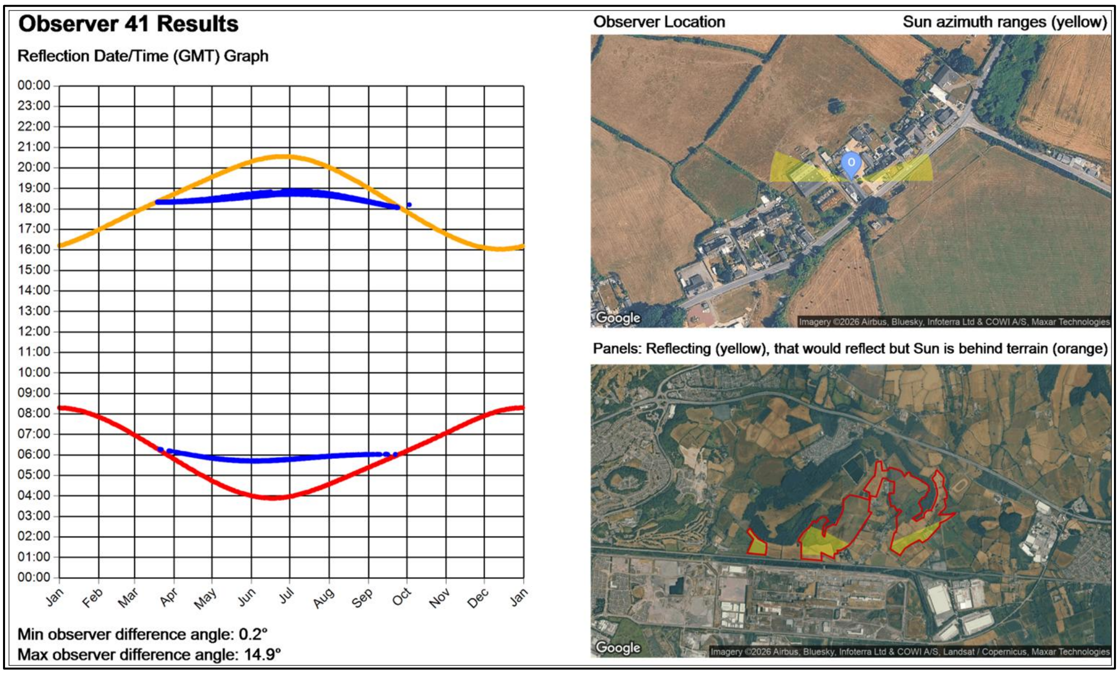


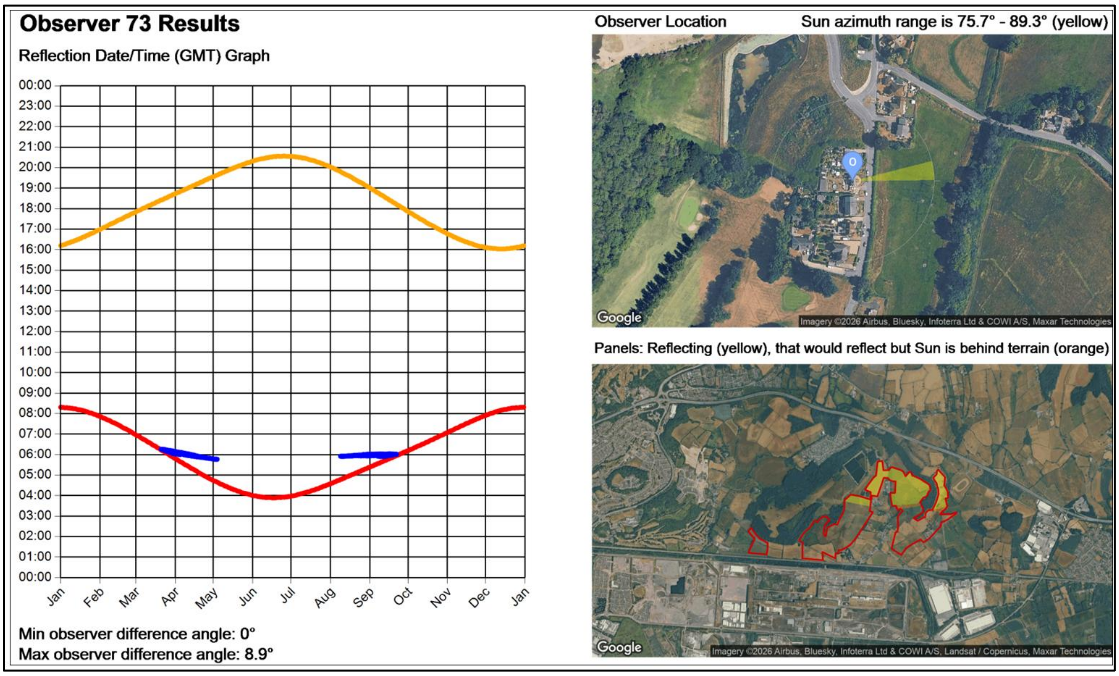


Dwelling Receptors






Observer 41 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: 0.2°
Max observer difference angle: 14.9°
Observer Location
Sun azimuth ranges (yellow)
Google
Imagery ©2026 Airbus, Bluesky, Infoterra Ltd & COWI A/S, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2026 Airbus, Bluesky, Infoterra Ltd & COWI A/S, Landsat / Copernicus, Maxar Technologies


Observer 73 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°
Max observer difference angle: 8.9°
Observer Location
Sun azimuth range is 75.7° - 89.3° (yellow)
Google
Imagery ©2026 Airbus, Bluesky, Infoterra Ltd & COWI A/S, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2026 Airbus, Bluesky, Infoterra Ltd & COWI A/S, Landsat / Copernicus, Maxar Technologies

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