



# Technical Aviation Assessment: Atlas Business Park PV Array / Manchester International Airport Solar Panel Glint & Glare Analysis

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## Glossary

| Term | Meaning                                    |
|------|--------------------------------------------|
| AIP  | Aeronautical Information Publication       |
| AIS  | Aeronautical Information Service           |
| ALP  | Airport Layout Plan                        |
| ARC  | Anti-Reflective Coating                    |
| ATC  | Air Traffic Control                        |
| ATCT | Airport Traffic Control Tower              |
| ATS  | Air Traffic Services                       |
| BST  | British Summer Time                        |
| CAA  | UK Civil Aviation Authority                |
| CAP  | Civil Aviation Publication                 |
| CNS  | Communication, Navigation and Surveillance |
| DOE  | US Department of Energy                    |
| FAA  | US Federal Aviation Administration         |
| ft   | Feet                                       |
| G&G  | Glint & Glare                              |
| GA   | General Aviation                           |
| IN   | Information Notice                         |
| km   | Kilometre                                  |
| LoS  | Line of Sight                              |
| m    | Metre                                      |
| MW   | Megawatt                                   |

|       |                                  |
|-------|----------------------------------|
| NATS  | National Air Traffic Services    |
| nm    | Nautical Miles                   |
| PV    | Photovoltaic                     |
| RWY   | Runway                           |
| SGHAT | Solar Glare Hazard Analysis Tool |
| Thld  | Threshold                        |
| UTC   | Universal Time Coordinated       |
| VCR   | Visual Control Room              |

Table 1 Glossary of Terms

# 1 Introduction

## 1.1 Stakeholder Overview

Manchester International Airport (MAN) is owned and operated by Manchester Airports Group Plc (MAG). MAG operates three major UK airports (MAN, London Stansted and East Midlands), and is the largest UK -owned airport operator.

Ridge, a property and construction consultancy firm operating on behalf of Aviva investors, are advancing plans to develop land adjoining to the Wythenshaw's Atlas Business Park. The plans include approximately 40,000sqm of warehousing and office space for light industrial use. The development is projected to boost the local economy by forty-two million pound and generate over six hundred jobs. The developer has included key environmental design principles throughout their planning process, such as landscaping the site for outdoor spaces and employee benefits, sustainability of construction/maintenance and a net-zero energy footprint, finally promoting existing and new transport network infrastructure.

## 1.2 Document Purpose and Scope

Given the proximity of the proposed Atlas Business Park Photo Voltaic (PV) solar panel development (Figure 1) to a live operational international airport, it is important that the construction and operation of the proposed PV array does not have an adverse impact on the day-to-day operations at MAN.

The purpose of this document is to provide a detailed set of analysis, conclusions, and recommendations to determine whether the proposed PV solar panels, located on the Atlas Business Park site, located immediately east (1.29km) of MAN runway 23R threshold, will have an adverse impact on aviation operations.



Figure 1 Distance from PV array site to MAN Rwy 23R Thld  
(Source: Google Earth Pro)

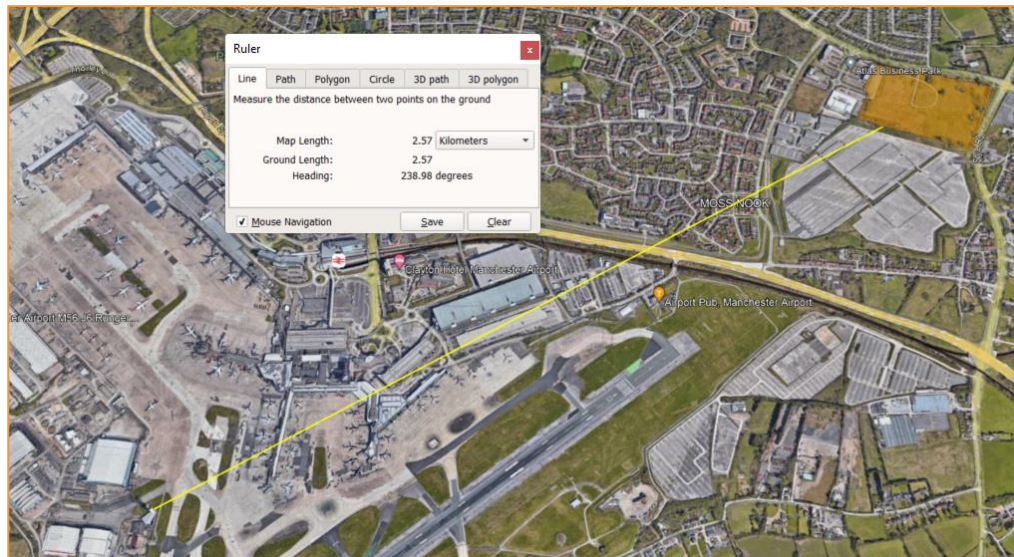


Figure 2 Distance from PV array site to MAN ATC Tower (Source: Google Earth Pro)

### 1.3 Document Structure

This document is structured as follows:

1. Introduction
2. Requirements Review
3. Glint & Glare Analysis
4. Conclusion
5. References

### 1.4 Background & Context

The Atlas Business Park plans include four building structures (five units in total) and six apex roofs (Figure 3). Eleven of the apexed pitched roofs are planned to mount a multiple configuration PV array of fixed and non-rotatable solar panels. The PV Arrays are not limited to a southerly direction. The PV plans are situated within the MAN Inner Horizontal Surface and is located beneath the runway 23R Approach path.

Ridge, the client, is seeking to ensure the safeguarding of the aerodrome against the potential hazard to aviation of all ground / building PV solar panel developments within 15km range from the aerodrome.



Figure 3 Proposal Plans for roof mounted PV Solar Array (Source: Client Supplied)

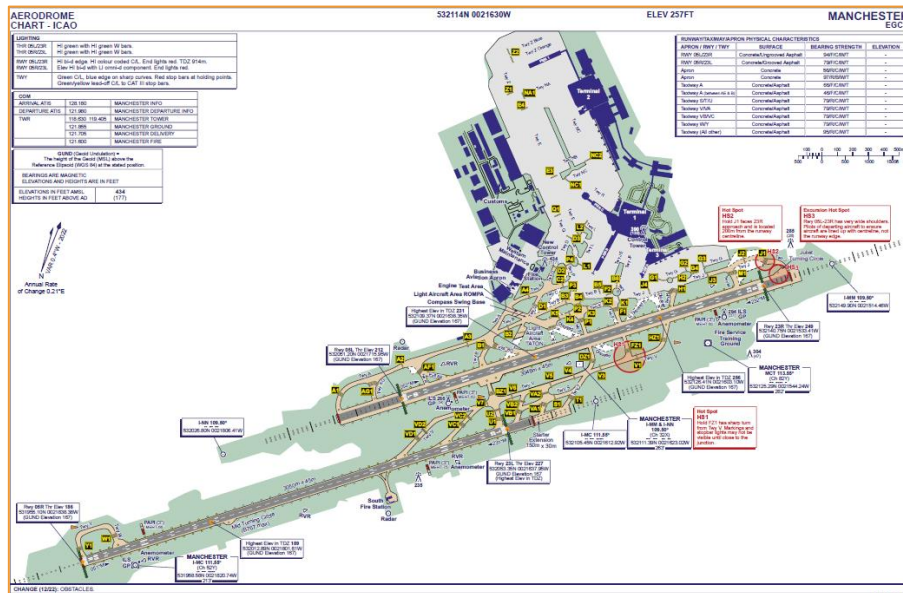


Figure 4 Manchester Aerodrome Chart (Source: UK Civil AIP (NATS))

Figure 3 above depicts an overview of the Atlas Business Park development plans. Figure 4 above shows the MAN aerodrome chart published in the UK Civil Aeronautical Information Publication (AIP).

## 2 Requirements Review

---

### 2.1 CAA Information Notice

#### 2.1.1 Background

As interest in the solar energy sector grew, the CAA published its Interim Guidance in 2010 to discuss associated regulatory and other obligations for aerodrome operators, planners, and PV developers. This was replaced in 2015 when the CAA published its Information Notice IN-2015-0NN *CAA Guidance – Solar Photovoltaic Energy System projects on and in the Vicinity of Aerodromes* [Ref 1]. The purpose of the Information Notice was to update and replace the Interim Guidance, providing further information to stakeholders considering PV developments. This document has since been withdrawn and superseded by UK Civil Aviation Publication (CAP) guidance.

#### 2.1.2 Scope

Where a solar PV development is being proposed within a licensed aerodrome boundary, the aerodrome operator must follow the process outlined in CAP 791 – Procedures for Changes to Aerodrome Infrastructure [Ref 2]. CAA approval for any development must be received prior to commencement of any construction, which requires the aerodrome operator to submit a formal application setting out the proposed development and that the necessary safety considerations have been fully assessed. This should include considerations concerning: a formal glint/glare or reflectivity assessment; details concerning the safeguarding assessment of the applicable obstacle limitation surfaces; the ANSP assessment of interference concerning Communication, Navigation & Surveillance (CNS) equipment; control of works; access to the site by the emergency services and wildlife hazard control.

Where a solar PV development is being proposed outside of the licensed aerodrome boundary, there is no requirement for the aerodrome operator to consult or notify the CAA to seek CAA approval prior to installation. However, in addition to statutory safeguarding obligations via the local planning authority, relevant aeronautical safety issues should be considered prior to any planning application.

#### 2.1.3 Further Information

The Federal Aviation Administration (FAA) in the United States issued an interim policy, titled *FAA Review of Solar Energy System Projects on Federally Obligated Airports* [Ref 3], in 2013. The CAA accepts and advocates use of this guidance until such time that the FAA had finalised and published their revised formal technical guidance for evaluating solar technologies for airports (CAP 738).

In 2021 the FAA updated its guidance [Ref 4] and determined that the glint and glare from solar energy systems to pilots on final approach is similar to what pilots routinely experience from water bodies, glass facades, buildings, car parks, and similar features. However, glint and glare reported by Air Traffic Control Tower (ATC-T) personnel is significant and thus the scope of the FAA policy is now directed towards minimising the effect on them.

The influence of this policy change on the CAA's policy is unknown at the present time so Osprey continue to assess the impact on pilots on approach, in accordance with CAP 738 Appendix C (as described in Section 2.2.2 below).

## 2.2 CAP 738

### 2.2.1 Introduction

CAP 738 – Safeguarding of Aerodromes Third edition published October 2020 [Ref 6] offers guidance to those responsible for the safe operation of an aerodromes or technical site, to help them assess what impact a proposed development or construction might have on that operation. The assessment is known as Safeguarding. The common aim of all safeguarding is to assess the implications of any development being proposed within the vicinity of an established aerodrome to ensure, as far as practicable, that the aerodrome and its surrounding airspace is not adversely impacted by the proposal, thus ensuring the continued safety of aircraft operating at the location.

### 2.2.2 Appendix C – Solar Photovoltaic Cells

Appendix C of CAP 738 gives details of all the regulatory guidance around the installation of a solar PV farm in and around an aerodrome. The guidance is brief, referencing the CAA Interim Guidance published in 2010, but makes no reference to the Information Notice IN-2015-0NN described above. It does state however, that the CAA would review its policy based on research carried out by the FAA and that the FAA had reviewed its original document, *Technical Guidance for Evaluating Selected Solar Technologies on Airports* [Ref 5], whilst providing a link to the Interim Policy published in 2013 [Ref 3].

Appendix C also states that it would be wise to consider other implications of accepting solar PV installations, especially in the event of an aircraft accident. Aerodrome operators should conduct a risk assessment to help understand what actions should be taken given this scenario.

## 2.3 CAP 791

### 2.3.1 Introduction

CAA Information Notice IN-2015-0NN states that where a solar PV development is being proposed within the licensed aerodrome boundary, the aerodrome operator must follow the process outlines in CAP 791 – Procedures for Changes to Aerodrome Infrastructure [Ref 2]. The purpose of CAP 791 is to give guidance on the procedures to be used to notify the CAA of changes at an aerodrome. It also includes guidance to help ensure that the changes comply with the licensing and certification criteria and are managed safely.

CAP 791 details a three-stage process to ensure operations at an aerodrome remain safe during construction of any on-aerodrome development and that it is transitioned into operations in a safe and efficient manner. The three stages detailed in CAP 791 are:

- Part 1 – Compliance
- Part 2 – Control
- Part 3 – Completion

### **2.3.2 The Atlas Business Park PV Development Site**

In the case of the Atlas Business Park PV development, the site is to the west of Manchester International Airport and outside the aerodrome boundary (Figure 3), resulting in the non-applicability of CAP 791. This PV solar development would mean that standard planning application regulations apply.

## **2.4 The Air Navigation Order**

### **2.4.1 Background**

Although there is no mandated requirement to seek permission from CAA to shine or reflect light into the sky, solar PV developers must ensure compliancy against The Air Navigation Order 2016 [Ref 10] which is the UK's legal statutory instrument for air navigation. Awareness of the following articles are required:

- Article 224 – Lights liable to endanger
- Article 225 – Lights which dazzle or distract
- Article 240 – Endangering safety of an aircraft

## **2.5 FAA Interim Policy 2013**

### **2.5.1 Introduction**

On 23<sup>rd</sup> October 2013, the FAA established interim FAA policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports [Ref 3], for proposals by sponsors of federally obligated airports to construct solar energy systems on airport property. The FAA adopted the interim policy because it was in the public interest to enhance safety by clarifying and adding standards for measuring ocular impact of proposed solar energy systems.

### **2.5.2 Background**

While solar PV are designed to absorb solar energy to maximise electrical energy production, in certain situations the glass surfaces of the solar energy systems can reflect sunlight and produce glint (a momentary flash of bright light) and glare (a continuous source of bright light). In conjunction with the United States Department of Energy (DOE), the FAA has determined that glint and glare from solar energy systems could result in an ocular impact to pilots and/or air traffic control (ATC) facilities and compromise the safety of the air transportation system. While the FAA supports solar energy systems on airports, the FAA seeks to ensure safety by eliminating the potential for ocular impact to pilots and/or air traffic control facilities due to glare from such projects.

The interim policy clarified one aspect and added standards for measurement of glint or glare presented in a Technical Guidance document, published in 2010. The 2 key points noted in the interim policy were as follows: are:

- The interim policy clarified the responsibility of airports to evaluate the potential for solar energy systems installed on airports to either block, reflect or disrupt radar signals, NAVAIDS, and other equipment required for safe aviation operations. The airport sponsor, in siting a proposed solar energy system, is responsible for limiting the potential for inference with communication, navigation, and surveillance (CNS) facilities. The sponsor should do so by ensuring that solar energy systems remain clear of the critical areas surrounding CNS facilities.
- Ocular impact must be analysed using the Solar Glare Hazard Analysis Tool (SGHAT) which is designed to determine whether a proposed solar energy project would result in the potential for ocular impact on an aerodrome. To obtain FAA approval to revise an airport layout plan to depict a solar installation, the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:
  - 1 No potential for glint or glare in the existing or planned Airport Traffic Control (ATC) Tower cab, and
  - 2 No potential for glare or “low potential for after-image” along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as 2 miles from 50 feet above the landing threshold using a standard 3° glidepath.

The update to the standards for measuring glint and glare included in the interim policy would be included in an update to the technical guidance, which would also provide enhanced criteria to ensure the proper siting of a solar energy installation to eliminate the potential for harmful glare to pilots or air traffic control facilities. The updated technical guidance, FAA Technical Guidance for Evaluating Selected Solar Technologies on Airports [Ref 5], originally due for release in 2013, was published in April 2018.

## 2.6 FAA Interim Policy 2021

In 2021, the FAA updated their 2013 Interim Policy on a FAA Review of Solar Energy System Projects on Federally Obligated Airports [Ref 3]. The latest version of the policy was updated to reflect the shifting safety approach to PV solar panels based on real world applications. The FAA has subsequently concluded that in most cases, the glint and glare affects routinely experienced by pilots on final approach is similar to those caused by existing water bodies, glass façade buildings, car parks and other similar features. As a result, the 2021 policy [Ref 4] only requires the glint & glare effects on the ATC Tower to be considered. For completeness, Osprey has completed the assessment based on the 2013 Interim Policy as this is still referred to in the UK regulatory guidance documentation. Therefore, the 2-mile final approach flight path has been included.

Additionally, the policy clarifies that, with reference to glint & glare, the scope of assessments should be limited to those developments located on the airfield rather than those off the airfield.

The Atlas Business Park PV development site is located outside the official licenced aerodrome boundary (Figures 2 & 3). As such, the policy does not apply to the proposed SP development site.

## 2.7 FAA Technical Guidance

### 2.7.1 Introduction

In April 2018, the FAA published version 1.1 of its Technical Guidance for Evaluating Selected Solar Technologies on Airports [Ref 5]. Originally published in 2010, the updated Version 1.1 specifically incorporated updated information about evaluating solar glint and glare. The guidance is intended to provide a readily usable reference for FAA technical staff, providing clear and consistent procedures for reviewing solar projects. It also provides the airport sponsors and the aviation community that may be considering a solar installation with a reference for technical, financial, and regulatory issues associated with solar energy.

The guidance identifies that, given the constraints of some solar energy systems, a solar photovoltaic system, which collects the sun's radiated energy and converts it into electricity, tends to be the technology that provides the best opportunity for airports, as they are more compatible with airport land use because it:

- Is most cost-effective when serving a smaller on-site electricity demand as opposed to large-scale generation for the electricity grid.
- Has a low profile and modular design, which is compatible with low-demand airport property such as rooftops and airfields.
- Is designed to absorb sunlight (rather than reflect it), minimizing potential impacts of glare.
- Does not attract wildlife, which is a critical aviation hazard.

### 2.7.2 Design Considerations

Solar PV is a technology that can readily be designed into an existing landscape without major modifications due to its relatively simple, modular construction. For the airport environment (or in proximity), this means that PV solar panels can be placed in locations that are not used for aviation activities and therefore have little value to the airport or for alternative developments. However, because solar panels are made of expensive materials that keep the cost of solar electricity comparatively high, it is important to minimize the amount of engineering and construction necessary to secure the panels to keep solar electricity cost competitive.

Roof-mountings are an optimal location for solar panels because they commonly receive unobstructed sun exposure and roofs may also provide a ready-made support structure for a solar installation, obviating the need for costly engineering and materials. South facing angled roofs require less support structure than flat roofs or those facing a direction other than south.

Ground-mounted fixed solar PV installations require flat or gently rolling terrain with unobstructed views to the south and geotechnical analysis to confirm the long-term stability of the soils that support them.

Tracking systems employ hydraulic or motor driven mechanisms to move the panels such that they are continuously perpendicular to the sun, maximizing their electric generation potential. Panels can move in two directions to optimize contact with the sun. One direction adjusts vertically to the sun's seasonal position in the sky whereby the panel angle relative to the ground increases or decreases. The second direction is a horizontal movement tracking the sun's daily path from sunrise to sunset. Tracking systems introduce a considerable amount of additional technology and complexity to solar systems, which increase capital and maintenance costs.

Solar PV projects are generally a compatible land use at airports because of their low profile and ease of integration with existing facilities. However, projects must meet standards to protect air navigation and existing aviation activities.

Airports have a primary mission to facilitate safe and convenient air travel. In determining whether a proposed solar project is compatible with aeronautical activities, sponsors should consider the following:

1. The project cannot be in a Runway Object Free Area, Obstacle Free Zone, Runway Safety Area, Taxiway Object Free Area or a Taxiway Safety Area.
2. The project cannot penetrate imaginary surfaces that define the lower limits of airspace including the clearway.
3. The project must demonstrate that glare will not impact airspace safety.
4. The project must consider construction period impacts on aviation. Airside projects may result in modifications to typical flight procedures if contractors and equipment produce a temporary impact on airspace. This may result from the need to access the project site by passing vehicles and equipment close to runways. It may also occur if a large crane is necessary for installation and the crane penetrates airspace due to its height.

### 2.7.3 Regulatory and Safety Requirements

Solar development proponents must plan their projects to avoid impacts on aviation and the environment. As part of an Airspace Review, Airport Sponsors should assess airspace penetration, reflectivity, and communication systems interference for all airport solar projects whether ground or building mounted. Aeronautical studies of proposed activities will include the review of physical incursions of proposed structures into airspace, interference with radar communications, and any other conditions that might negatively impact air traffic.

To conform with regulations relating to penetration of the imaginary surfaces in navigable airspace, airports must maintain vegetation, prevent permanent structures, and manage any temporary construction activity. Solar panels, when tilted properly to the south-facing sun, extend to a height of as little as three feet above the ground, making it possible for siting close to runways without penetrating the imaginary safeguarding surface. The low profile of solar panels allows for greater flexibility in finding the most appropriate location on the airport for electricity generation. Projects that have located solar panels in close proximity to runways and taxiways have conducted analyses to ensure that the solar panels do not penetrate the imaginary surface.

Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.

Solar PV panels are constructed of dark, light-absorbing materials and covered with an anti-reflective coating designed to maximize absorption and minimize reflection. However, the glass surfaces of solar PV systems also reflect sunlight to varying degrees throughout the day and year. The amount of reflected sunlight is based on the incidence angle of the sun relative to the light-sensitive receptor (e.g., a pilot or air traffic tower controller). The amount of reflection increases with lower incidence angles. In some situations, 100% of the sun's energy can be reflected from solar PV panels.

Because solar energy systems introduce new visual surfaces to an airport setting where reflectivity could result in glare that can cause flash blindness to those that require clear, unobstructed vision, project proponents should evaluate reflectivity during project siting and design.

Communication systems interference includes negative impacts on radar, NAVAIDS, and infrared instruments. Radar interference occurs when objects are placed too close to a radar antenna and reflect or block the transmission of signals between the radar antenna and the receiver. Though it is possible for interference to be caused by other communication signals, more commonly, it is caused by a physical structure placed between the transmitter and receiver. However, similar concerns have been raised for airport-based navigational aids and communication facilities. NAVAIDS can be impacted similarly to radar, but they include passive systems with no transmitting signals. Impacts on infrared communications can occur because the solar panels continue to retain heat into the first part of dusk and the heat, they release can be picked up by infrared communications in aircraft causing an unexpected signal.

Due to their low profiles, solar PV systems typically represent little risk of interfering with radar transmissions. In addition, solar panels do not emit electromagnetic waves over distances that could interfere with radar signal transmissions, and any electrical facilities that do carry concentrated current are buried beneath the ground and away from any signal transmission.

Because solar energy systems do not release any emissions or store any hazardous materials, potential environmental damage is limited to impacts associated with land development.

Solar projects constructed off-airport are proposed and managed by private developers and public agencies. The FAA has broad authority for airspace review and the evaluation of any solar project that could pose a potential hazard to air navigation. The clearest trigger for FAA review would be a physical penetration of airspace.

Further supporting information can be found in CAP 168 – Licencing of Aerodrome [Ref 7] and CAP 670 – Air Traffic Services Safety Requirements [Ref 8].

## 2.8 Airfield User Operational Requirements

In 2021, MAN handled a total of 66,310 aircraft movements and a total of 6,085,103 passengers. Today, MAN is currently averaging 11,648 aircraft movements and 1,724,877 passengers per month in 2022<sup>1</sup>. MAN aircraft movement activity severely reduced in 2020, arguable due to the impact of COVID-19 and applied national restrictions. However, given the airports return to growth, it is essential that operations at MAN are safeguarded for the future (Table 2).

|                                         | 2020    | 2021      | 2022 (Jan -Sept) |
|-----------------------------------------|---------|-----------|------------------|
| Total Aircraft Movements <sup>1</sup>   | 3,444   | 66,310    | 11,648           |
| Total Number of Passengers <sup>1</sup> | 247,729 | 6,085,103 | 15,523,891       |

Table 2 MAN Aircraft Movements & Passenger Numbers per annum

Given the proposed height and location of the proposed PV site, it is not anticipated that any adverse impacts shall be realised when ground-handling operations are considered. However, this assessment will conduct the appropriate checks to ensure no adverse impacts are present.

The Atlas Business Park PV development site is located 1.29km east of runway 23R threshold (Figure 1). As such, the high-level Glint & Glare Assessment will consider the final approaches for all airport runway thresholds, taxiways and ATCT cab.

## 2.9 Conclusion

The CAA have limited regulatory policy or guidance specific to solar PV developments on or near airfields. However, guidance provided as part of CAA Information Notice IN-2015/0NN [Ref 1] and Appendix C of CAP 738 – Safeguarding of Aerodromes [Ref 6] refers to policy and guidance material issued by the FAA in the USA, where the concept of solar generation at airports is more mature. The FAA Interim Policy, ‘FAA Review of Solar Energy System Projects on Federally Obligated Airports’ (FAA Doc 78 FR 63276) [Ref 3] is deemed to be the most developed regulatory policy concerning the development of solar farms at, or near, airfields.

Solar PV developments that are proposed within the aerodrome boundary are to follow the process outlined in CAP 791 – Procedures for Changes to Aerodrome Infrastructure [Ref 2]. This will demonstrate that the necessary safety considerations have been fully addressed, and should include, but not limited to:

- A formal glint/glare or reflectivity assessment.
- Details concerning the safeguarding assessment of the applicable obstacle limitation surfaces.
- An assessment of interference concerning CNS equipment.

The Atlas Business Park PV development is outside the aerodrome boundary and is not required to comply with CAP 791. Where a solar PV development is being proposed outside of the licensed aerodrome boundary, there is no requirement for

<sup>1</sup> Aircraft movement and Air Passenger data provided by CAA UK Airport data.

the aerodrome operator to consult or notify the CAA in order to seek CAA approval prior to installation. However, in addition to statutory safeguarding obligations via the local planning authority, relevant aeronautical safety issues should be considered prior to any planning application.

## 3 Glint & Glare Analysis

### 3.1 Background

#### 3.1.1 Overview

The installation of solar panels provides the opportunity for the Atlas Business Park PV development to harness the use of solar energy to provide electricity to the onsite users, reducing their carbon footprint and achieving environmental sustainability. However, one of the disadvantages of solar panels is that some energy is reflected off the panel and not utilised for energy generation. The level of reflection is often dependent on the panels position and orientation relative to the sun. Some studies show that a panel may absorb 90% of the sunlight when directly facing the sun, but only 60% when not directly facing the sun. [Ref 9]

This reflection can cause what is known as Glint & Glare (G&G). Glint is defined as a temporary flash of bright light caused by reflection off a moving surface. On the other hand, glare is a continuous source of bright light, commonly caused by reflection off stationary objects and as such lasts for longer. Therefore, the key difference between glint and glare is the duration. For example, Figure 5 below shows the glare produced by solar panels located on the roof of a car park, as seen from the Air Traffic Control (ATC) Tower at Manchester-Boston Regional Airport, New Hampshire, USA, taken in May 2012. It is worth noting that there are numerous factors that affect the intensity and duration of G&G relating to the environmental conditions, surrounding landscape and panel specifications, some of which are described in the subsequent sub-sections.



Figure 5 Example of solar panel glare

#### 3.1.2 Solar Panel Tilt & Orientation

One of the biggest factors that affects the efficiency of solar PV panels is their angle and orientation relative to the sun. The angle of the panel relative to the sun is known as the incidence angle. As visualised in Figure 6 below, the more acute the incidence angle, the less sunlight is reflected. Of course, this is dependent on the time of year and location of the sun. Therefore, the tilt (vertical) and orientation (horizontal) of the panels is key.

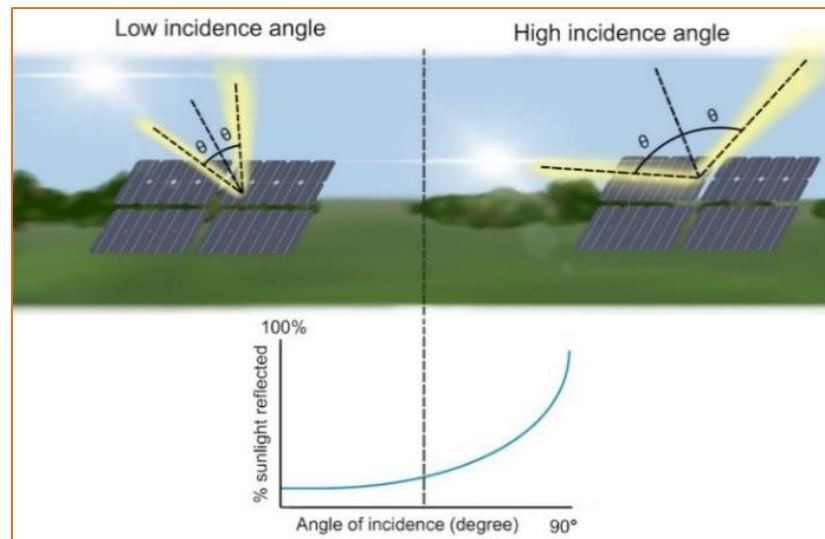


Figure 6 Incidence Angle (Source: Forge Solar)

The design and development of solar panels has taken this into account. Solar panels can be fixed in a certain tilt and orientation, solely tilt vertically (known as single axis tracking) or combine this with rotating horizontally (known as double axis tracking) depending on the location of the sun.

### 3.1.3 Solar Panel Texture

Another key factor affecting the amount of solar energy reflected by solar PV panels is the texture of the panel itself. There are multiple options available to meet different requirements ranging from a smooth glass panel to a deep textured panel. A textured panel works by providing a rough surface so that when sunlight reaches it, the light can be reflected onto the panel rather than straight back out towards the sky. This is illustrated in Figure 7 below. Some panels also have an Anti-Reflective Coating (ARC) to further reduce the amount of light reflected.

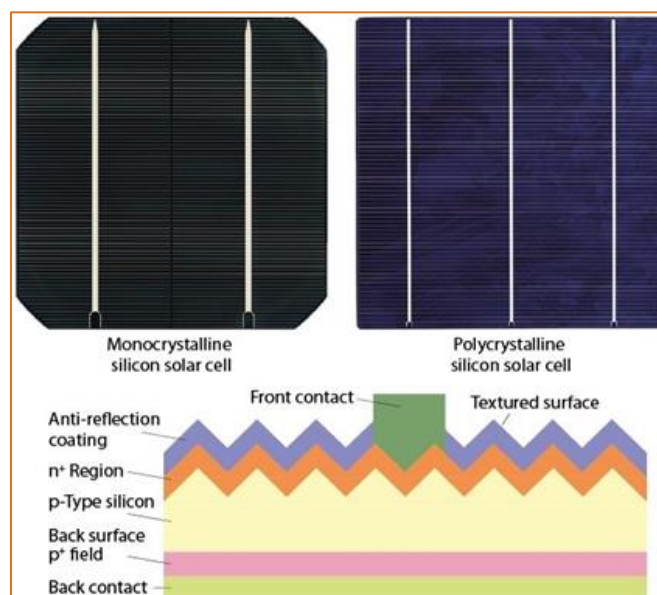


Figure 7 Textured Solar Panel Surface (Source: NPG Asia Materials)

## 3.2 Assessment Methodology

### 3.2.1 Glint & Glare Analysis Tool

To determine the G&G impact of the proposed Atlas Business Park PV solar panel development site, the Glare Gauge tool provided by Forge Solar was utilised. This is a web-based tool which is regarded as the industry standard tool used for this purpose and has been developed from the Solar Glare Hazard Analysis Tool (SGHAT), created by Sandia Laboratories in the USA. It is worth noting that this tool is fully compliant with Federal Aviation Administration (FAA) guidelines, the importance of which is described in Section 2.5.

To create the desired outputs, the tool requires a wide variety of inputs, parameters, and specifications to be entered before the point of analysis. The proposed siting of the solar panels has been assessed against each roof pitch of the single apex building. This can be found in Annex A1. However, some of the other parameters are very technical (such as the exact specifications of the PV panels themselves) and it is acknowledged that at this stage, the exact nature of all parameters is not known. To facilitate this report, as much accurate information (where available) as possible has been gathered and entered into the tool. However, to progress with the analysis, various parameters have been assumed. A full list of these parameters can be found in Annex 0. It is worth stressing that as the project progresses, the exact specifications and parameters regarding the PV panels may differ from the assumptions listed in Annex 0. As a result, the results and analysis conducted may be invalid and may require updating once these parameters are known.

Once inputs had been established, they were entered into the tool along with various other operational inputs to enable the tool to be fully utilised based on the context of an airfield.

Along with site locations, 2-mile approach paths were entered using the directional drawing tool. The mid-point of each RWY threshold was taken as the baseline and then a 2-mile path was plotted in the RWY direction, as indicated in the UK Civil AIP.

Observation points (shown as red markers in Figure 8) were also added. These included the ATC Tower.

Finally, multiple routes (shown in light blue lines in Figure 8) were entered into the tool manually using the 'Route Drawing' function. These were selected to give a broad representation of likely taxi routes from known parking areas to all four runway thresholds and are described in Annex A2. All these operational inputs are shown below in Figure 8.

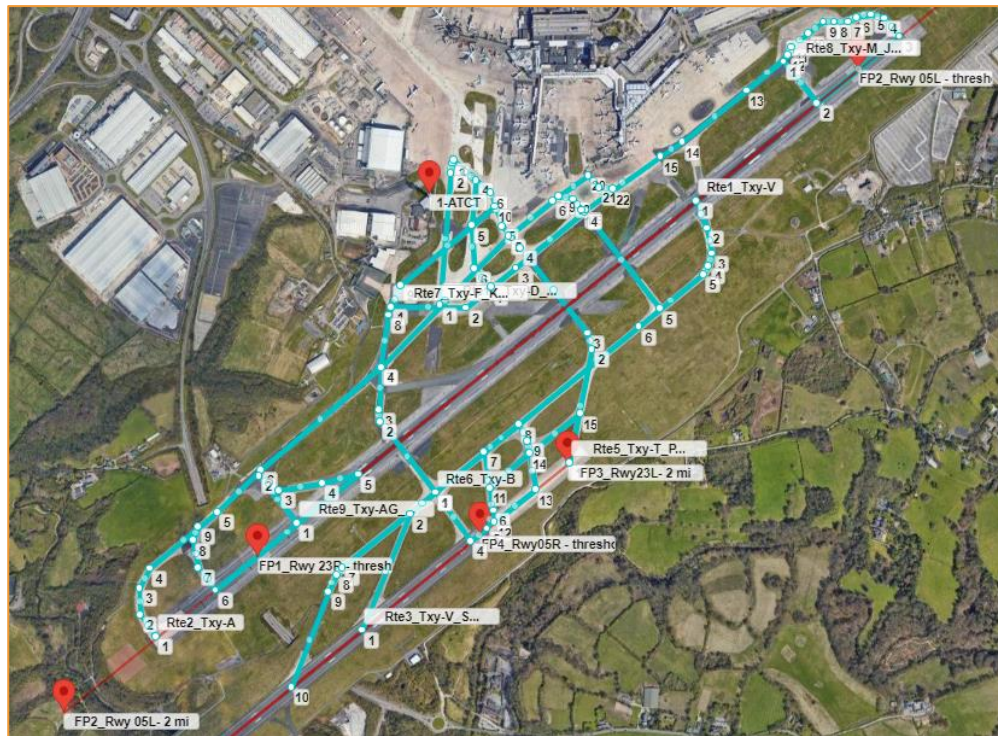


Figure 8 G&G Tool Assessment Features (Source: Forge Solar)

With regards to outputs, the G&G tool generates a wide variety of results including the required hazard plot diagram as required by the FAA. In addition to this, the tool will generate a specialised 'Aviation Report' providing a simple 'PASS' or 'FAIL' summary in terms of aviation safety and regulatory compliance.

### 3.2.2 Regulatory Guidance

As described in Section 2, the UK CAA have limited regulatory policy or guidance relating to the realisation of solar panel developments on or near airfields. However, guidance provided as part of CAA Information Notice IN-2015/0NN [Ref 1] and Appendix C of CAP 738 (Safeguarding of Aerodromes) [Ref 6] refers to policy and guidance material issued by the FAA in the USA, where the concept of solar generation at airports is more mature. The FAA Interim Policy, 'FAA Review of Solar Energy System Projects on Federally Obligated Airports' (FAA Doc 78 FR 63276) [Ref 3] is deemed to be the most developed regulatory policy concerning the development of solar farms at airfields. In terms of G&G, the FAA have adopted the following standards:

1. "No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and
2. No potential for glare or "low potential for after-image" along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath." [Ref 3]

However, as highlighted, the 2021 FAA policy [Ref 4] discounts the need to consider the 2-mile flight path but this has been considered within the analysis as the 2013 FAA policy [Ref 3] is still referenced in CAP 738 [Ref 6].

### 3.2.3 ATC Tower Line of Sight

It is worth noting that one of the limitations of the G&G tool used as part of this analysis is that it does not take any obstructions (such as terrain, buildings, fences, and trees) into account. The analysis therefore portrays the landscape as completely unobstructed. However, there may be obstacles between the ATC Tower and solar panels that prevent any G&G from reaching the Visual Control Room (VCR).

Based on the PV solar panel layout provided, it can be viewed that the PV solar panels at the Atlas Business Park PV site may be seen from the ATC Tower. This is principally due to the height of the ATCT (60m), which is taller than the surrounding units and at a distance of 2.57km away. However, due to the PV solar arrays omnidirectional orientation and the buildings (multistorey car park) situated in between the ATCT and the PVs, the likelihood of glare reaching the VCR and the need for mitigating action is highly unlikely. Figure 2 illustrates the proximity of the Atlas Business Park PV development to the ATC Tower.

## 3.3 Results & Analysis

### 3.3.1 Summary - ATC Tower and 2-mile Flight Path

Following the completion of analysis based on the initial inputs provided (as shown in Annex 0), Table 3 summarises the results for the proposed PV site utilising a 'PASS/FAIL' methodology to determine compliance with FAA standards. Please note, as stated in Section 3.2.3, the G&G Tool does not account for obstructions to the Line of Sight (LoS) to the ATC Tower, therefore, at this stage, it cannot be said with certainty whether any G&G indicted by the tool will be blocked by a building.

| Site Location                       | ATC Tower (PASS/FAIL) | 2-mile Approach Paths (PASS/FAIL) |
|-------------------------------------|-----------------------|-----------------------------------|
| Atlas Business Park PV Site Complex | PASS                  | PASS                              |

Table 3 Aviation Regulatory Compliance Summary – PASS/FAIL

The tool categorises glare into three hazard levels: Red, Yellow and Green. The results are plotted on a graph with layman's axes of size (x) and intensity (y). The graph shows the coloured hazard zones.

From the Summary Table above, the proposed PV solar panel surfaces do meet the regulatory requirements in terms of no adverse glint & glare impacts. However, it must be acknowledged that some "green" glare will be visible on the ATC-T cab and other identified receptors. Tables 4, 5, 6 & 7 (below) show the minutes of "green" and "yellow" glare which shall be present annually against the affected receptors.

### 3.3.2 2-Mile Flight Path Receptors (2-MFPR) – PV Array Impacts on Flight Paths

As part of the analysis the solar PV analysis area was enlarged to include the whole surface of each PV Array designated pitched roof. This has supported the analysis to potentially allow the installation of a multiple configuration PV solar array at the site. Figures 9 & 10 illustrates the approximate analysis section areas.



Figure 9 Building Units 1 (top), 2 & 3 (bottom) PV Area of Analysis



Figure 10 Building Units 4 (bottom), & 5 (top) PV Area of Analysis

| 2-Mile FP Receptors – Atlas Business Park PV Solar Array - Impact Summary |                                                                                     |                                                                                  |
|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Airfield Component                                                        | “Green” glare with low potential to cause temporary after-image (minutes per annum) | “Yellow” glare with potential to cause temporary after-image (minutes per annum) |
| RWY 05R Approach                                                          | 0                                                                                   | 0                                                                                |
| RWY 23R Approach                                                          | 0                                                                                   | 0                                                                                |
| RWY 05L Approach                                                          | 0                                                                                   | 0                                                                                |
| RWY 23L Approach                                                          | 0                                                                                   | 0                                                                                |
| <b>TOTAL</b>                                                              | <b>0</b>                                                                            | <b>0</b>                                                                         |

Table 4 2-Mile FP Receptors – Atlas Business Park PV Solar Array - Impact Summary

### 3.3.3 Observation Points (OP)

Analysis shows that the ATC Tower was the only Observation Point included within the G&G analysis. For all the PV arrays, the ATC Tower receptor received 11,079 minutes of “green” glare per annum.

| Observation Point Receptors – Atlas Business Park PV Solar Array - Impact Summary |                                                                                     |                                                                                  |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Airfield Component                                                                | “Green” glare with low potential to cause temporary after-image (minutes per annum) | “Yellow” glare with potential to cause temporary after-image (minutes per annum) |
| ATC-T                                                                             | 11,079                                                                              | 0                                                                                |
| <b>TOTAL</b>                                                                      | <b>11,079</b>                                                                       | <b>0</b>                                                                         |

Table 5 Observation Points - Atlas Business Park PV Solar Array - Impact Summary

*No additional Observation Points, such as local dwellings or pedestrian locations, were included within the scope of this assessment.*

### 3.3.3.1 Observation Point – Impacts on ATC-T

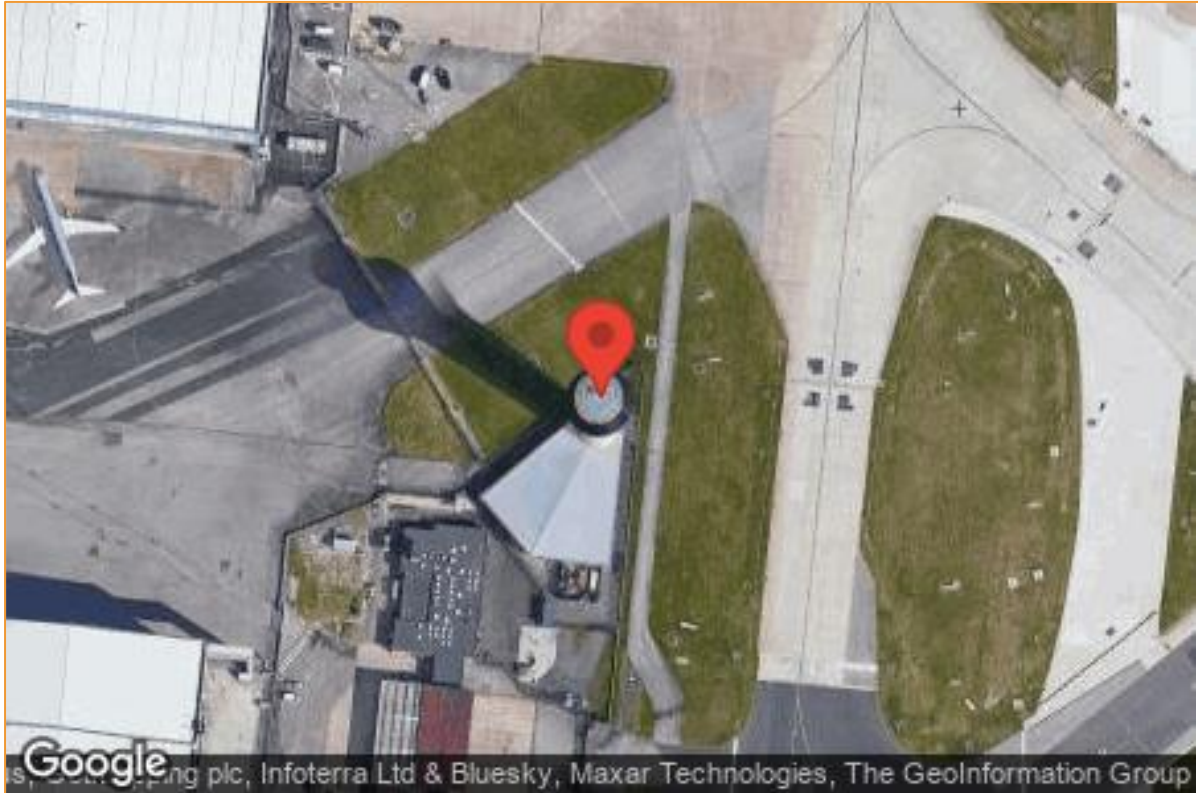
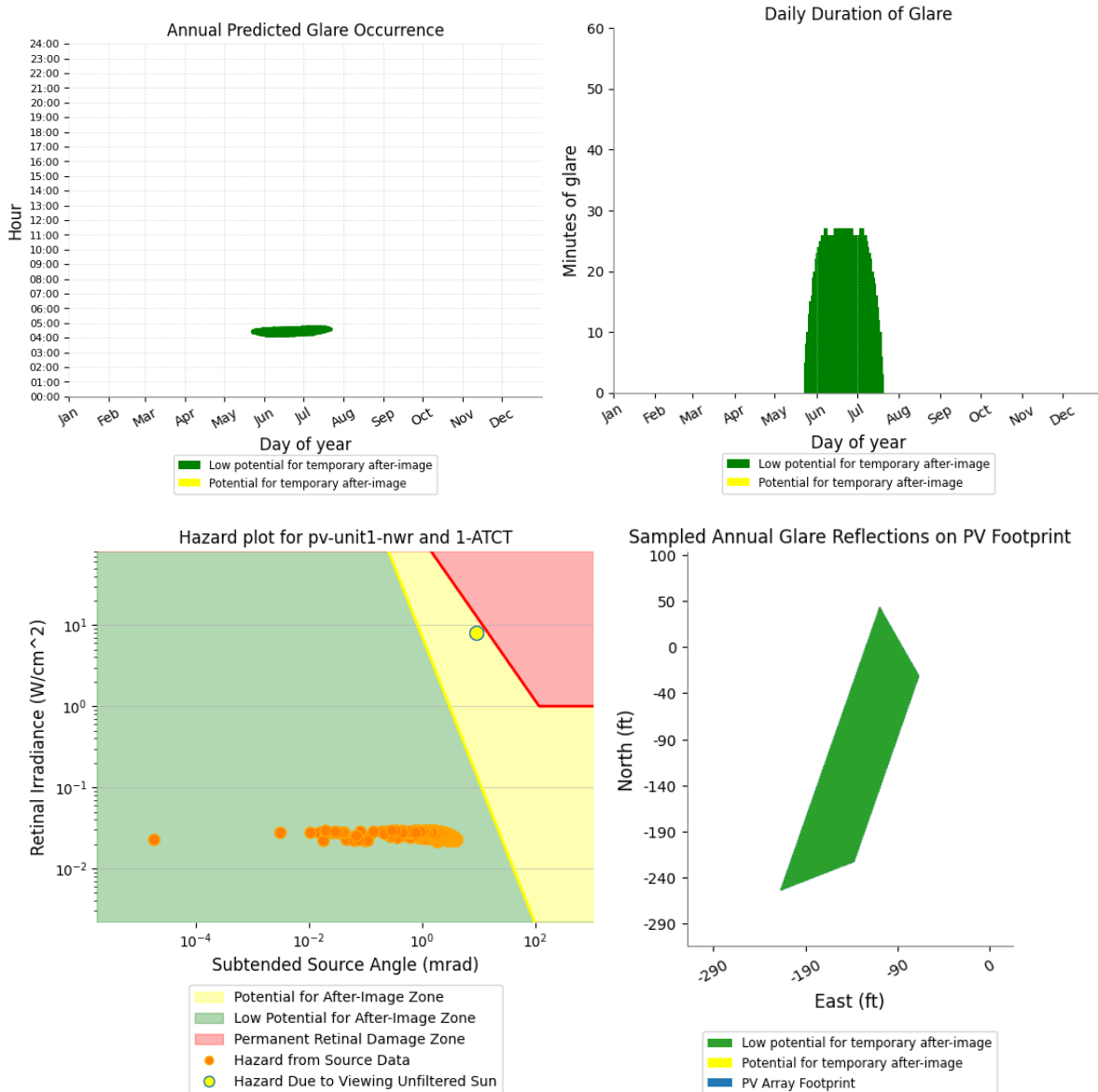


Figure 11 Observation Point - MAN ATC-T

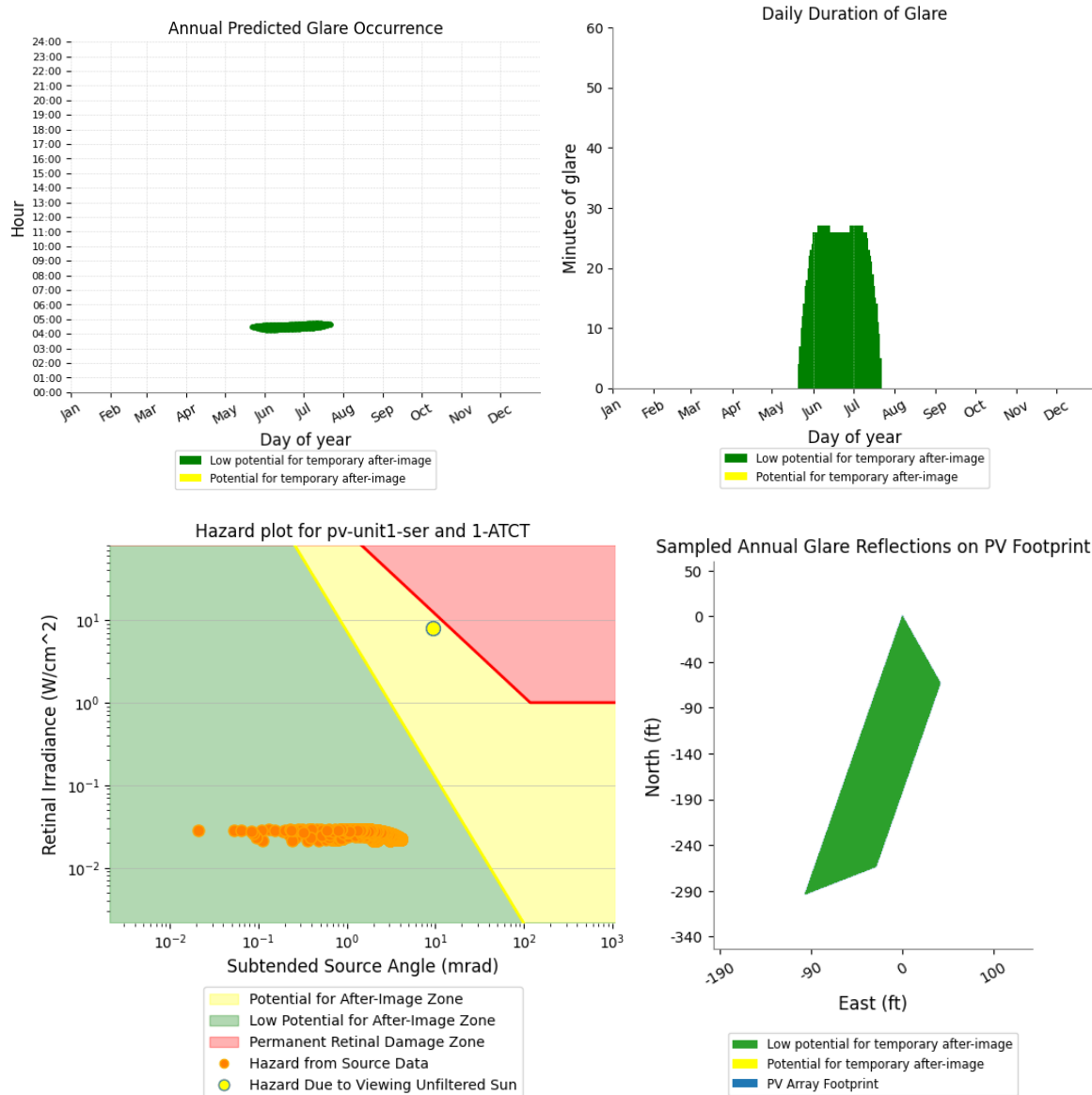
### 3.3.3.1.1 Unit 1 North-West Roof – West Pitch (ATC-T)



The analysis shows that the Unit 1 North-west roof, West pitch PV array produces 1,343 minutes of “green” glare per annum. The glare is evaluated as having a low impact and will only be visible to the ATC Tower between the months of May to July and will last no longer than 28 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

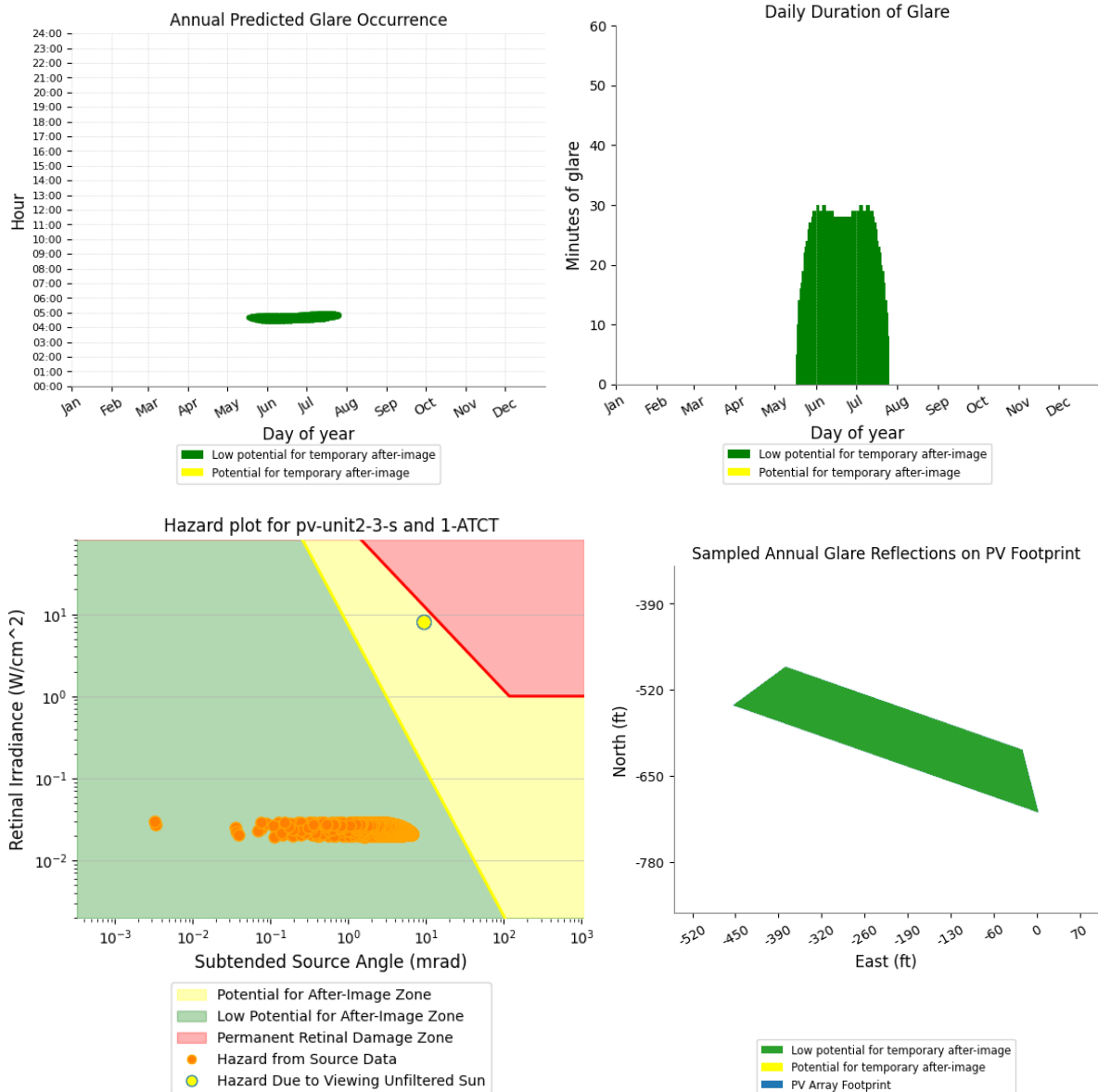
### 3.3.3.1.2 Unit 1 South-East Roof – West Pitch (ATC-T)



The analysis shows that the Unit 1 South-east roof, West pitch PV array produces 1,437 minutes of “green” glare per annum. The glare is evaluated as having a low impact and will only be visible to the ATC Tower between the months of May to July and will last no longer than 28 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

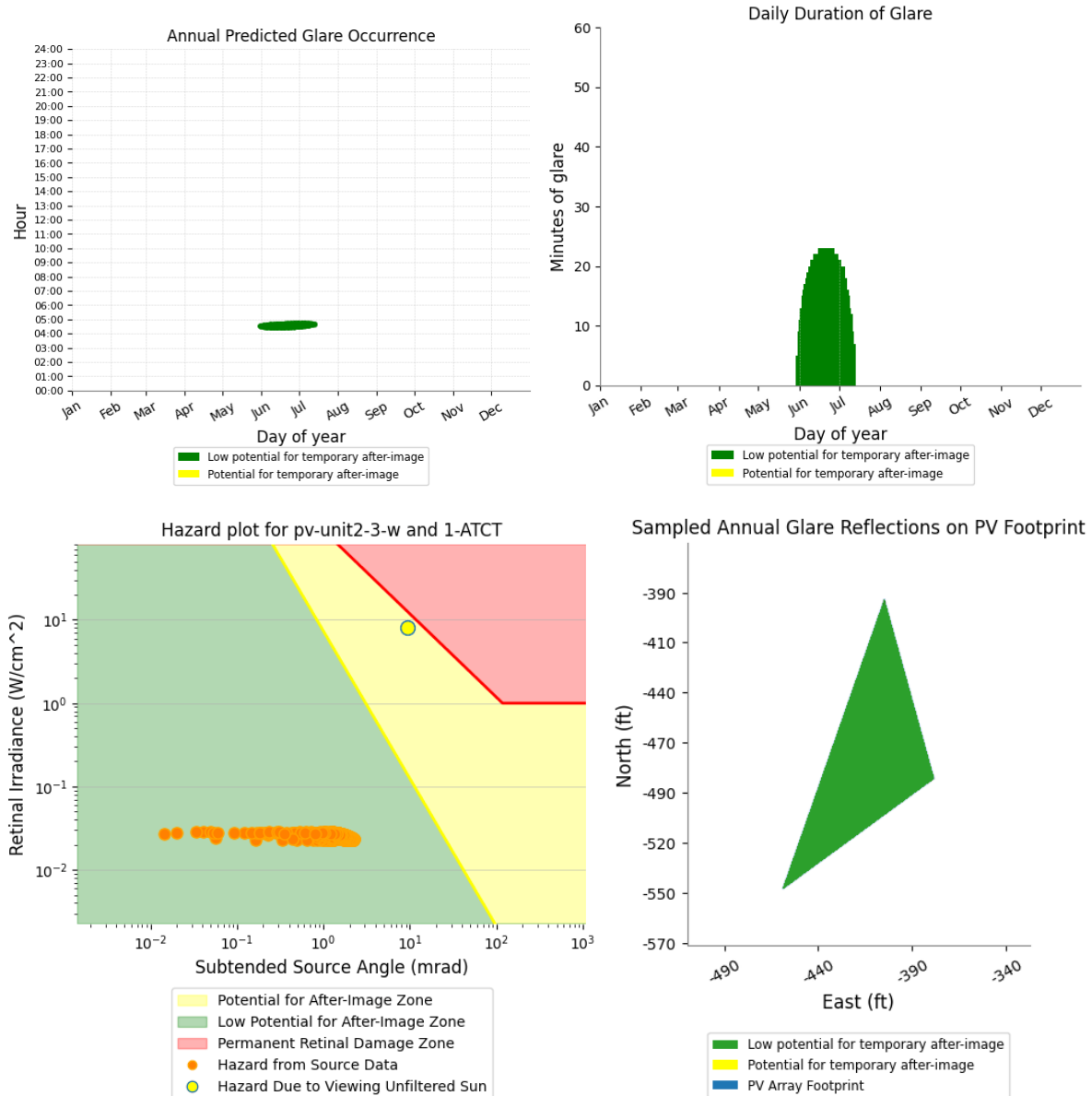
### 3.3.3.1.3 Unit 2 & 3 South Roof (ATC-T)



The analysis shows that the Unit 2 & 3 South roof PV array produces 1,830 minutes of “green” glare per annum. The glare is evaluated as having a low impact and will only be visible to the ATC Tower between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

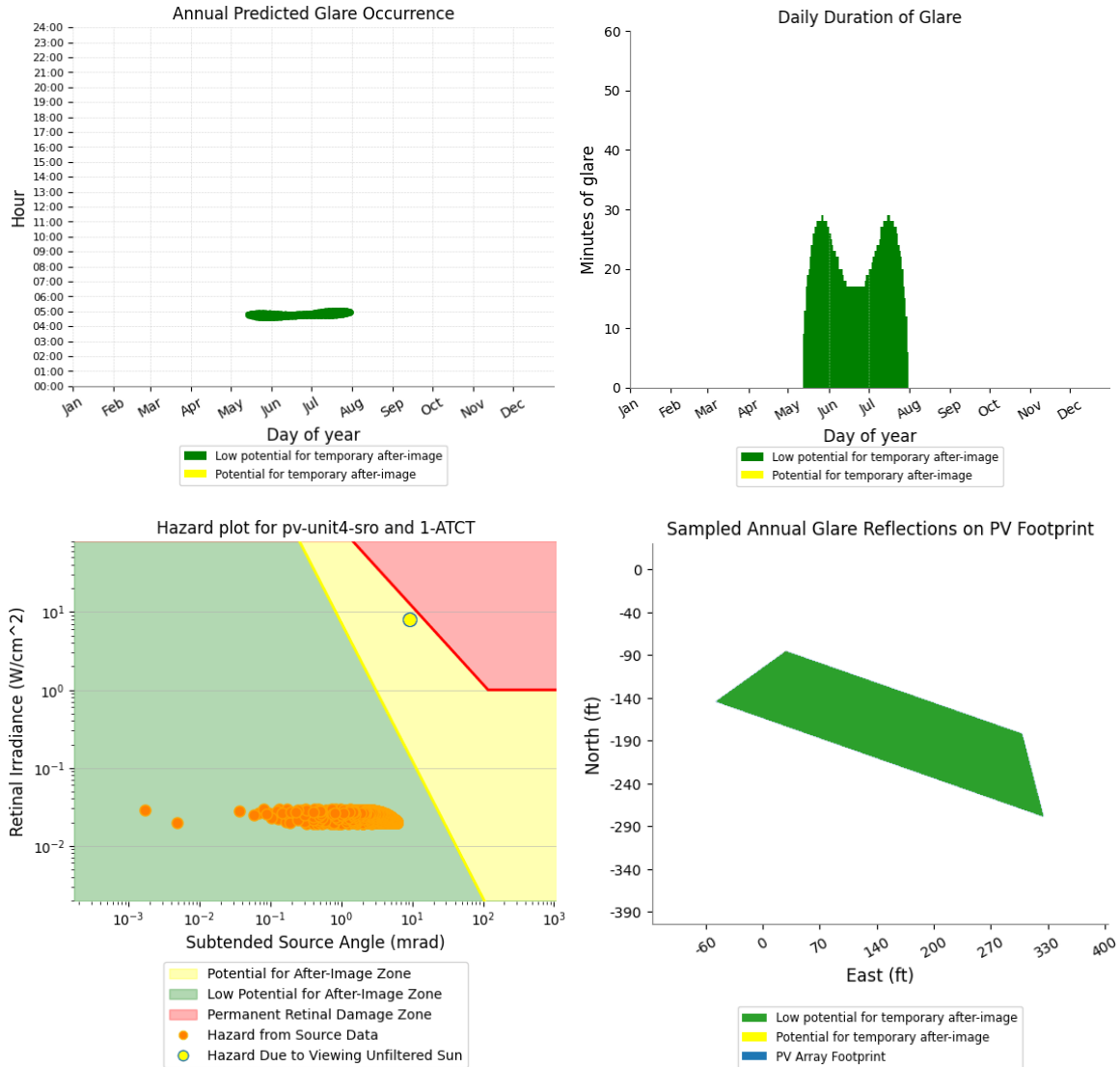
### 3.3.3.1.4 Unit 2 & 3 West Roof (ATC-T)



The analysis shows that the Unit 2 & 3 West roof PV array produces 845 minutes of “green” glare per annum. The glare is evaluated as having a low impact and will only be visible to the ATC Tower between the months of May to July and will last no longer than 24 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

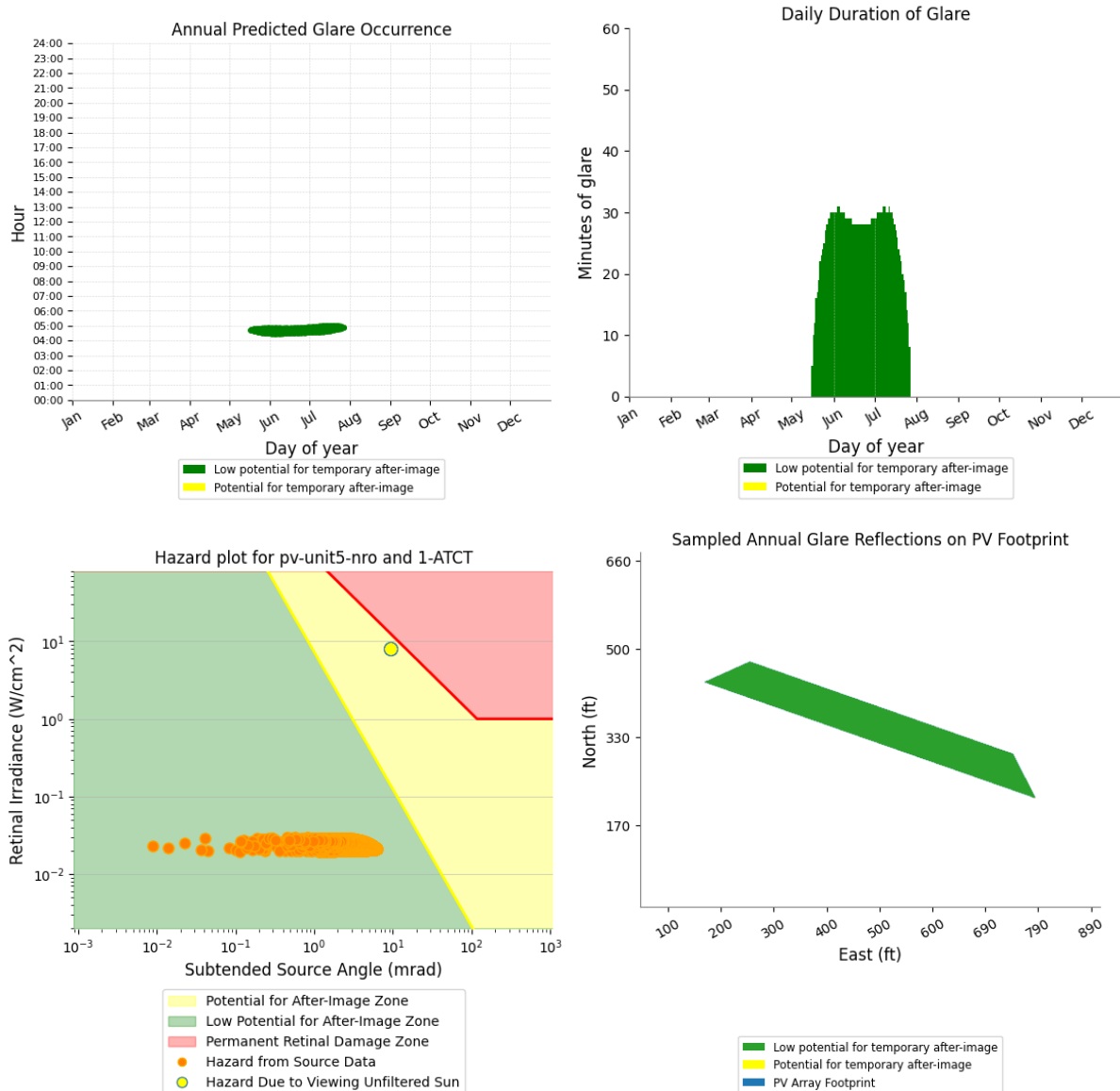
### 3.3.3.1.5 Unit 4 South Roof (ATC-T)



The analysis shows that the Unit 4 South roof PV array produces 1,757 minutes of “green” glare per annum. The glare is evaluated as having a low impact and will only be visible to the ATC Tower between the months of May to August and will last no longer than 28 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

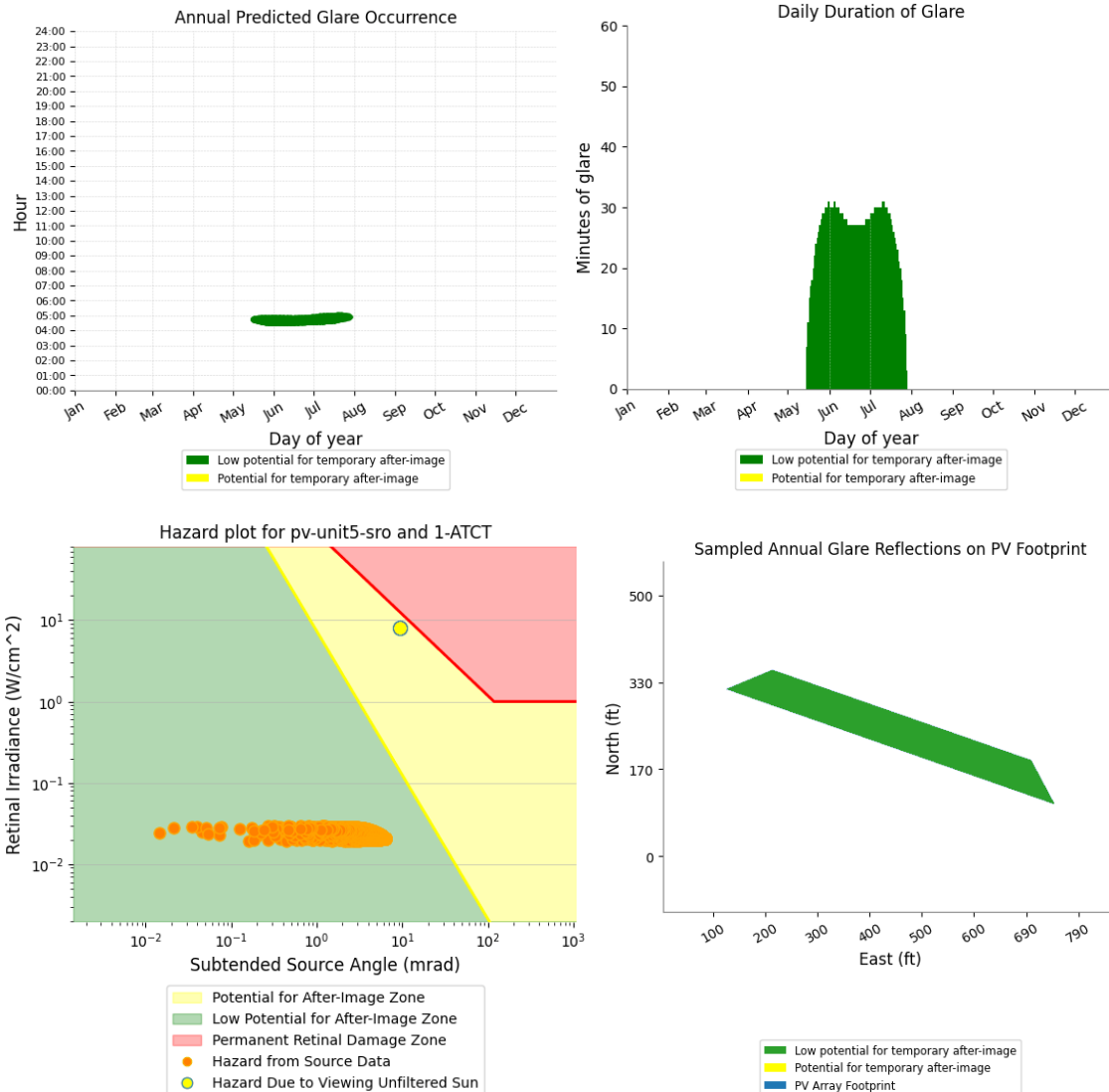
### 3.3.3.1.6 Unit 5 North Roof – South Pitch (ATC-T)



The analysis shows that the Unit 5 North roof, South pitch PV array produces 1,903 minutes of “green” glare per annum. The glare is evaluated as having a low impact and will only be visible to the ATC Tower between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:15 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.3.1.7 Unit 5 South Roof – South Pitch (ATC-T)



The analysis shows that the Unit 5 South roof, South pitch PV array produces 1,964 minutes of “green” glare per annum. The glare is evaluated as having a low impact and will only be visible to the ATC Tower between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4 Route Receptors (RR)

Analysis shows that the aerodrome taxiways included within the G&G analysis receives green glare.

| Route Receptors - Atlas Business Park PV Solar Array - Impact Summary |                                                                                     |                                                                                  |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Aerodrome Component                                                   | “Green” glare with low potential to cause temporary after-image (minutes per annum) | “Yellow” glare with potential to cause temporary after-image (minutes per annum) |
| Taxiway A                                                             | 7,827                                                                               | 0                                                                                |
| Taxiway B                                                             | 4,774                                                                               | 0                                                                                |
| Taxiways C, D & P                                                     | 13,442                                                                              | 0                                                                                |
| Taxiways F & K                                                        | 5,502                                                                               | 0                                                                                |
| Taxiway V                                                             | 0                                                                                   | 0                                                                                |
| Taxiways V & S                                                        | 0                                                                                   | 0                                                                                |
| Taxiways W & Y                                                        | 0                                                                                   | 0                                                                                |
| Taxiways B, J & M                                                     | 5,013                                                                               | 0                                                                                |
| Taxiways P & T                                                        | 0                                                                                   | 0                                                                                |
| Taxiways AE, AF & AG                                                  | 1,030                                                                               | 0                                                                                |
| <b>TOTAL</b>                                                          | <b>37,588</b>                                                                       | <b>0</b>                                                                         |

Table 6 Route Receptors – Taxiway Impact Summary

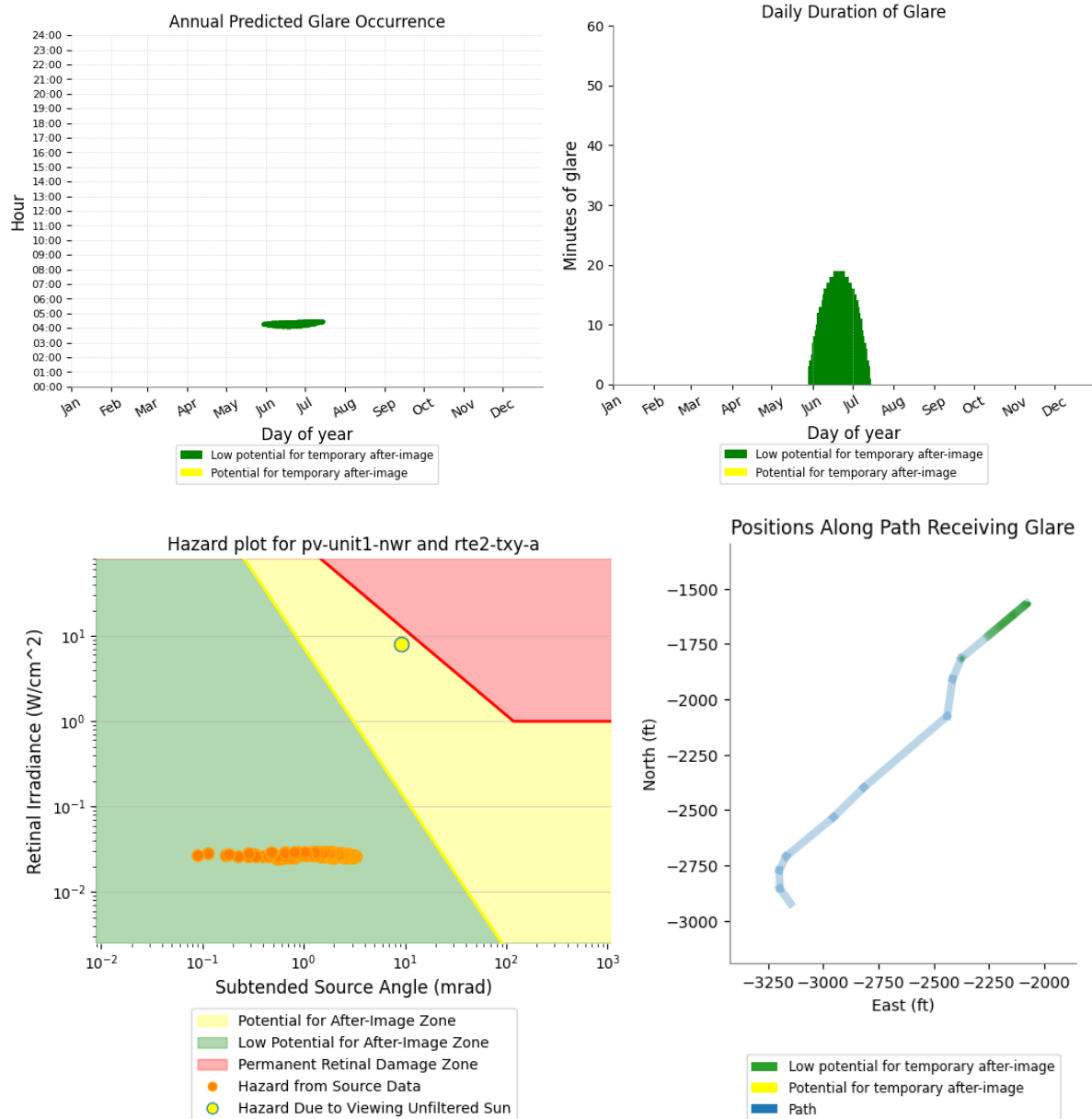
### 3.3.4.1 Route Receptor – PV Array Impacts on Taxiway A



Figure 12 Route Receptor - Taxiway A

Note: Route receptor analysis may not mirror the exact aerodrome plan depiction of taxiway designations. However, a full coverage of the major taxiway network analysis is captured throughout this report.

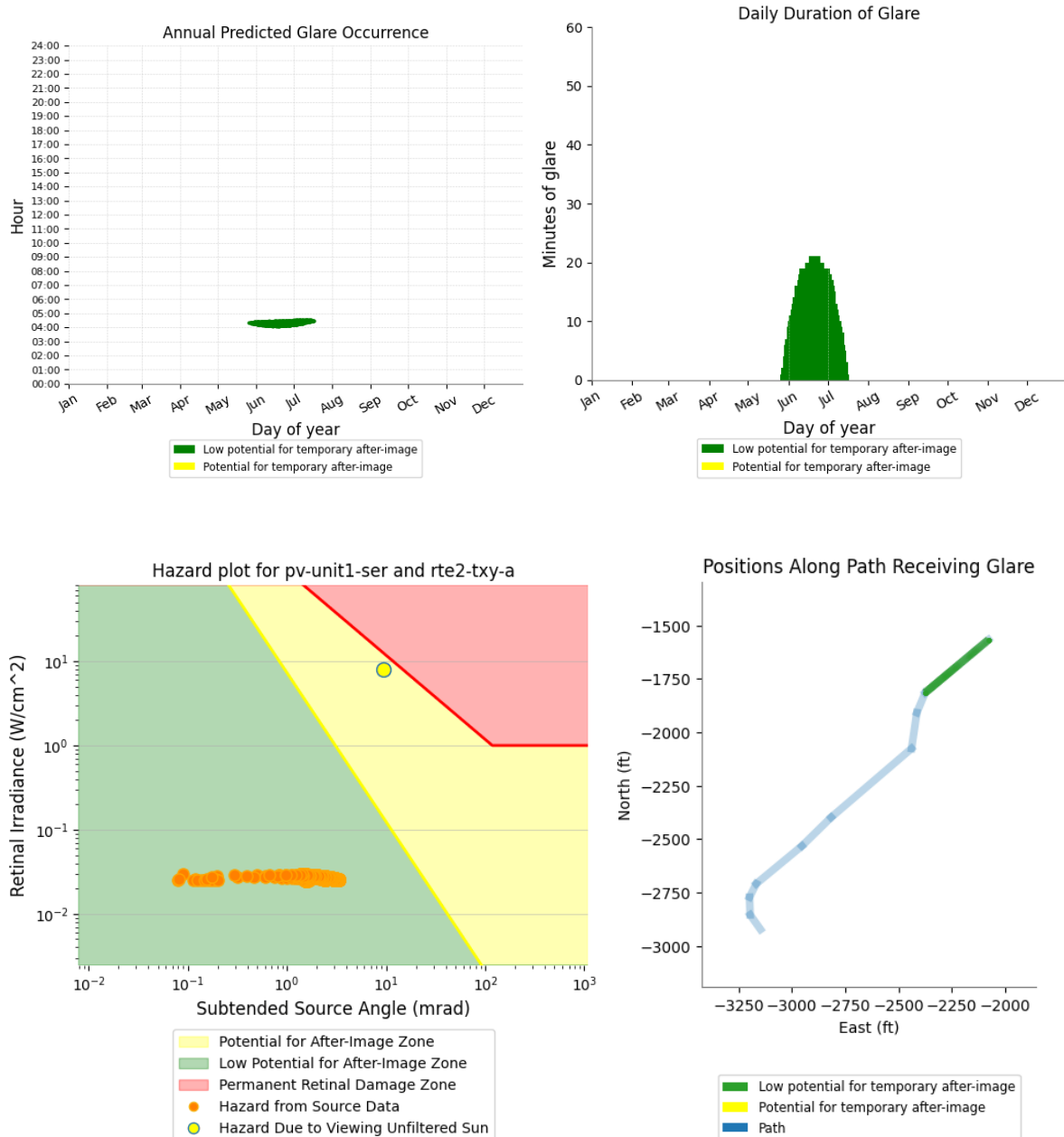
### 3.3.4.1.1 Unit 1 North-West Roof – West Pitch (Taxiway A)



The analysis shows that the Unit 1 North-west roof, West pitch PV array produces 642 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway A between the months of May to July and will last no longer than 20 minutes per day, between the hours of 03:50 to 04:45 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

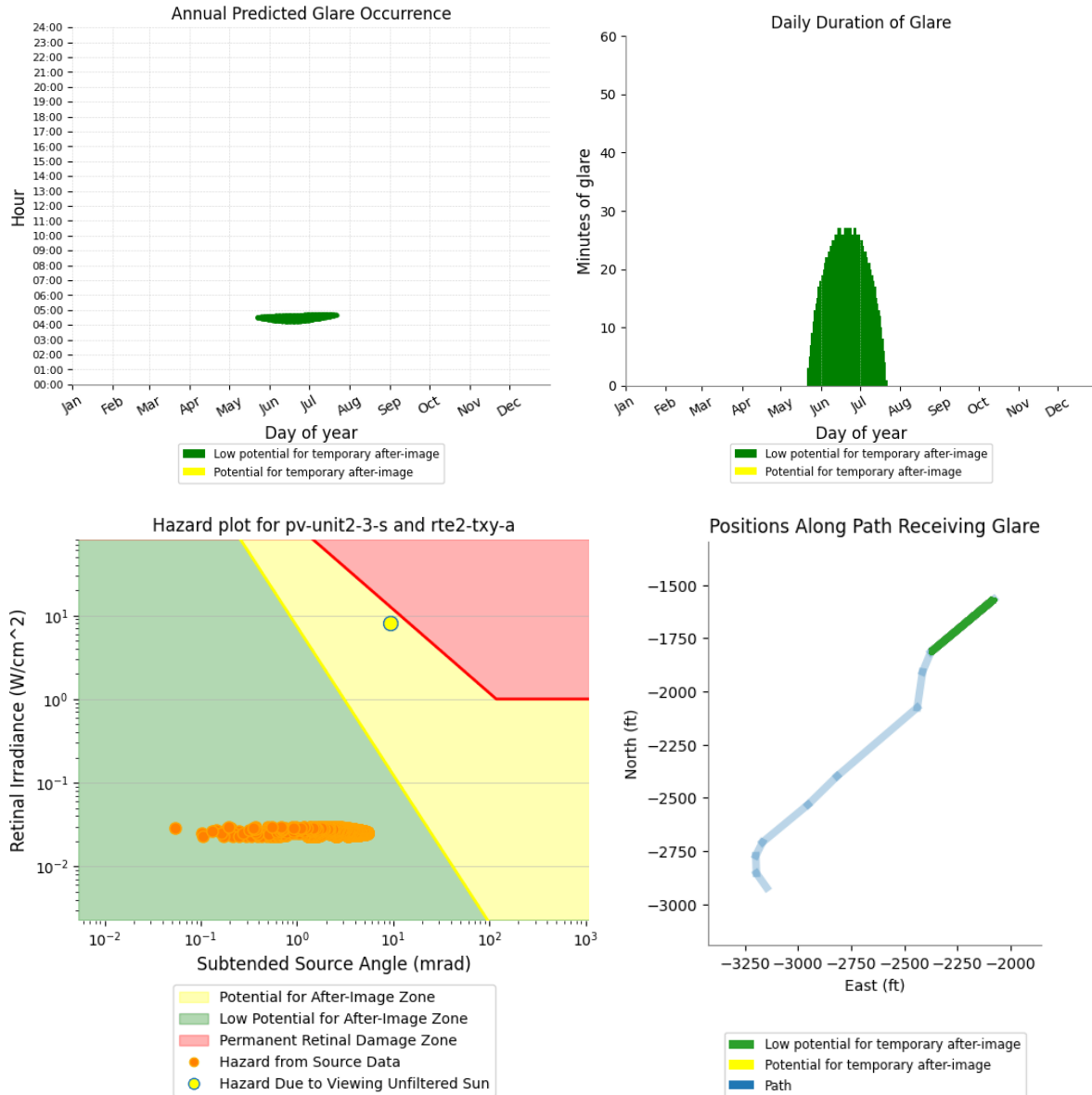
### 3.3.4.1.2 Unit 1 South-East Roof – West Pitch (Taxiway A)



The analysis shows that the Unit 1 South-east roof, West pitch PV array produces 779 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway A between the months of May to July and will last no longer than 20 minutes per day, between the hours of 03:50 to 04:50 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

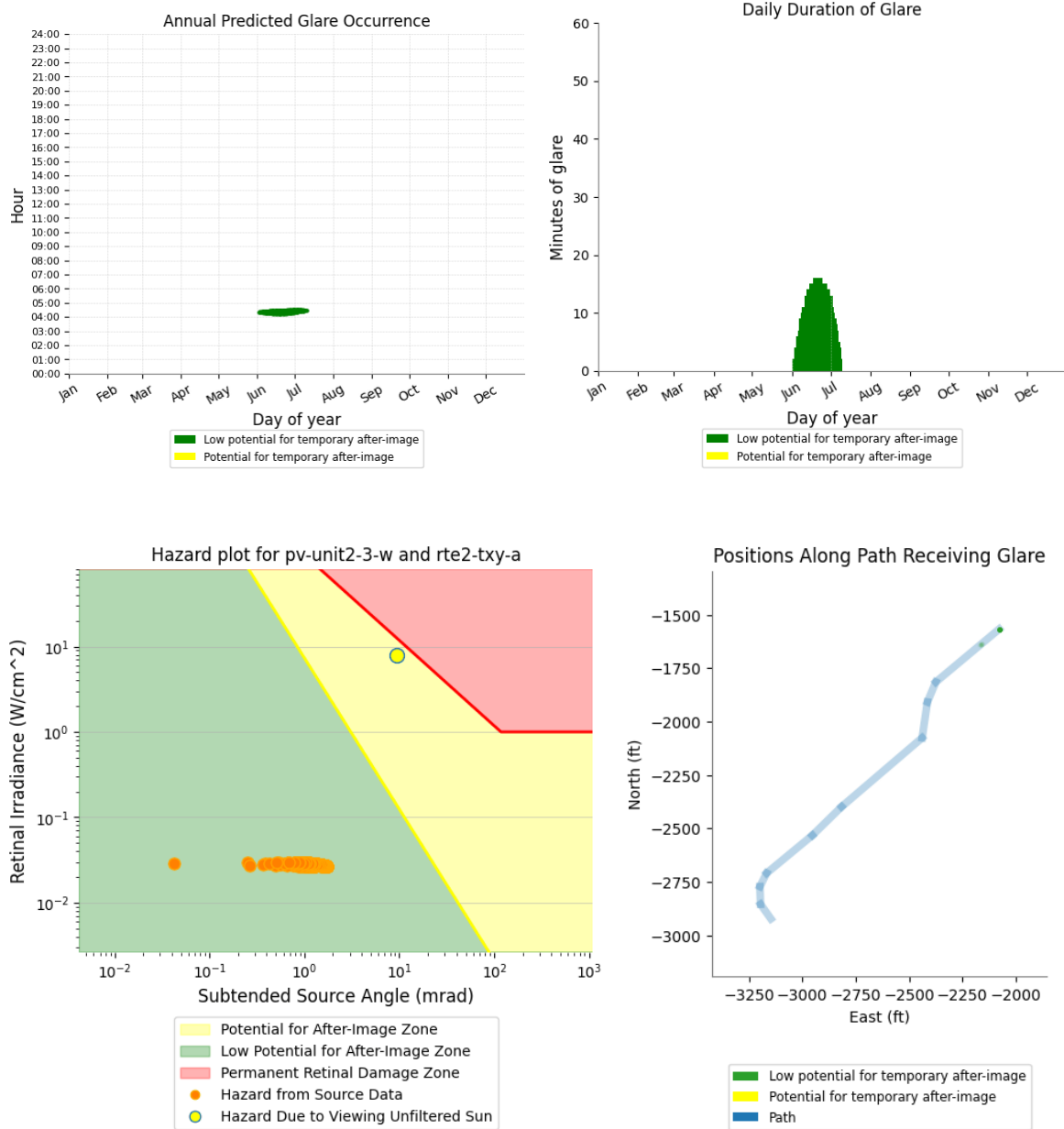
### 3.3.4.1.3 Unit 2 & 3 South Roof Pitch (Taxiway A)



The analysis shows that the Unit 2 & 3 South roof pitch PV array produces 1,227 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway A between the months of May to July and will last no longer than 28 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

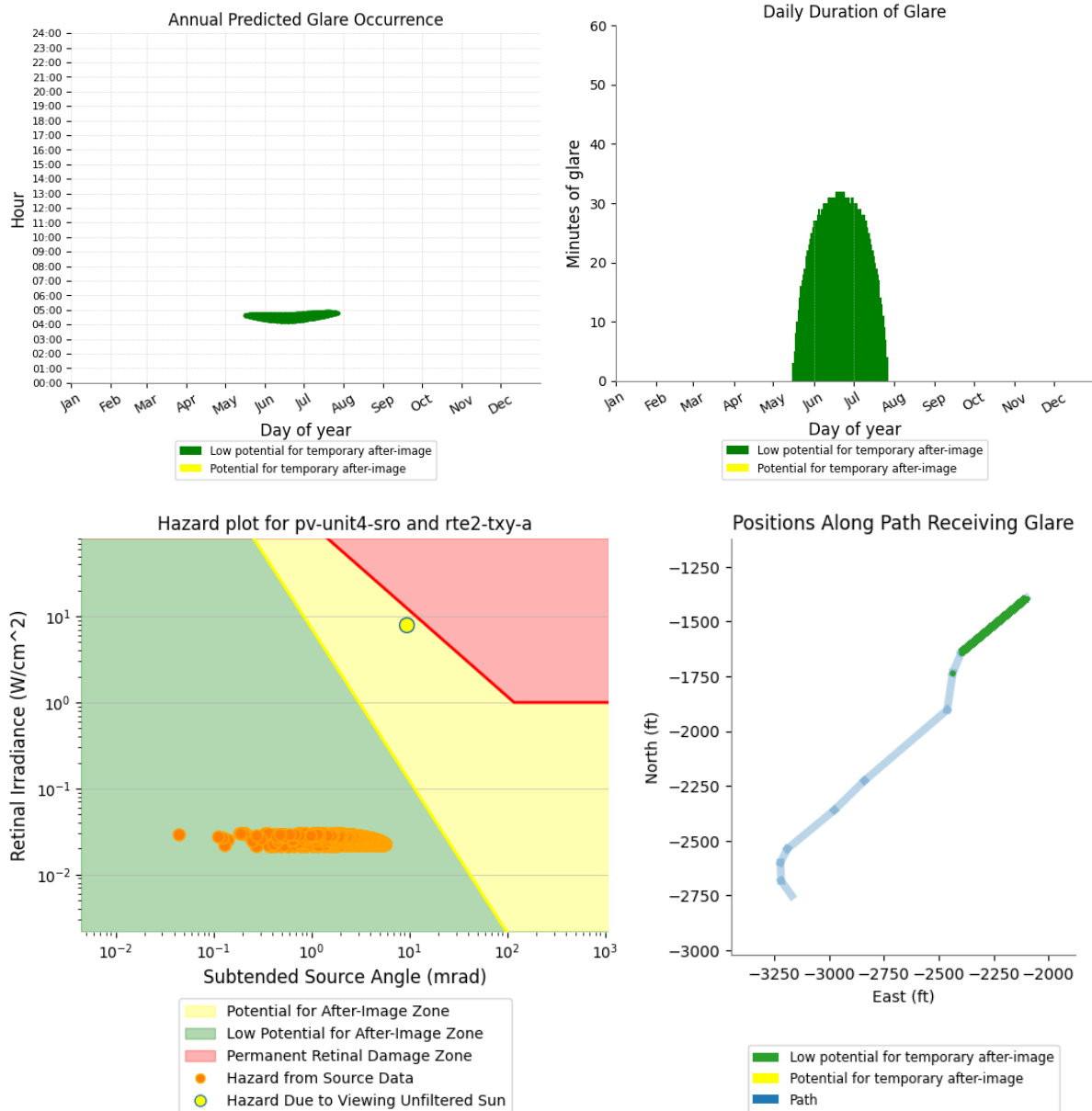
### 3.3.4.1.4 Unit 2 & 3 West Roof Pitch (Taxiway A)



The analysis shows that the Unit 2 & 3 West roof pitch PV array produces 445 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway A between the months of June to July and will last no longer than 15 minutes per day, between the hours of 03:50 to 04:45 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

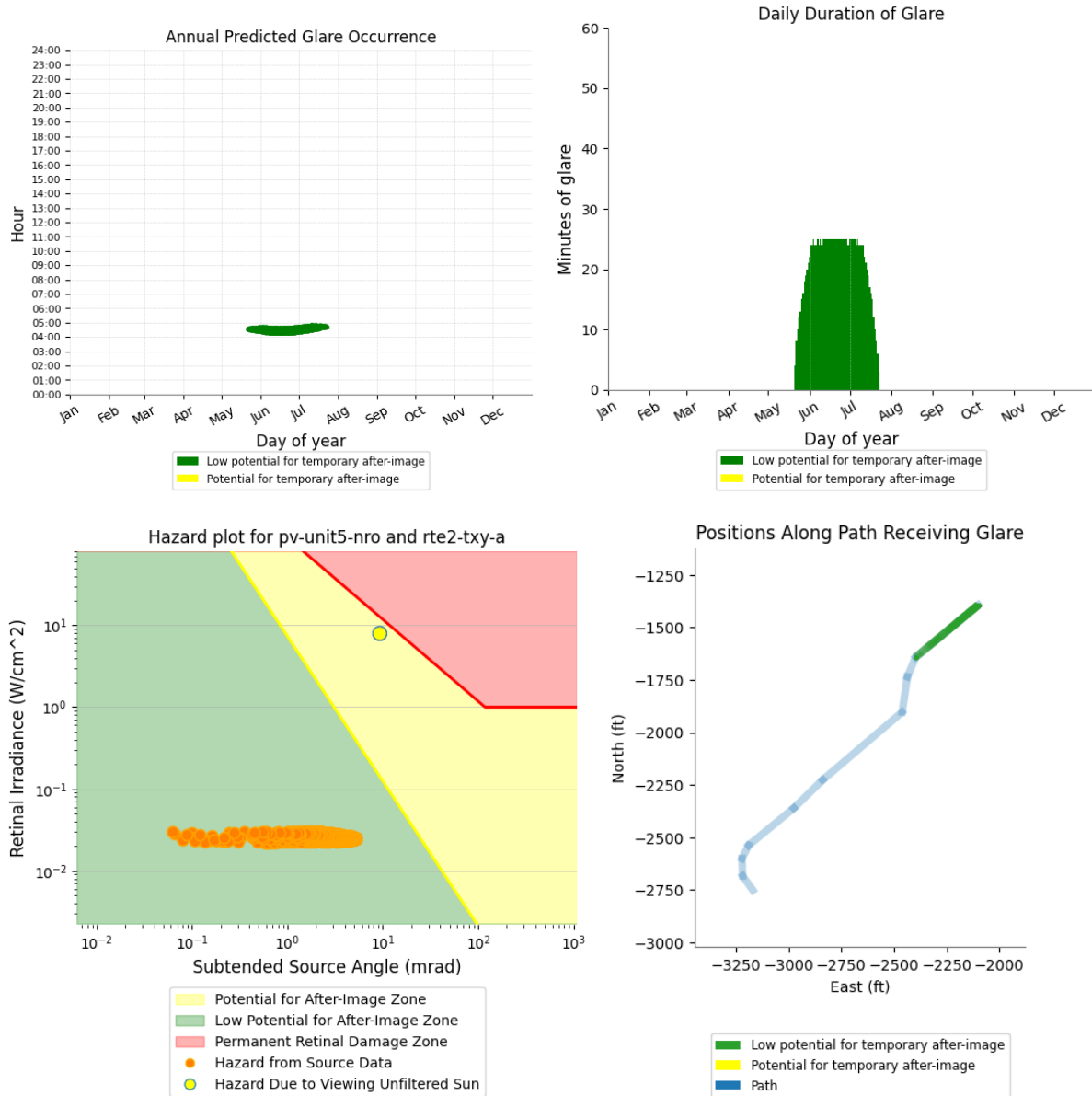
### 3.3.4.1.5 Unit 4 South Roof Pitch (Taxiway A)



The analysis shows that the Unit 4 South roof pitch PV array produces 1,765 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway A between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

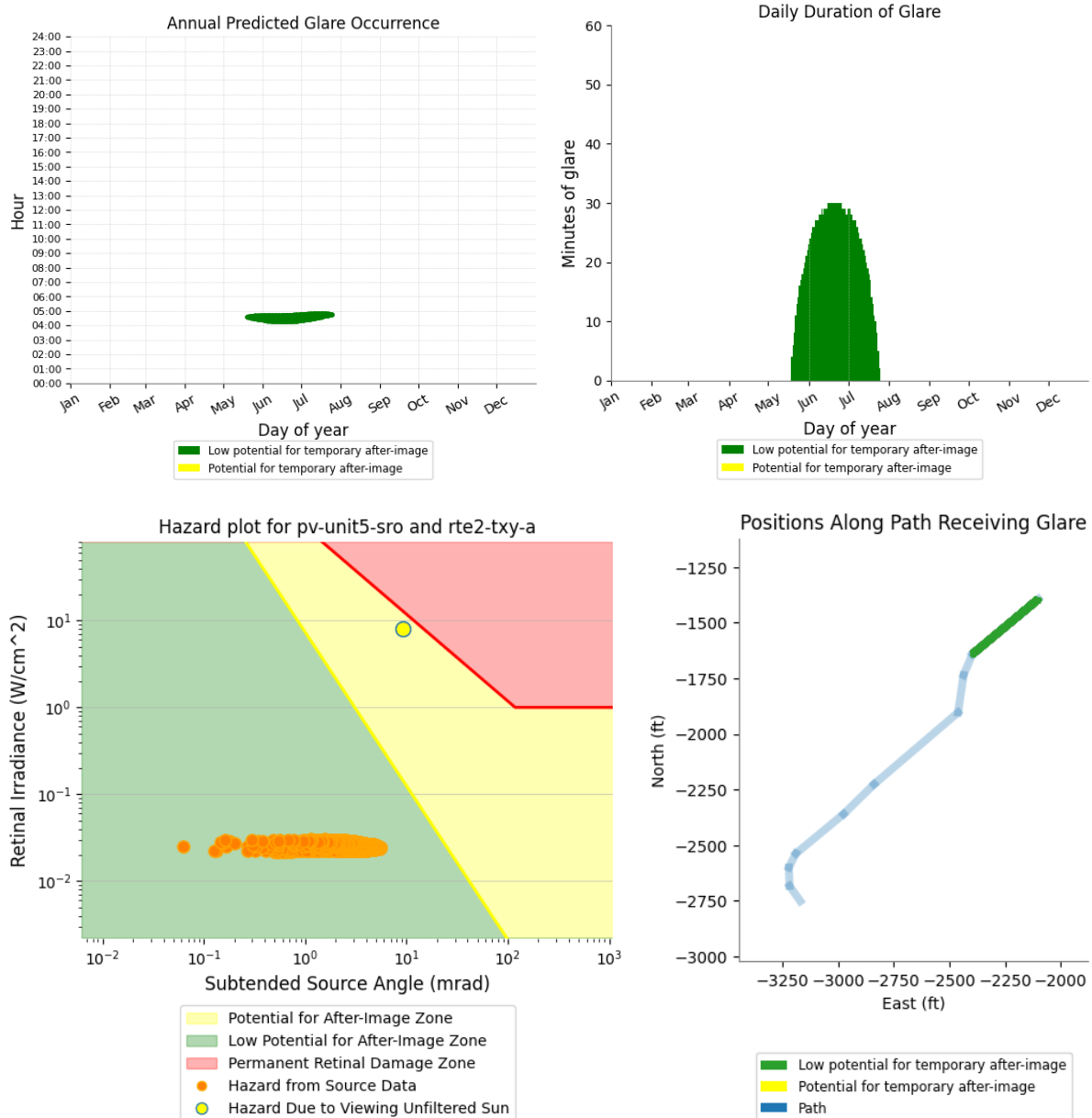
### 3.3.4.1.6 Unit 5 North Roof – South Pitch (Taxiway A)



The analysis shows that the Unit 5 North roof, South pitch PV array produces 1,429 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway A between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4.1.7 Unit 5 South Roof – South Pitch (Taxiway A)



The analysis shows that the Unit 5 South roof, South pitch PV array produces 1,536 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway A between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:15 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

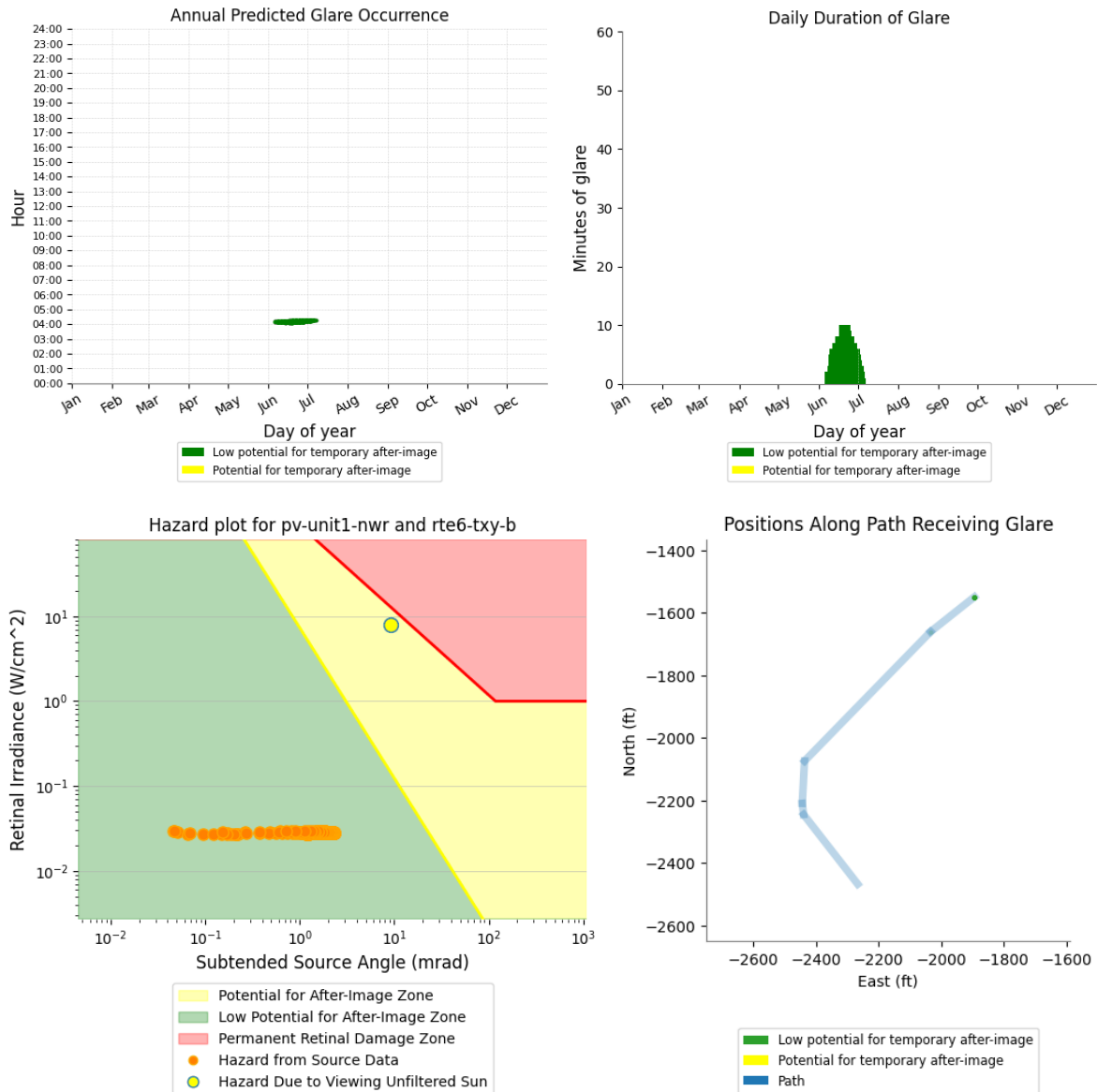
### 3.3.4.2 Route Receptor – PV Array Impacts on Taxiway B



Figure 13 Route Receptor - Taxiway B

Note: Route receptor analysis may not mirror the exact aerodrome plan depiction of taxiway designations. However, a full coverage of the major taxiway network analysis is captured throughout this report.

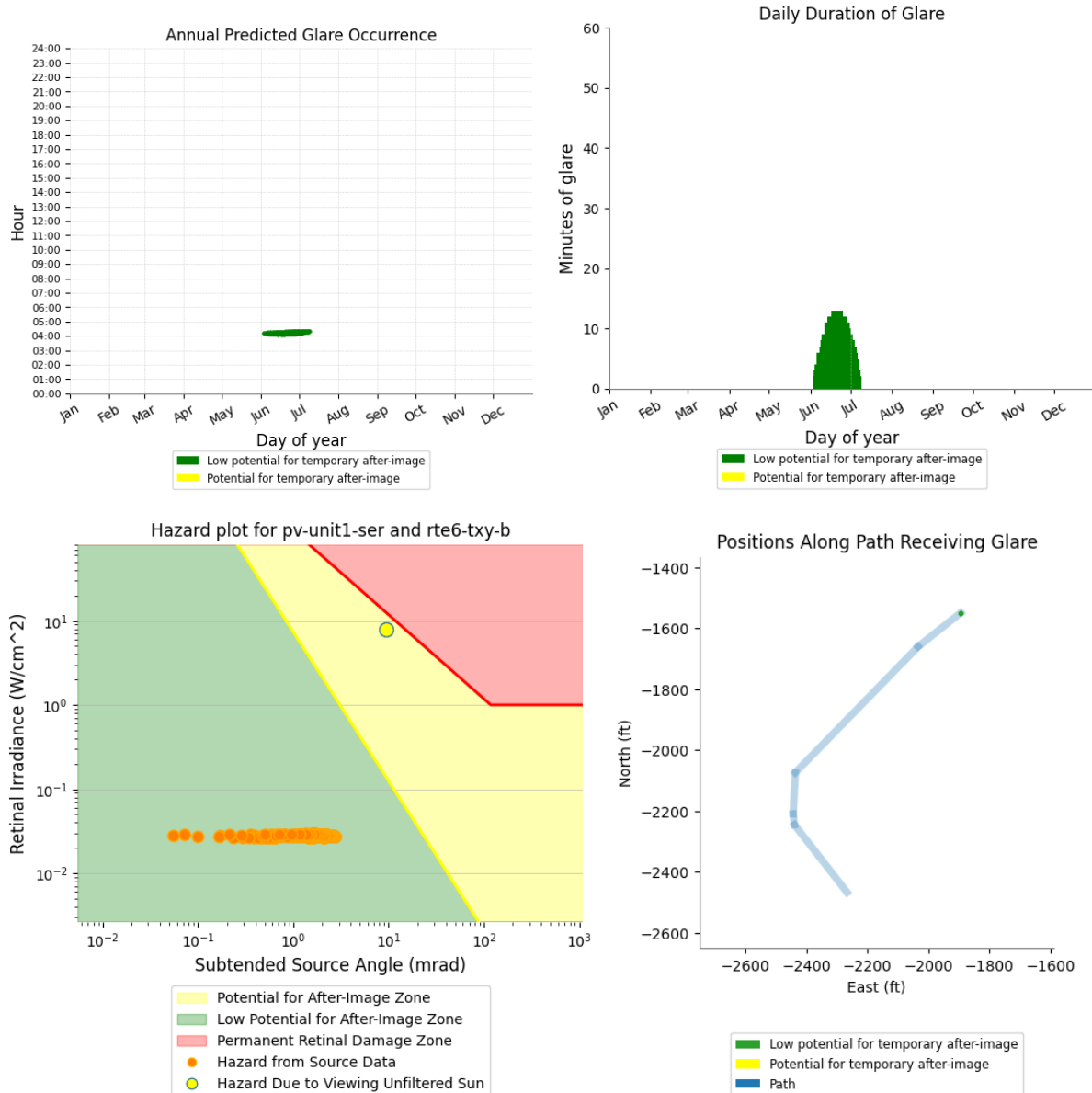
### 3.3.4.2.1 Unit 1 North-West Roof – West Pitch (Taxiway B)



The analysis shows that the Unit 1 North-west roof, West pitch PV array produces 218 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway B between the months of June to July and will last no longer than 10 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

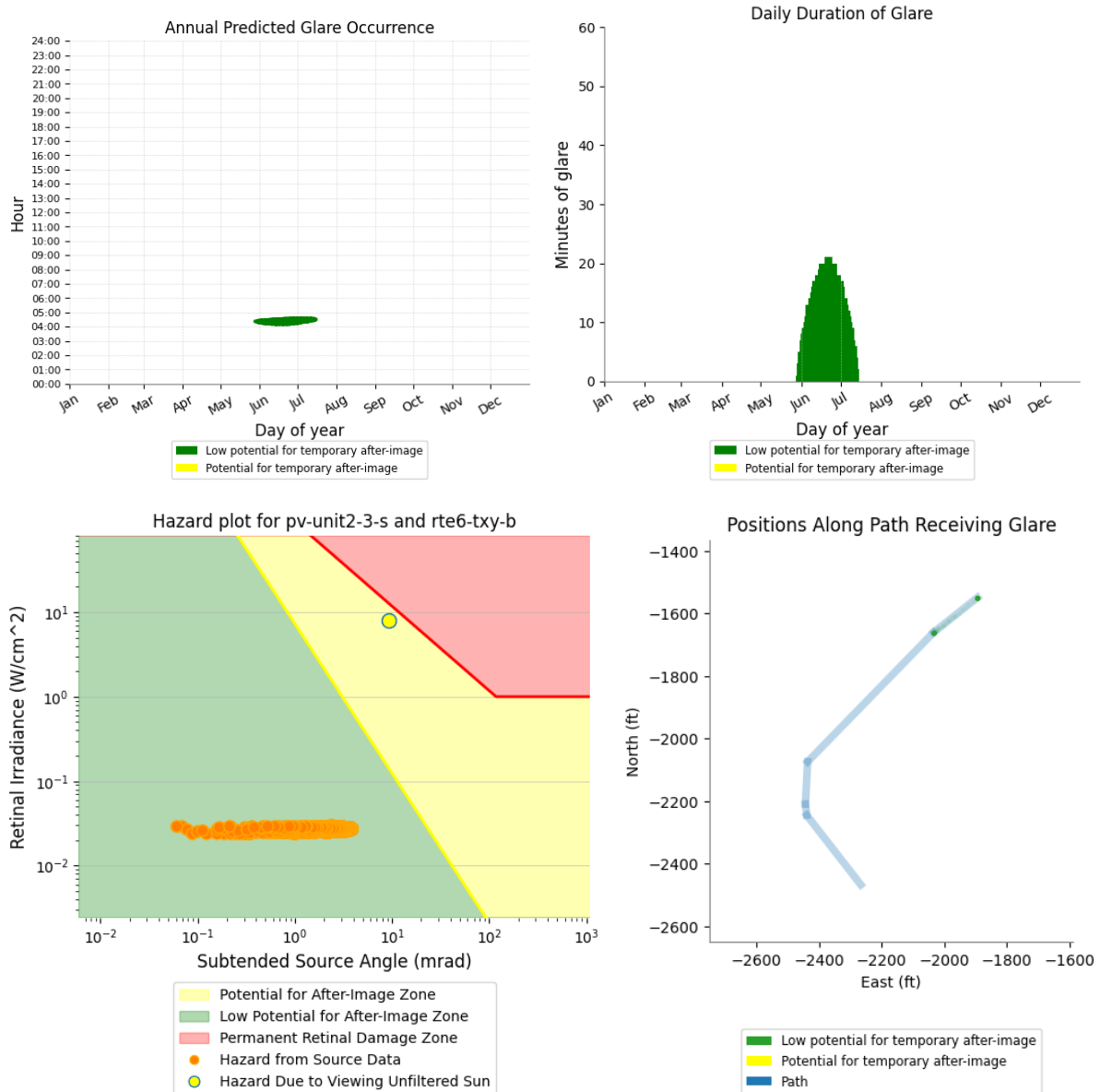
### 3.3.4.2.2 Unit 1 South-East Roof – West Pitch (Taxiway B)



The analysis shows that the Unit 1 South-east roof, West pitch PV array produces 345 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway B between the months of June to July and will last no longer than 13 minutes per day, between the hours of 04:00 to 04:50 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

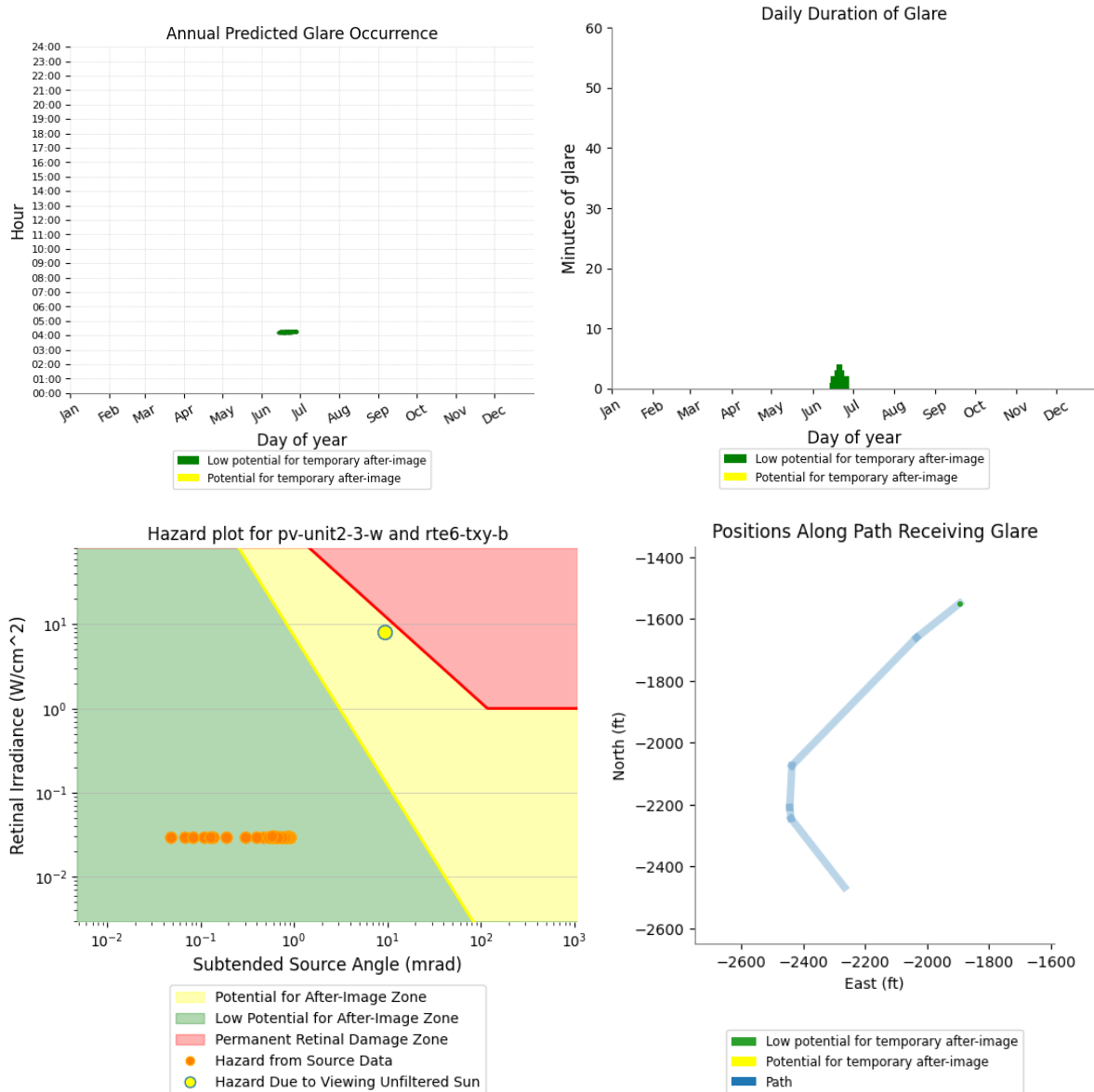
### 3.3.4.2.3 Unit 2 & 3 South Roof Pitch (Taxiway B)



The analysis shows that the Unit 2 & 3 South roof pitch PV array produces 706 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway B between the months of May to July and will last no longer than 22 minutes per day, between the hours of 04:00 to 04:55 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

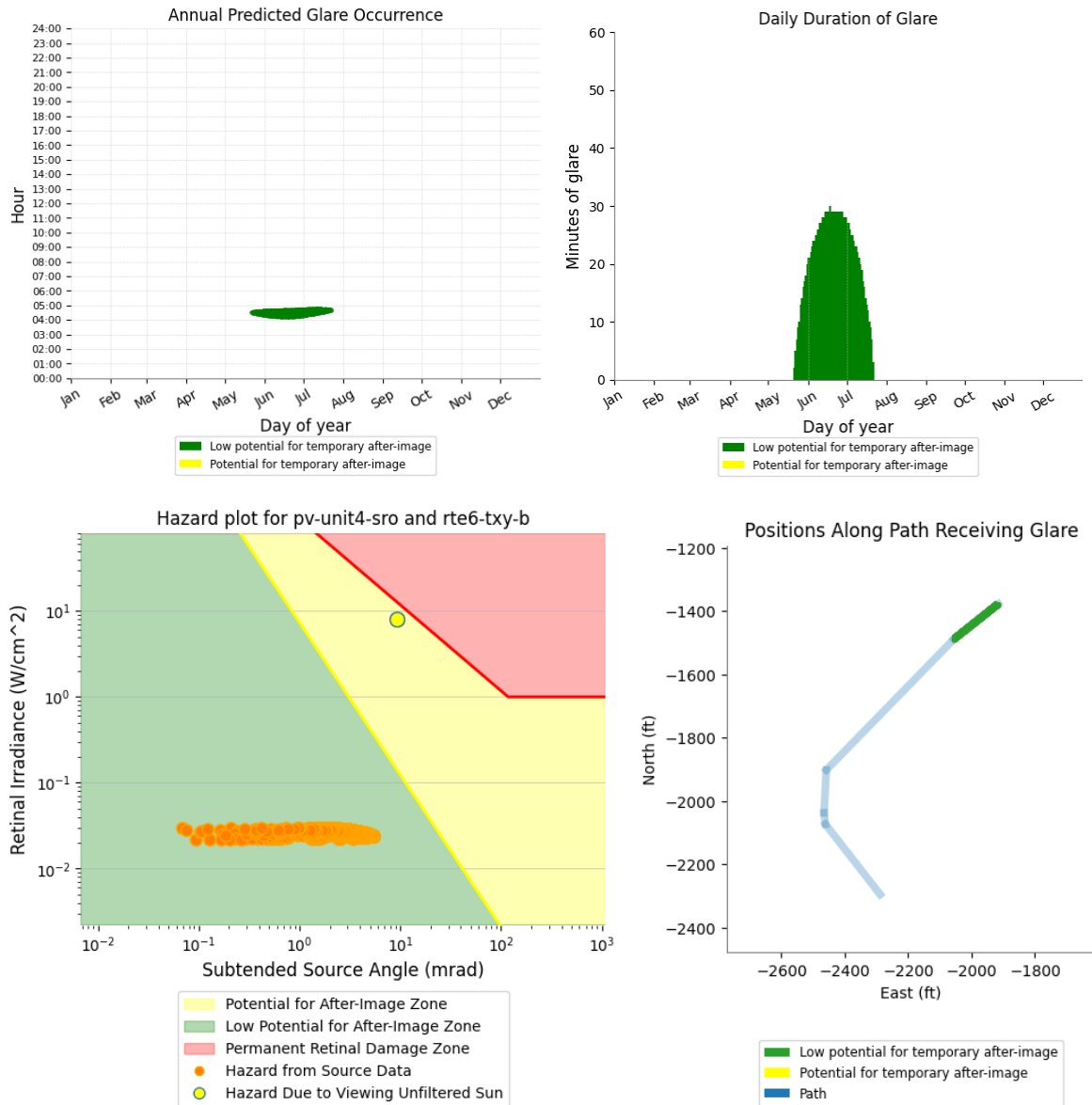
### 3.3.4.2.4 Unit 2 & 3 West Roof Pitch (Taxiway B)



The analysis shows that the Unit 2 & 3 West roof pitch PV array produces 41 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway B in the month of June and will last no longer than 5 minutes per day, between the hours of 04:00 to 04:30 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

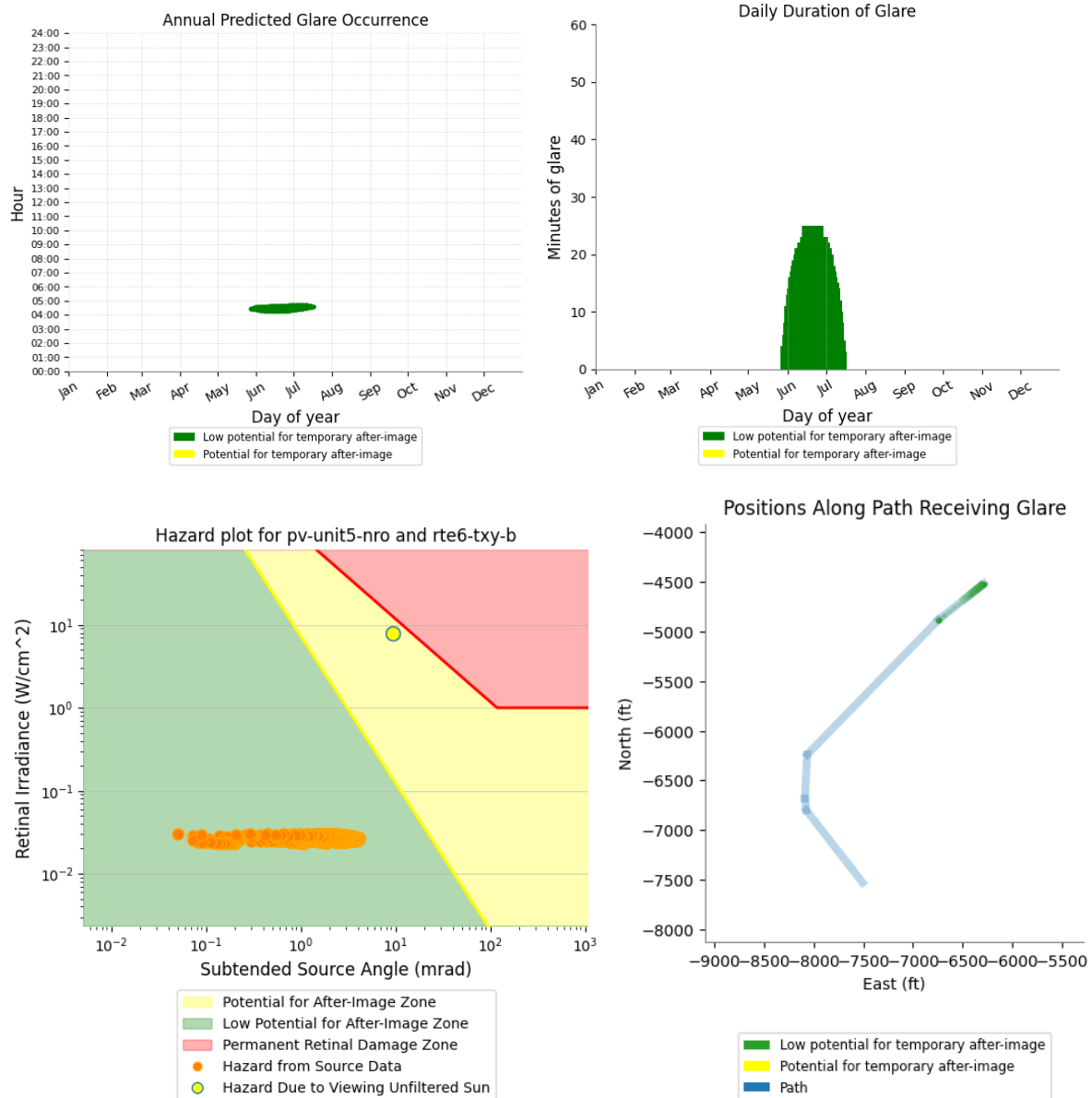
### 3.3.4.2.5 Unit 4 South Roof Pitch (Taxiway B)



The analysis shows that the Unit 4 South roof pitch PV array produces 1,356 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway B between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

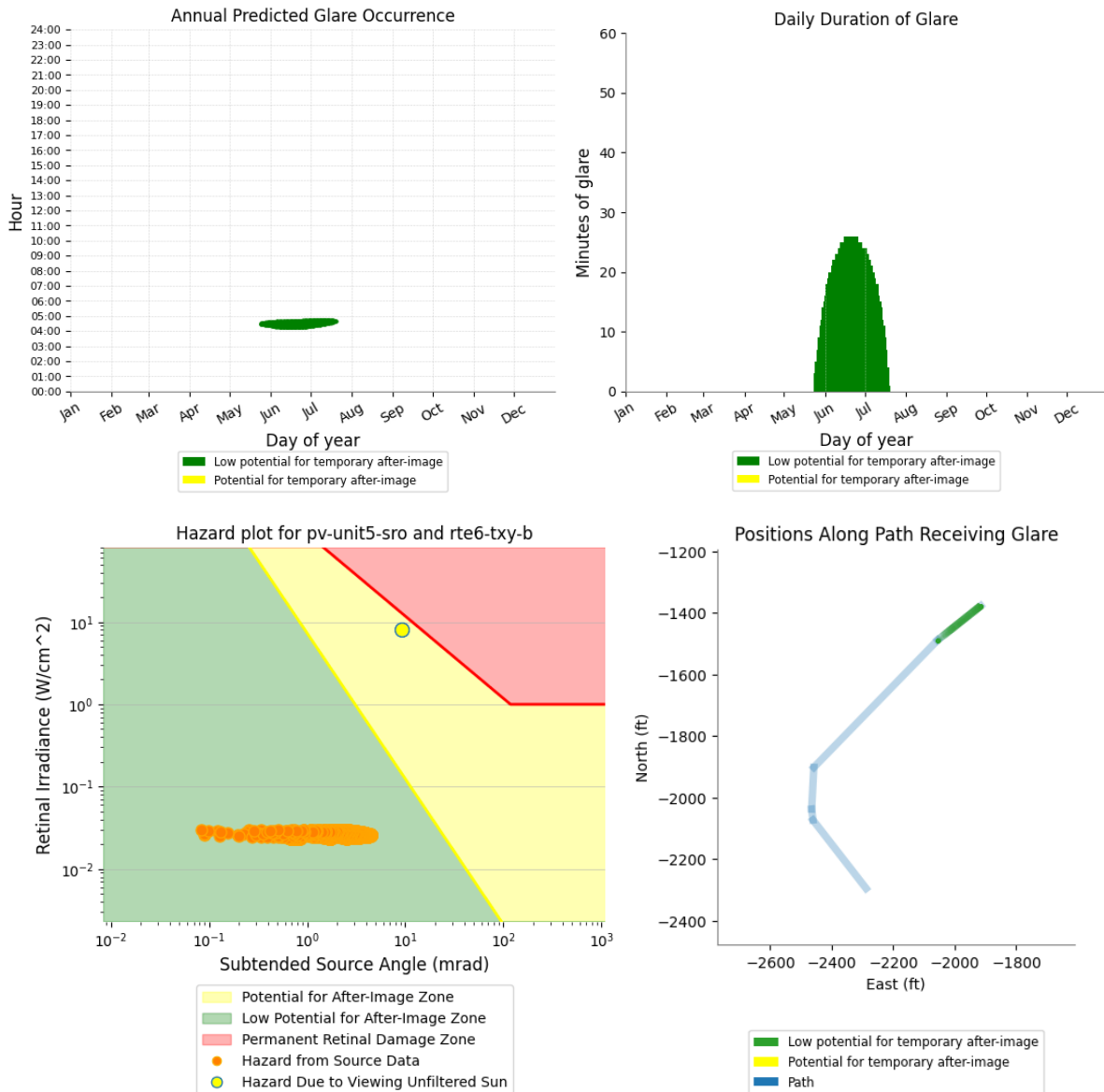
### 3.3.4.2.6 Unit 5 North Roof - South Pitch (Taxiway B)



The analysis shows that the Unit 5 North roof, South pitch PV array produces 998 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway B between the months of May to July and will last no longer than 25 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4.2.7 Unit 5 South Roof - South Pitch (Taxiway B)



The analysis shows that the Unit 5 South roof, South pitch PV array produces 1,110 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiway B between the months of May to July and will last no longer than 25 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

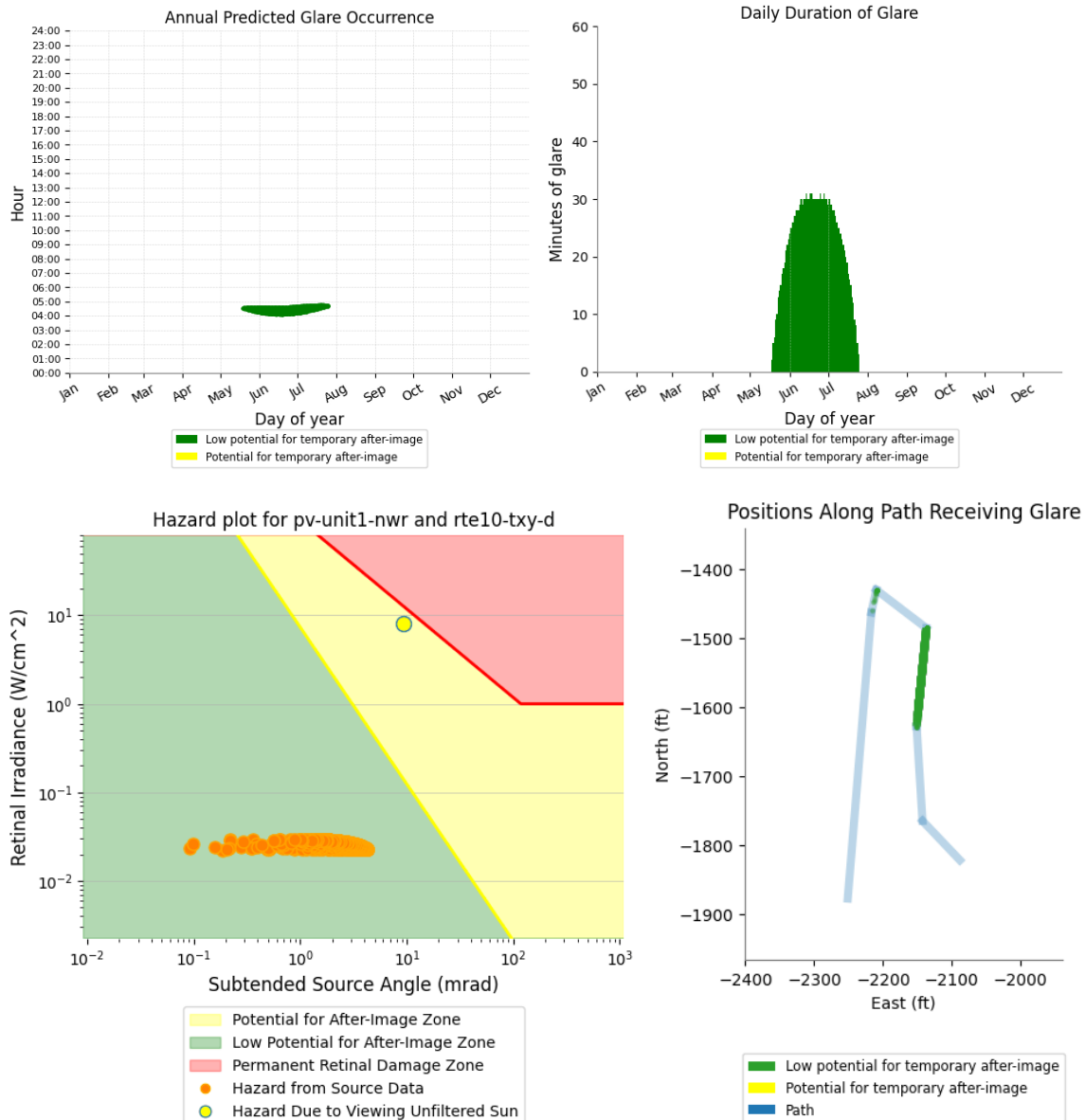
### 3.3.4.3 Route Receptor – PV Array Impacts on Taxiways C, D & P



Figure 14 Route Receptor - Elements of Taxiways C, D & P

Note: Route receptor analysis may not mirror the exact aerodrome plan depiction of taxiway designations. However, a full coverage of the major taxiway network analysis is captured throughout this report.

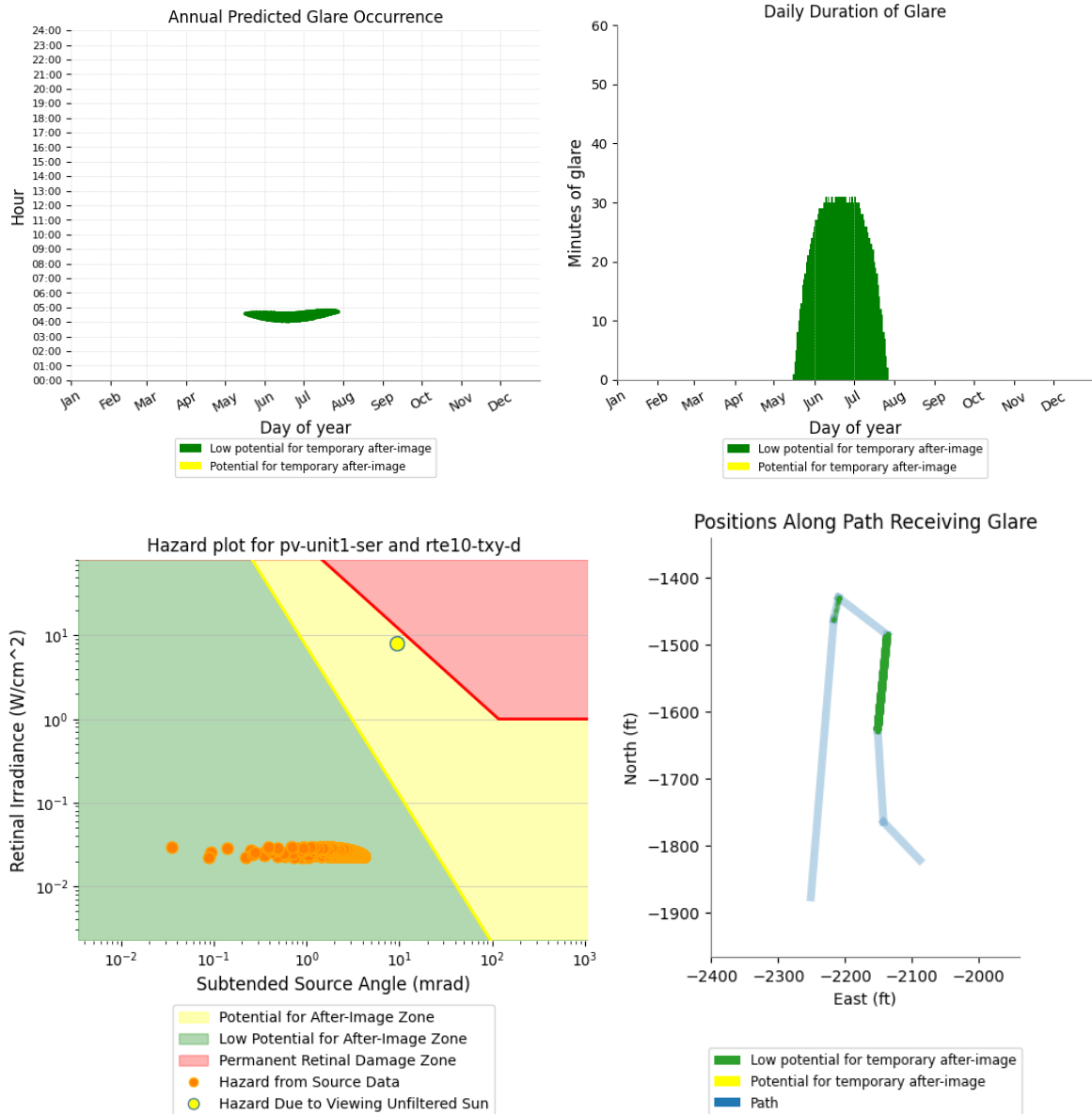
### 3.3.4.3.1 Unit 1 North-West Roof – West Pitch (Taxiway C, D & P)



The analysis shows that the Unit 1 North-west roof, West pitch PV array produces 1,572 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to the Taxiways C, D & P between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

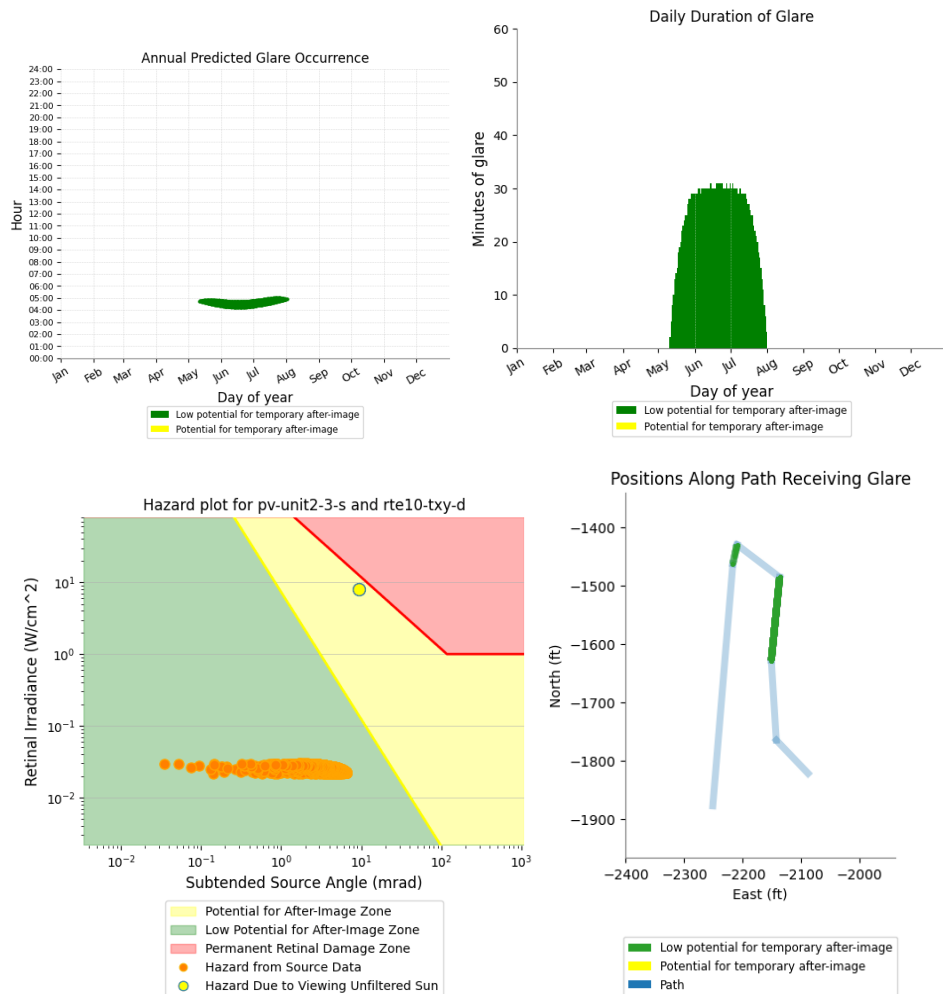
### 3.3.4.3.2 Unit 1 South-East Roof – West Pitch (Taxiway C, D & P)



The analysis shows that the Unit 1 South-east roof, West pitch PV array produces 1,701 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways C, D & P between the months of May to July and will last no longer than 30 minutes per day, between the hours of 03:50 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

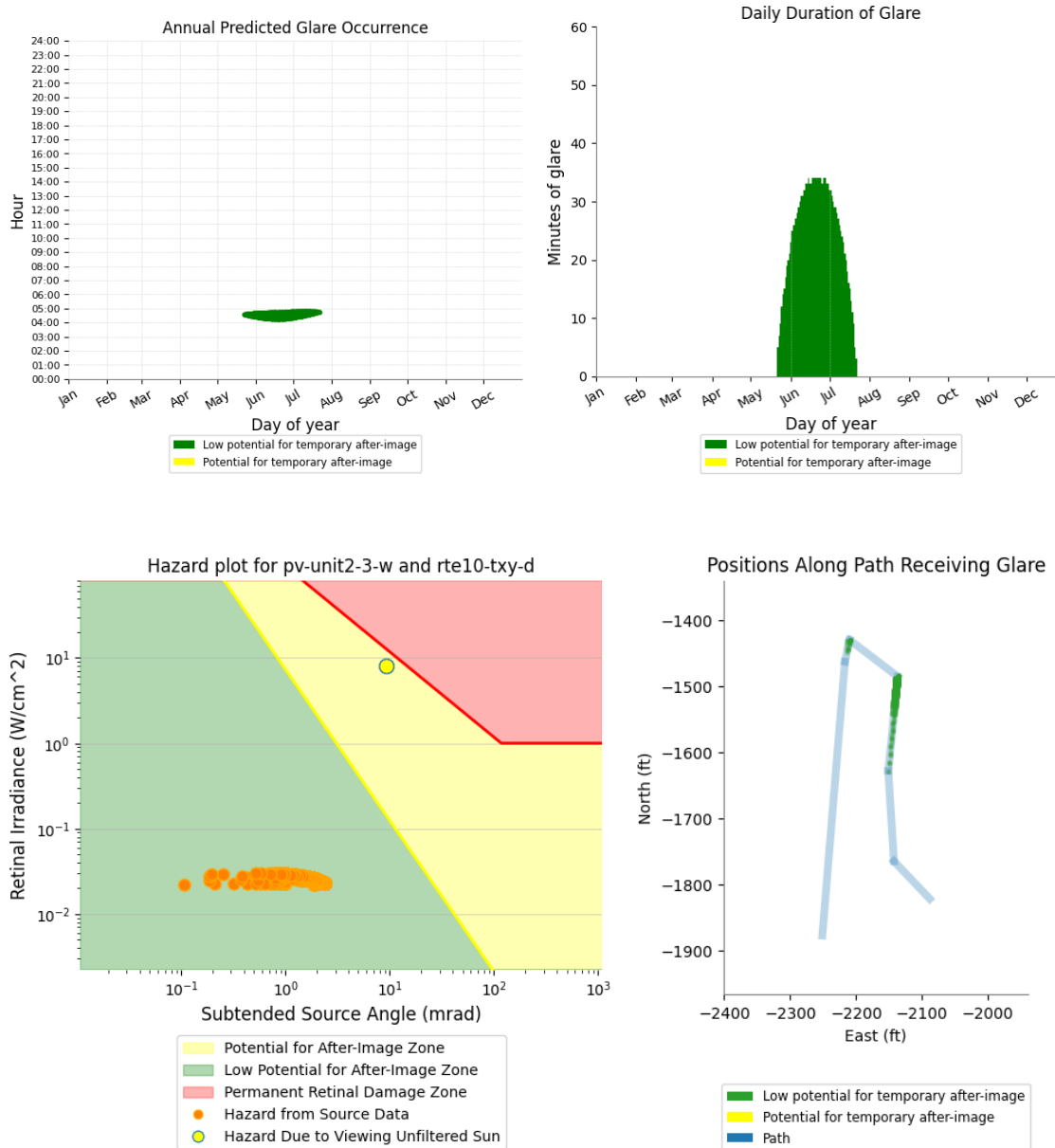
### 3.3.4.3.3 Unit 2 & 3 South Roof Pitch



The analysis shows that the Unit 2 & 3 South roof pitch PV array produces 2,070 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways C, D & P between the months of May to August and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

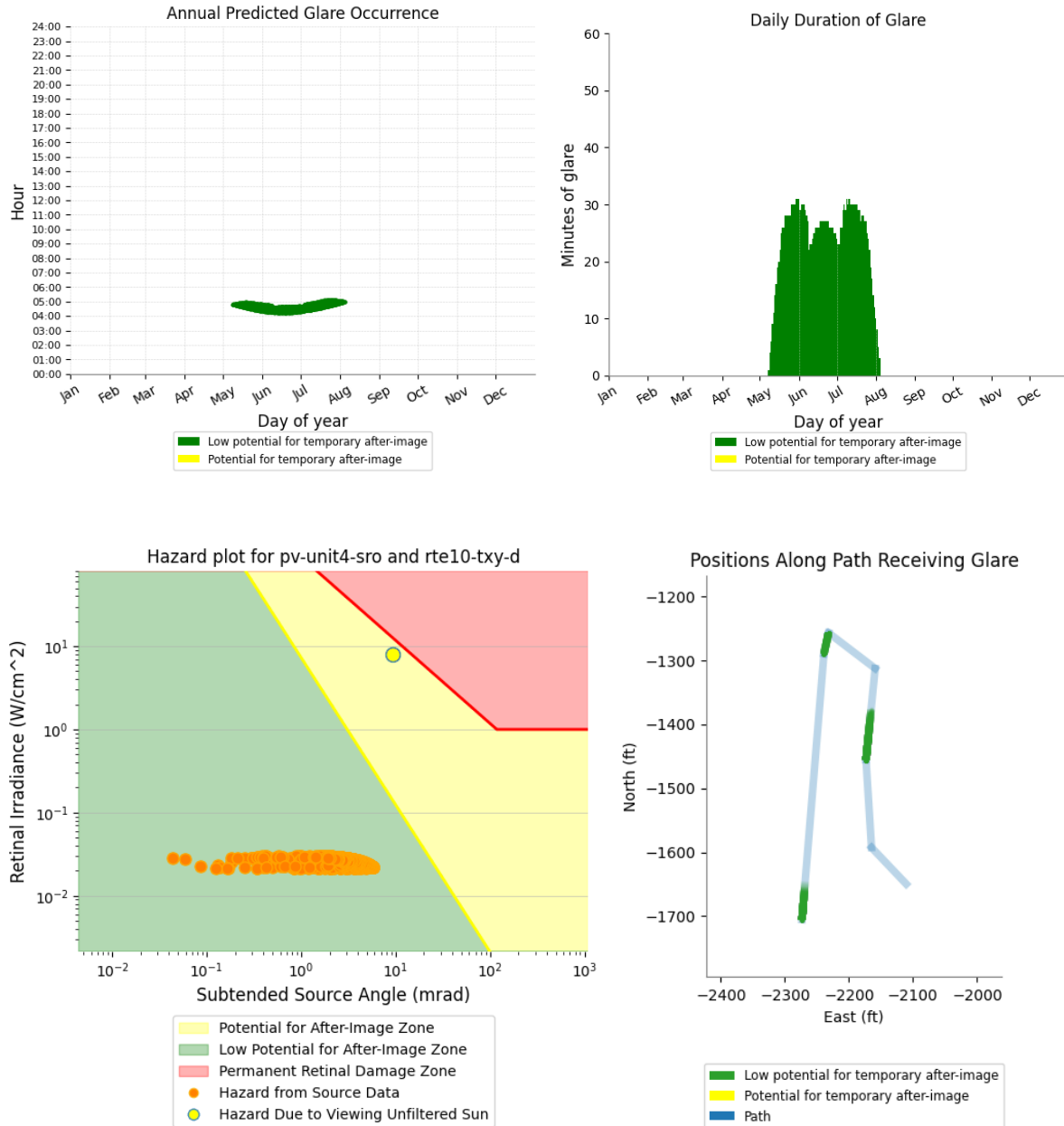
### 3.3.4.3.4 Unit 2 & 3 West Roof Pitch (Taxiway C, D & P)



The analysis shows that the Unit 2 & 3 West roof pitch PV array produces 1,550 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways C, D & P between the months of May to July and will last no longer than 35 minutes per day, between the hours of 03:50 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

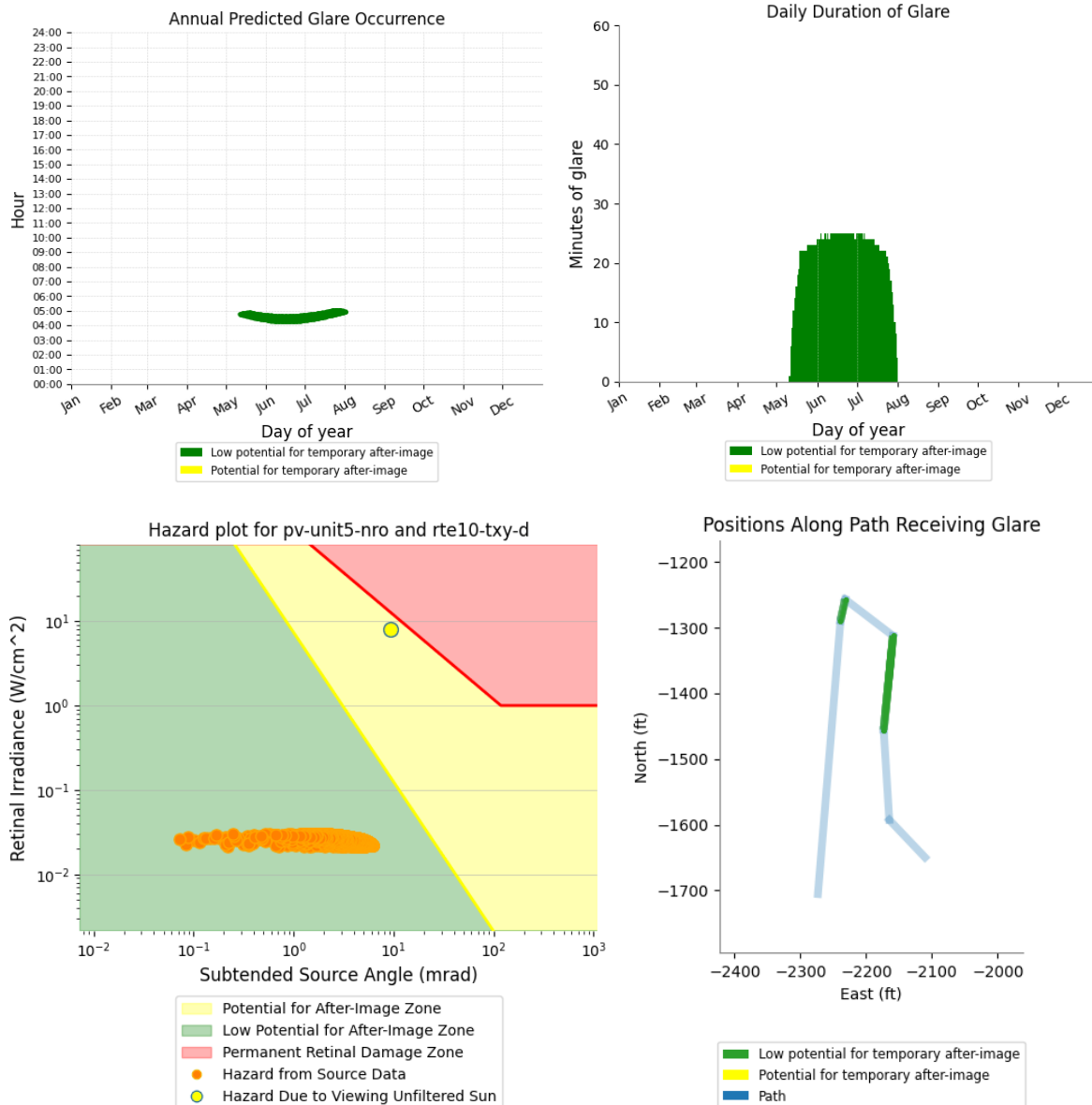
### 3.3.4.3.5 Unit 4 South Roof Pitch (Taxiway C, D & P)



The analysis shows that the Unit 4 South roof pitch PV array produces 2,155 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways C, D & P between the months of May to August and will last no longer than 30 minutes per day, between the hours of 03:50 to 05:15 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

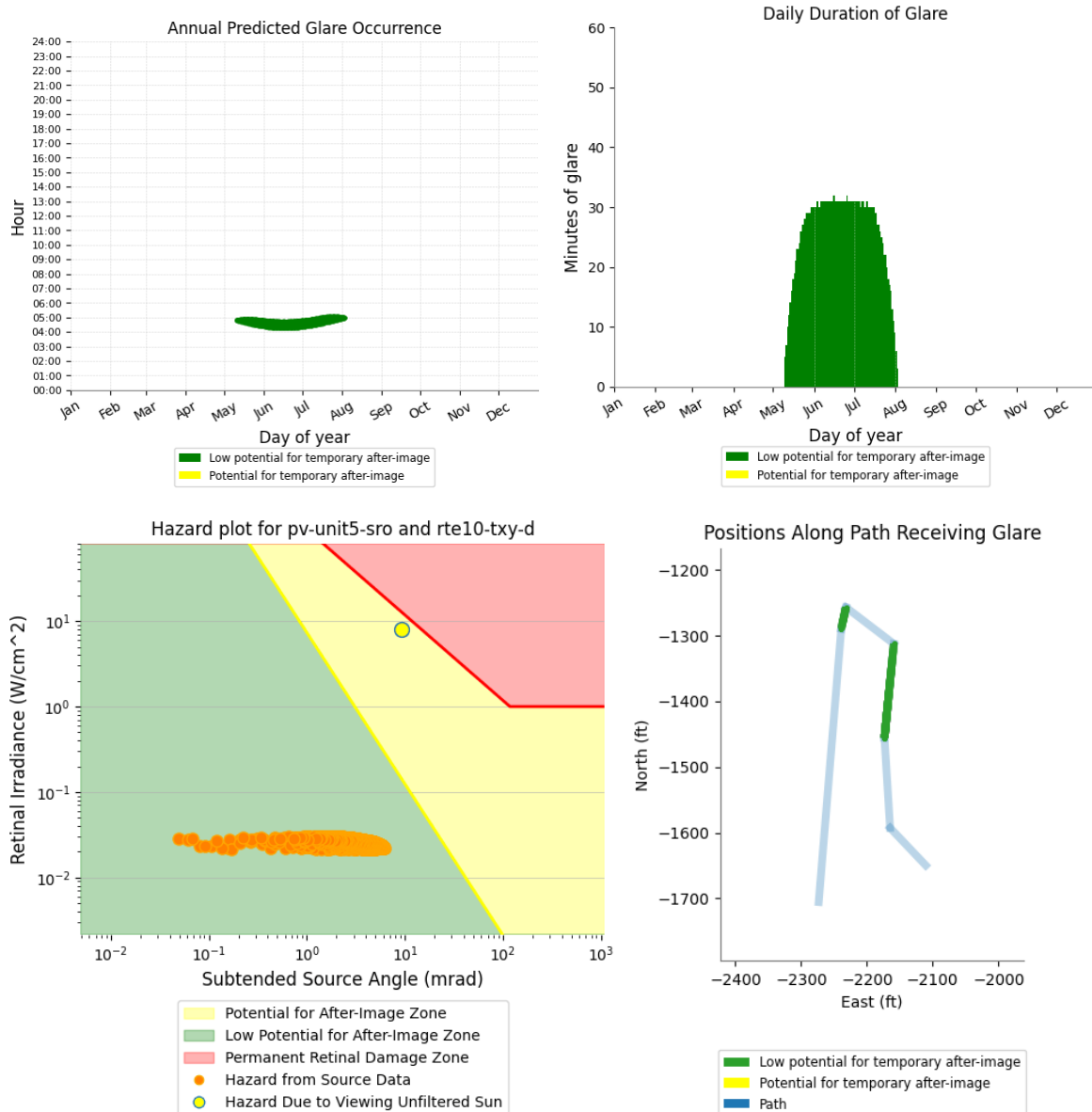
### 3.3.4.3.6 Unit 5 North Roof – South Pitch (Taxiway C, D & P)



The analysis shows that the Unit 5 North roof, South pitch PV array produces 2,167 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways C, D & P between the months of May to August and will last no longer than 25 minutes per day, between the hours of 04:00 to 05:15 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4.3.7 Unit 5 South Roof – South Pitch (Taxiway C, D & P)



The analysis shows that the Unit 5 South roof, South pitch PV array produces 2,237 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways C, D & P between the months of May to August and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:15 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

#### 3.3.4.4 Route Receptor – PV Array Impacts on Taxiways F & K



Figure 15 Route Receptor - Elements of Taxiways F & K

Note: Route receptor analysis may not mirror the exact aerodrome plan depiction of taxiway designations. However, a full coverage of the major taxiway network analysis is captured throughout this report.

### 3.3.4.4.1 Unit 1 North-West Roof – West Pitch (Taxiway F & K)



The analysis shows that the Unit 1 North-west roof, West pitch PV array produces 421 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways F & K between the months of June to July and will last no longer than 15 minutes per day, between the hours of 04:00 to 04:45 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

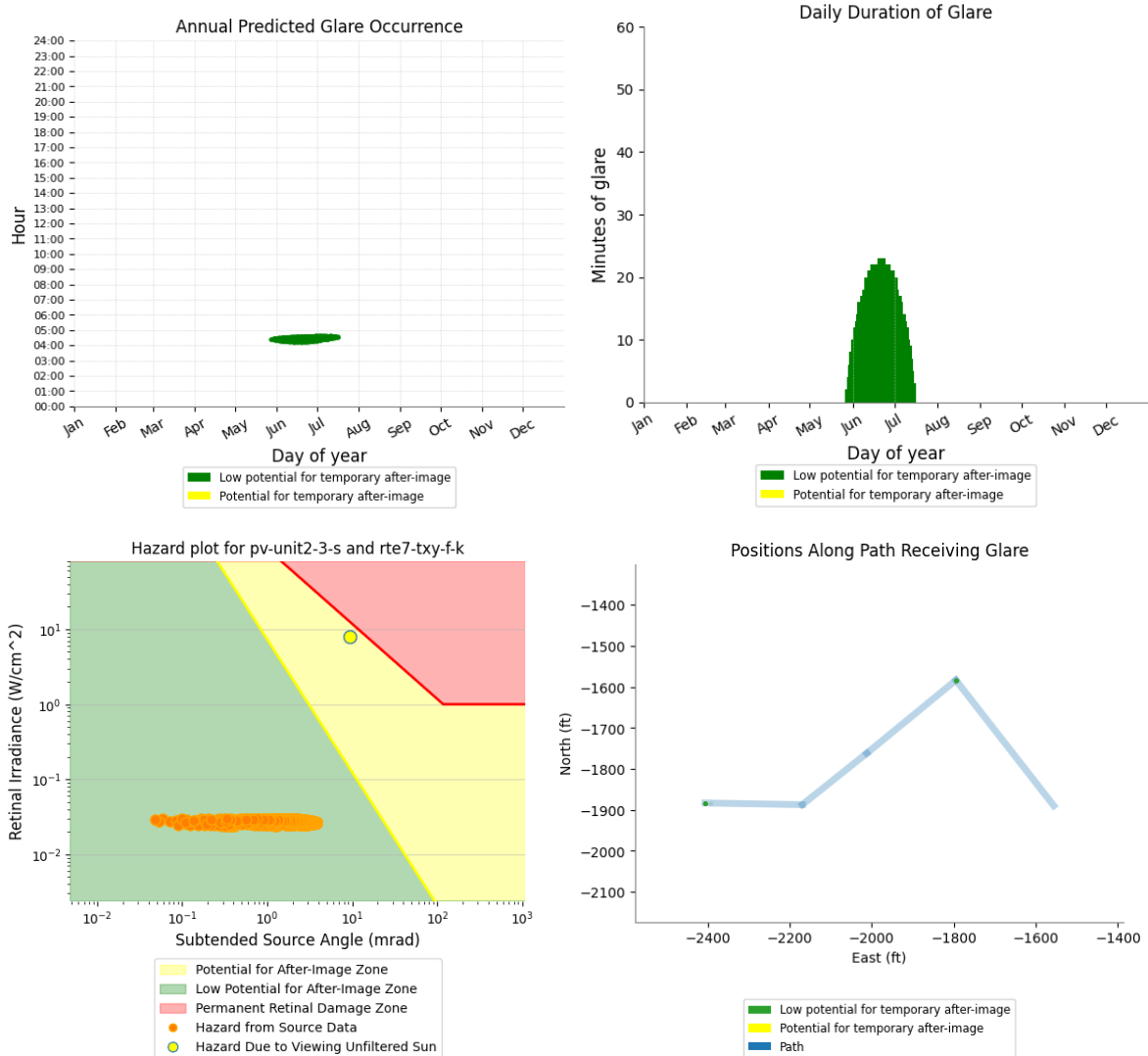
### 3.3.4.4.2 Unit 1 South-East Roof – West Pitch (Taxiway F & K)



The analysis shows that the Unit 1 South-east roof, West pitch PV array produces 530 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways F & K between the months of May to July and will last no longer than 18 minutes per day, between the hours of 03:50 to 04:50 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

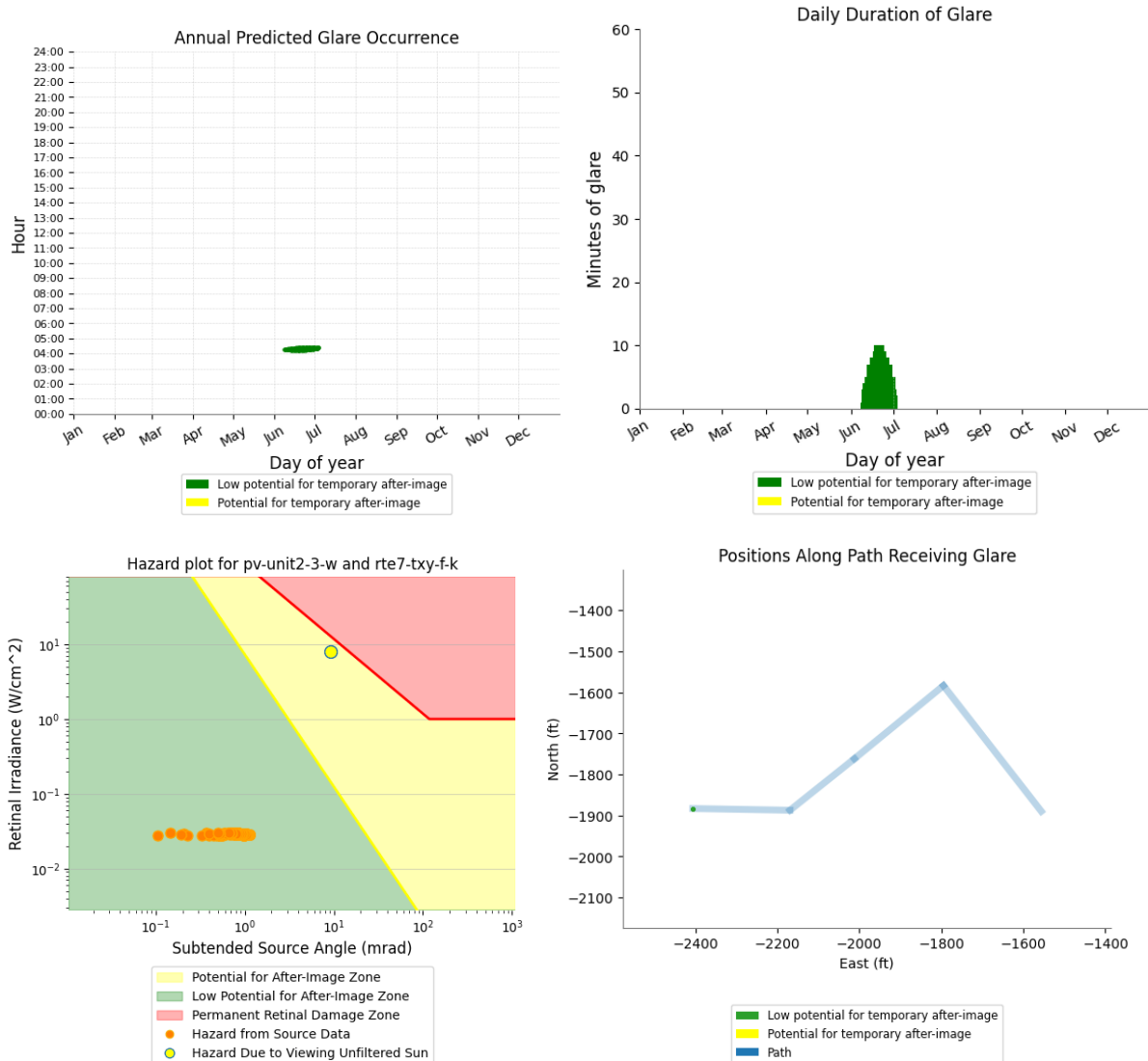
### 3.3.4.4.3 Unit 2 & 3 South Roof Pitch (Taxiway F & K)



The analysis shows that the Unit 2 & 3 South roof pitch PV array produces 840 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways F & K between the months of May to July and will last no longer than 24 minutes per day, between the hours of 04:00 to 04:55 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4.4.4 Unit 2 & 3 West Roof Pitch (Taxiway F & K)



The analysis shows that the Unit 2 & 3 West roof pitch PV array produces 190 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways F & K between the months of June to July and will last no longer than 10 minutes per day, between the hours of 04:00 to 04:50 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

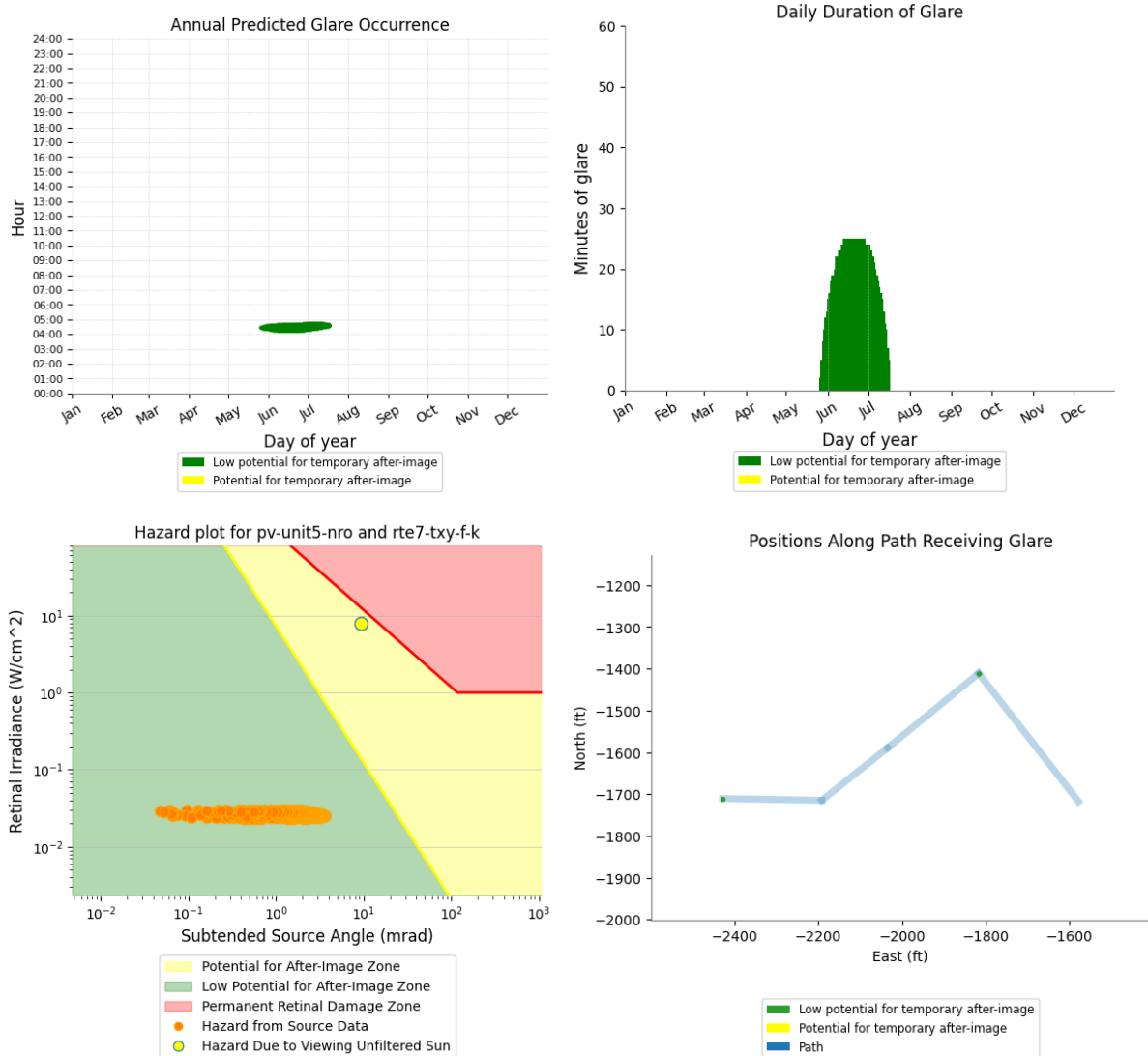
### 3.3.4.4.5 Unit 4 South Roof Pitch (Taxiway F & K)



The analysis shows that the Unit 4 South roof pitch PV array produces 1,356 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways F & K between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

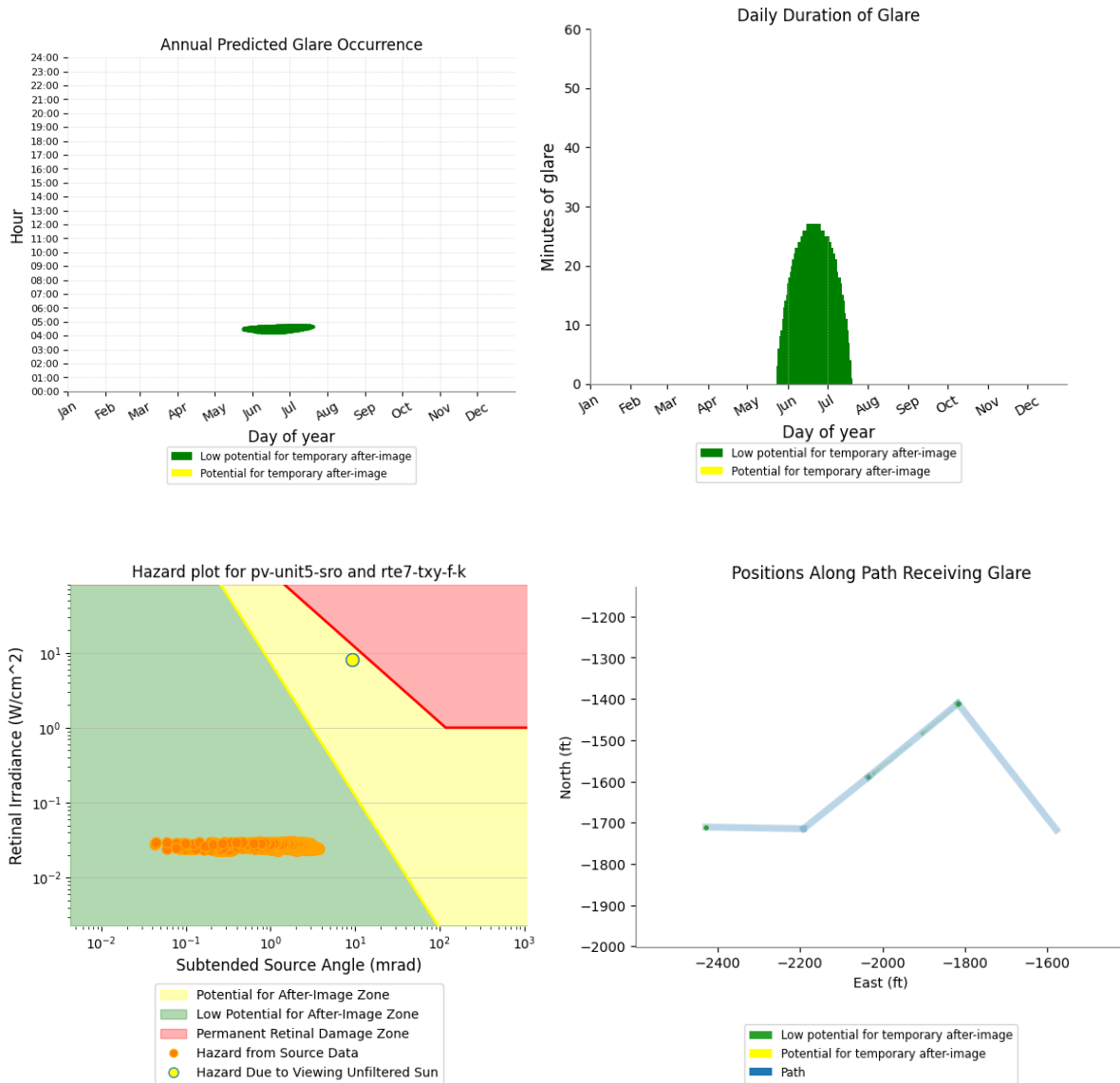
### 3.3.4.4.6 Unit 5 North Roof – South Pitch (Taxiway F & K)



The analysis shows that the Unit 5 North roof, South pitch PV array produces 1,017 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways F & K between the months of May to July and will last no longer than 25 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4.4.7 Unit 5 South Roof – South Pitch (Taxiway F & K)



The analysis shows that the Unit 5 South roof, South pitch PV array produces 1,149 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways F & K between the months of May to July and will last no longer than 25 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

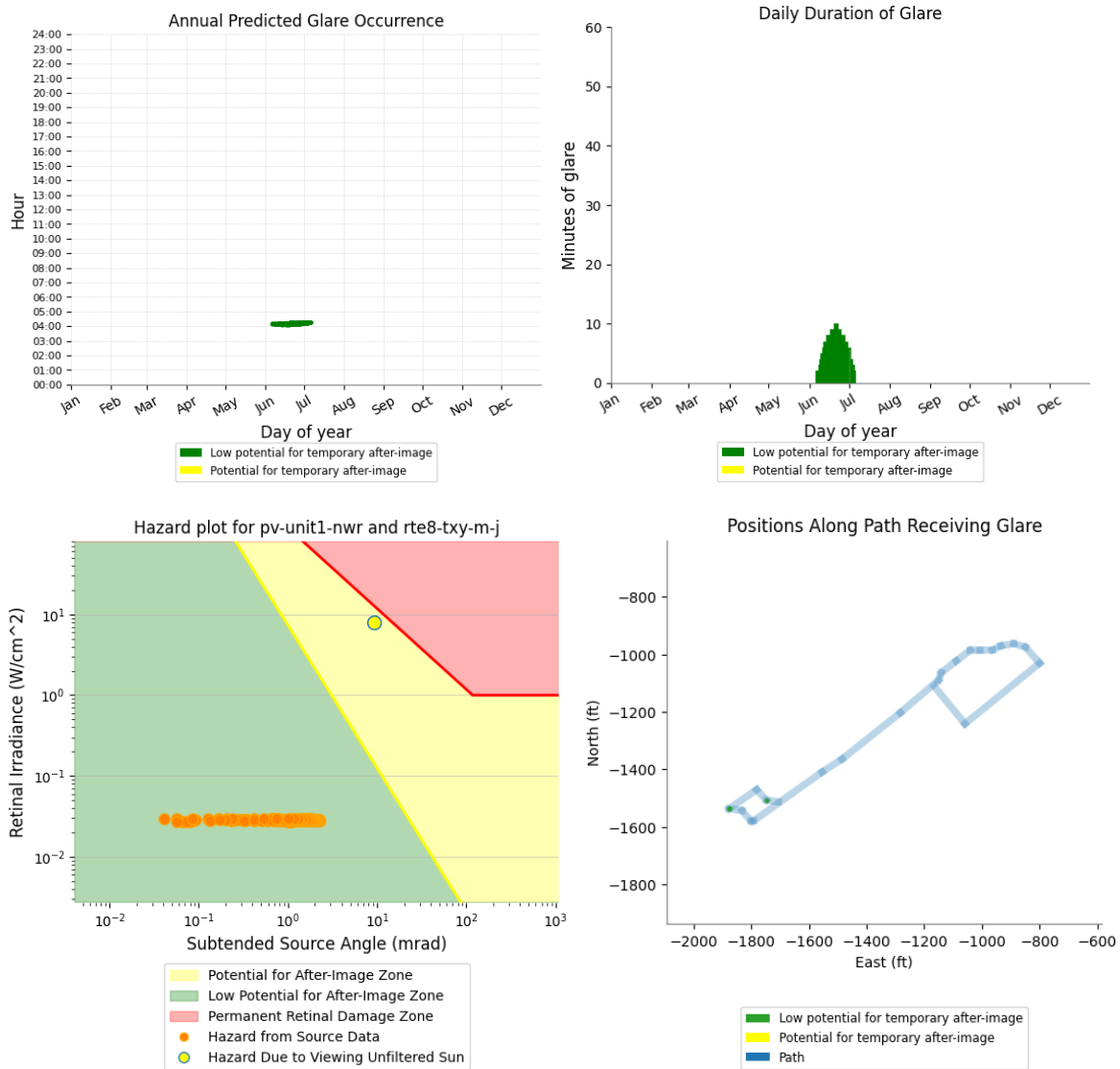
### 3.3.4.5 Route Receptor – PV Array Impacts on Taxiways B, J & M



Figure 16 Route Receptor - Elements of Taxiways B, J & M

Note: Route receptor analysis may not mirror the exact aerodrome plan depiction of taxiway designations. However, a full coverage of the major taxiway network analysis is captured throughout this report.

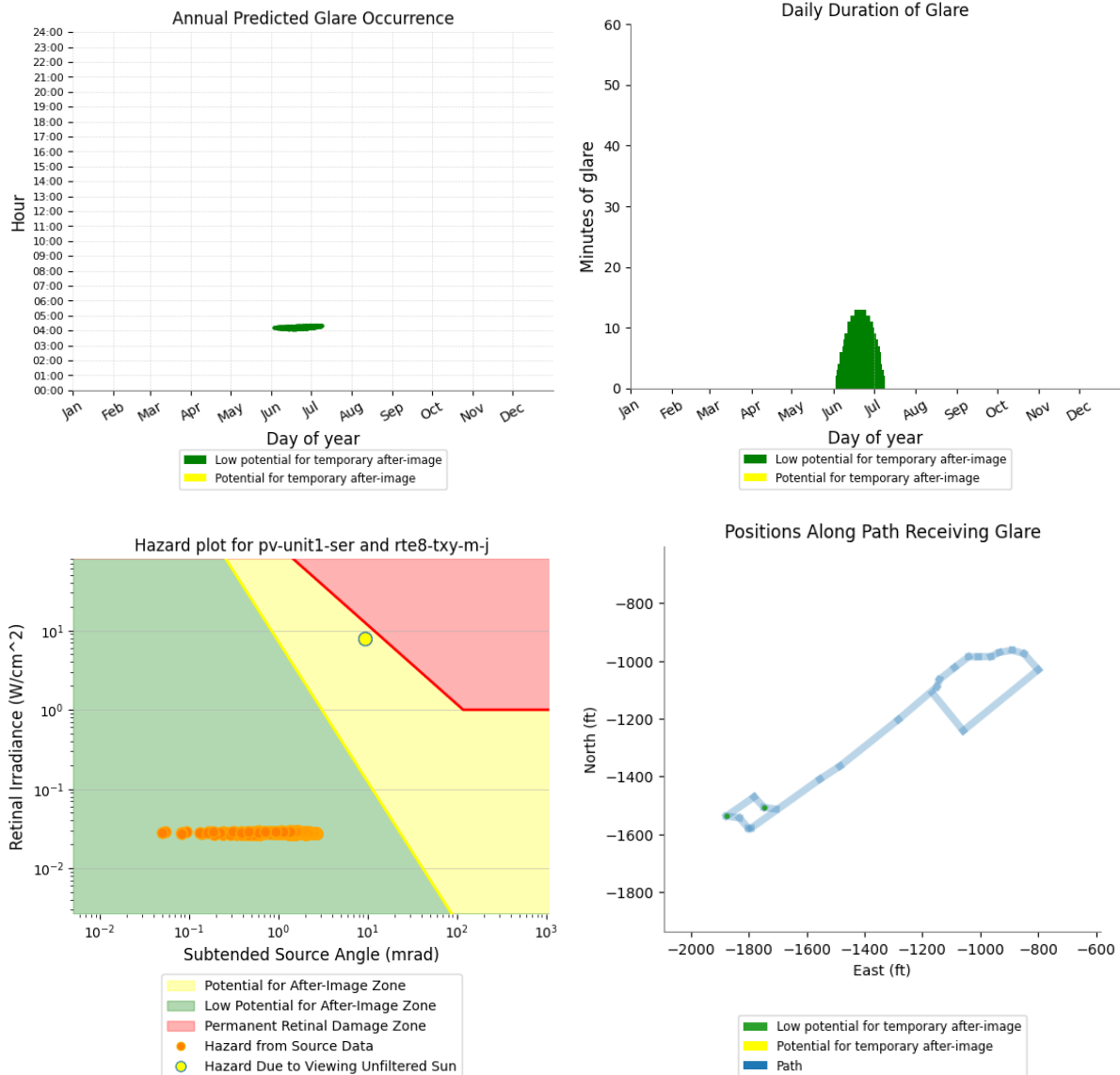
### 3.3.4.5.1 Unit 1 North-West Roof – West Pitch (Taxiways B, J & M)



The analysis shows that the Unit 1 North-west roof, West pitch PV array produces 208 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways B, J & M between the months of June to July and will last no longer than 10 minutes per day, between the hours of 04:00 to 04:45 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

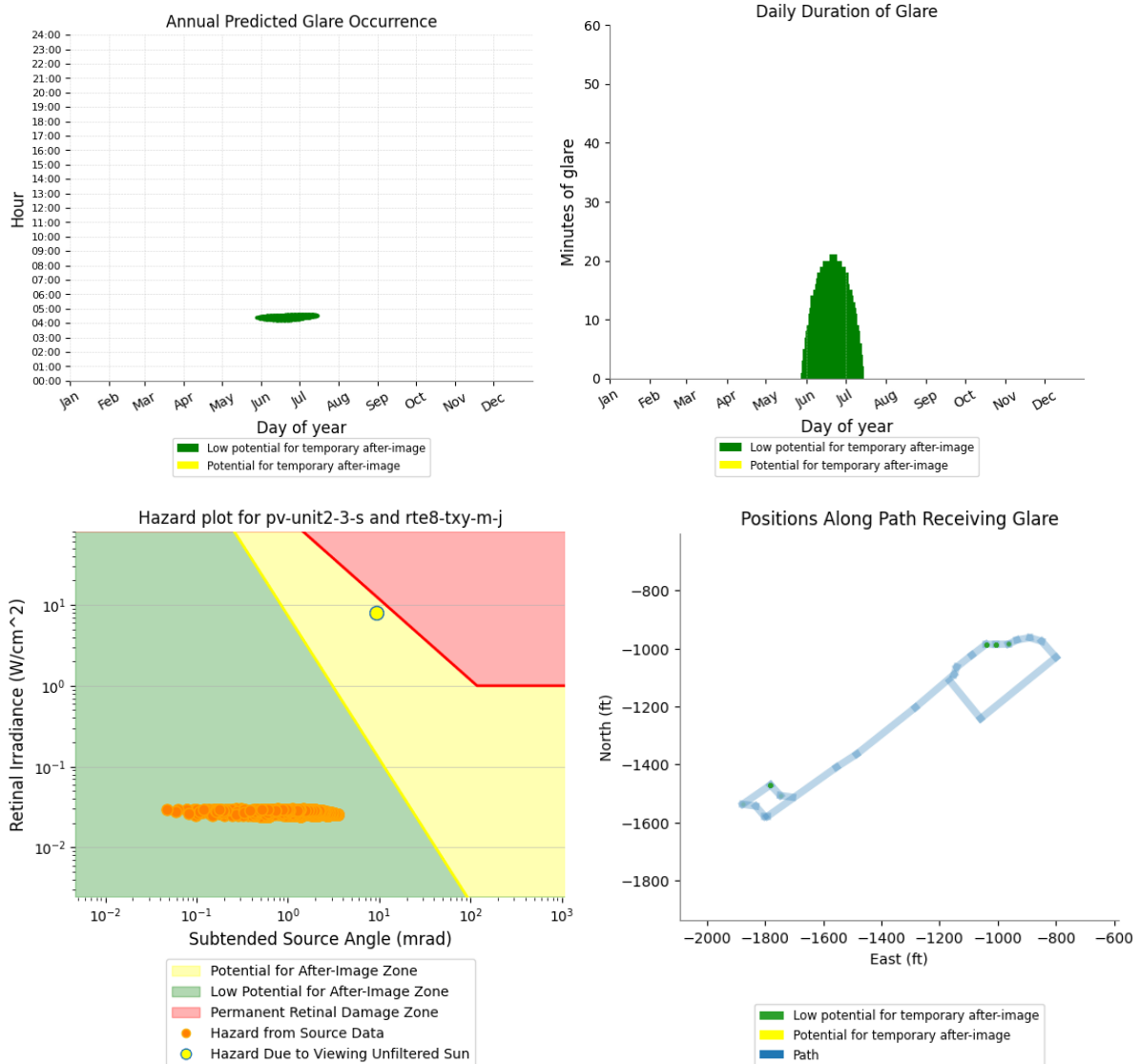
### 3.3.4.5.2 Unit 1 South-East Roof – West Pitch (Taxiways B, J & M)



The analysis shows that the Unit 1 South-east roof, West pitch PV array produces 344 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways B, J & M between the months of June to July and will last no longer than 13 minutes per day, between the hours of 04:00 to 04:45 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

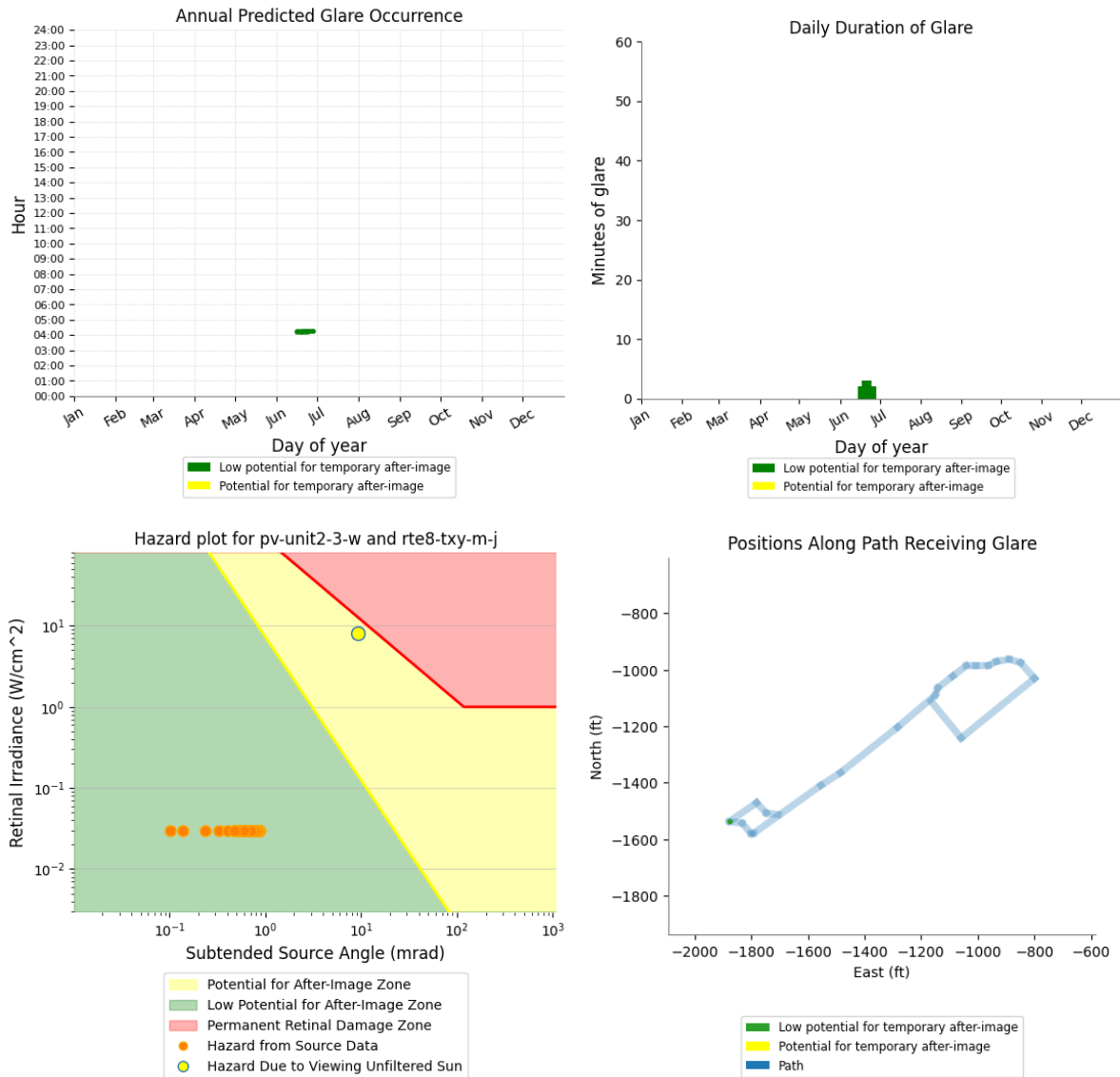
### 3.3.4.5.3 Unit 2 & 3 South Roof Pitch (Taxiways B, J & M)



The analysis shows that the Unit 2 & 3 South roof pitch PV array produces 730 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways B, J & M between the months of May to July and will last no longer than 22 minutes per day, between the hours of 04:00 to 04:50 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

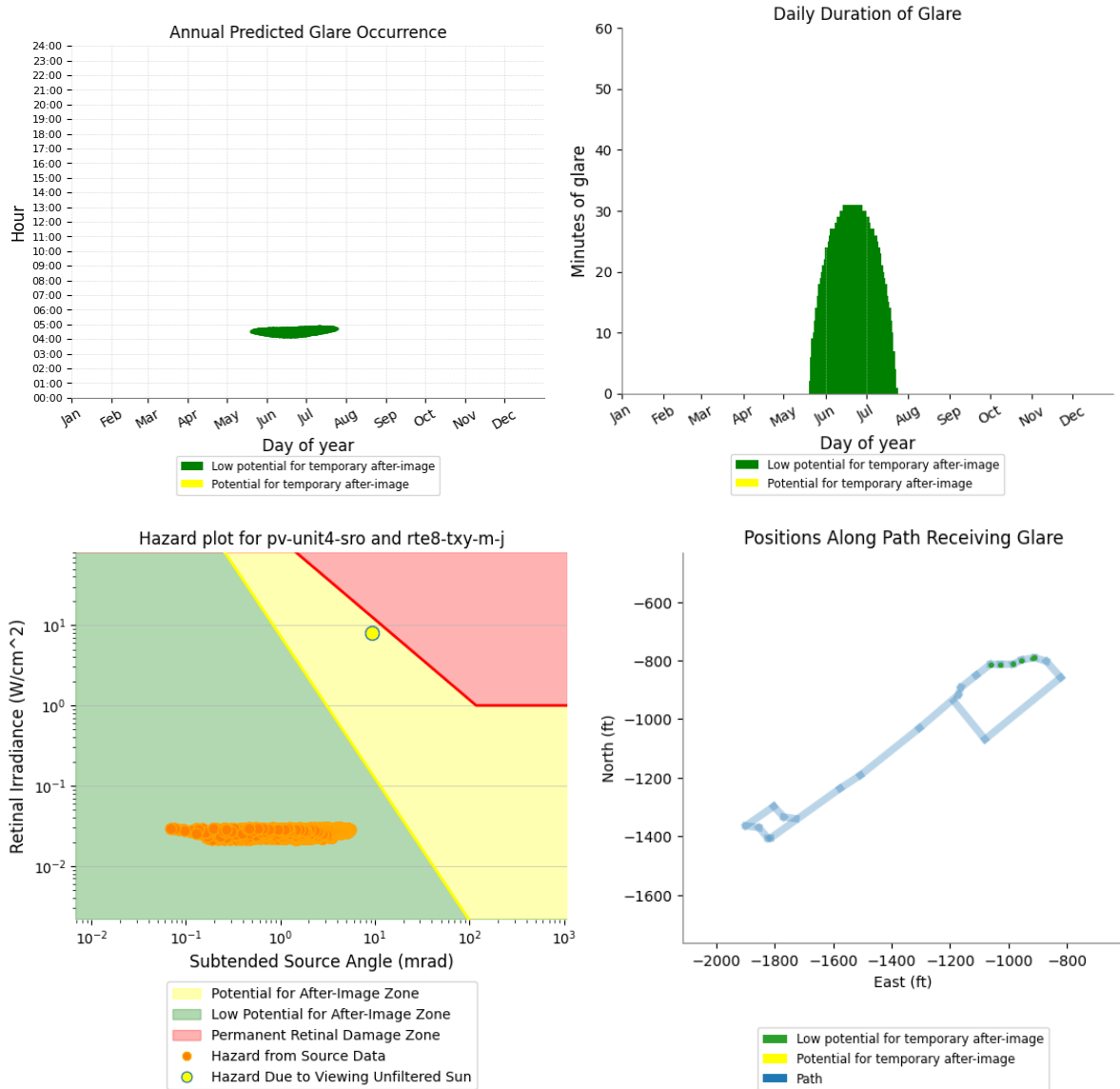
### 3.3.4.5.4 Unit 2 & 3 West Roof Pitch (Taxiways B, J & M)



The analysis shows that the Unit 2 & 3 West roof pitch PV array produces 35 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways B, J & M in the month of June and will last no longer than 4 minutes per day, between the hours of 04:00 to 04:30 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

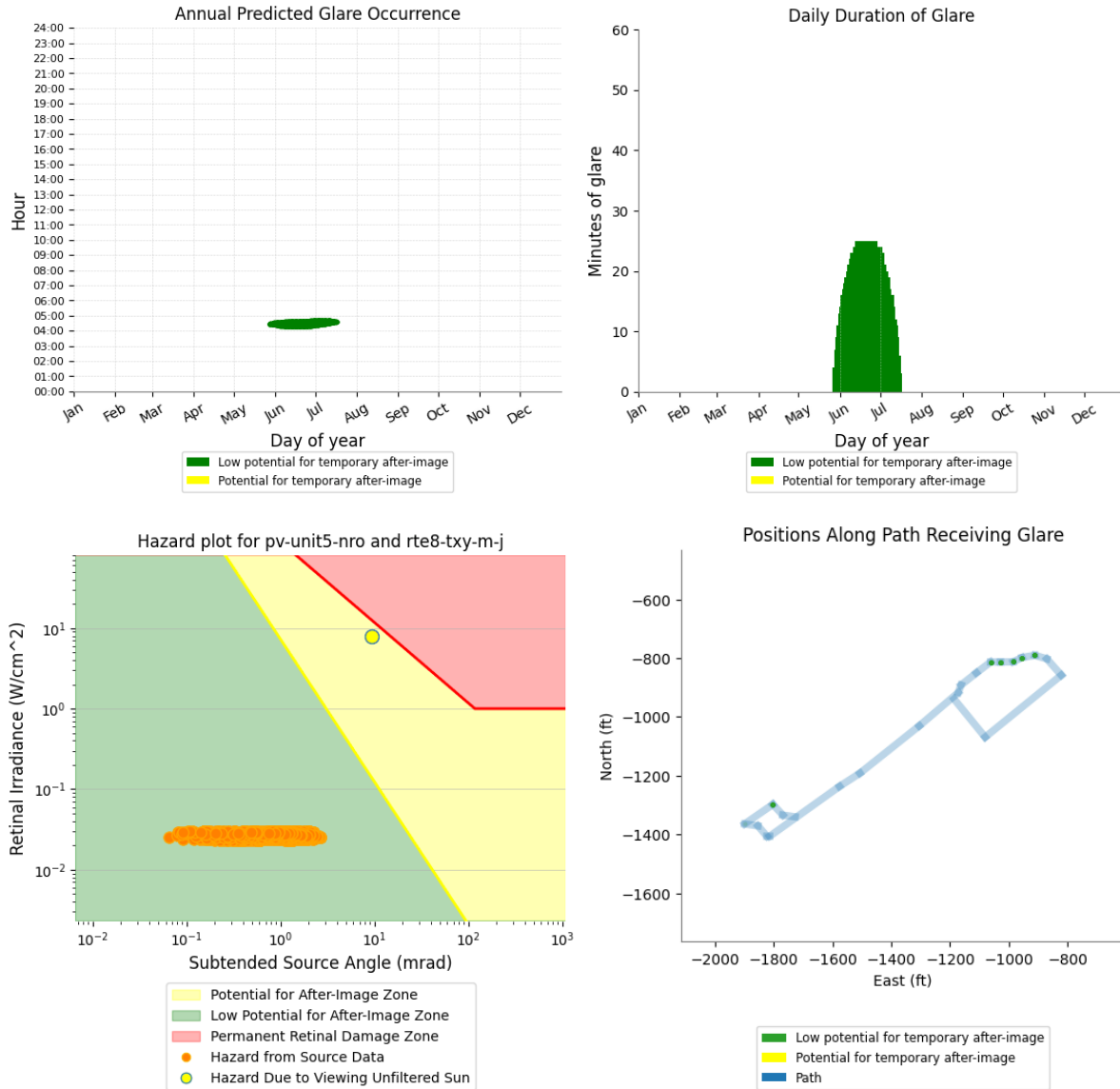
### 3.3.4.5.5 Unit 4 South Roof Pitch (Taxiways B, J & M)



The analysis shows that the Unit 4 South roof pitch PV array produces 1,526 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways B, J & M between the months of May to July and will last no longer than 30 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

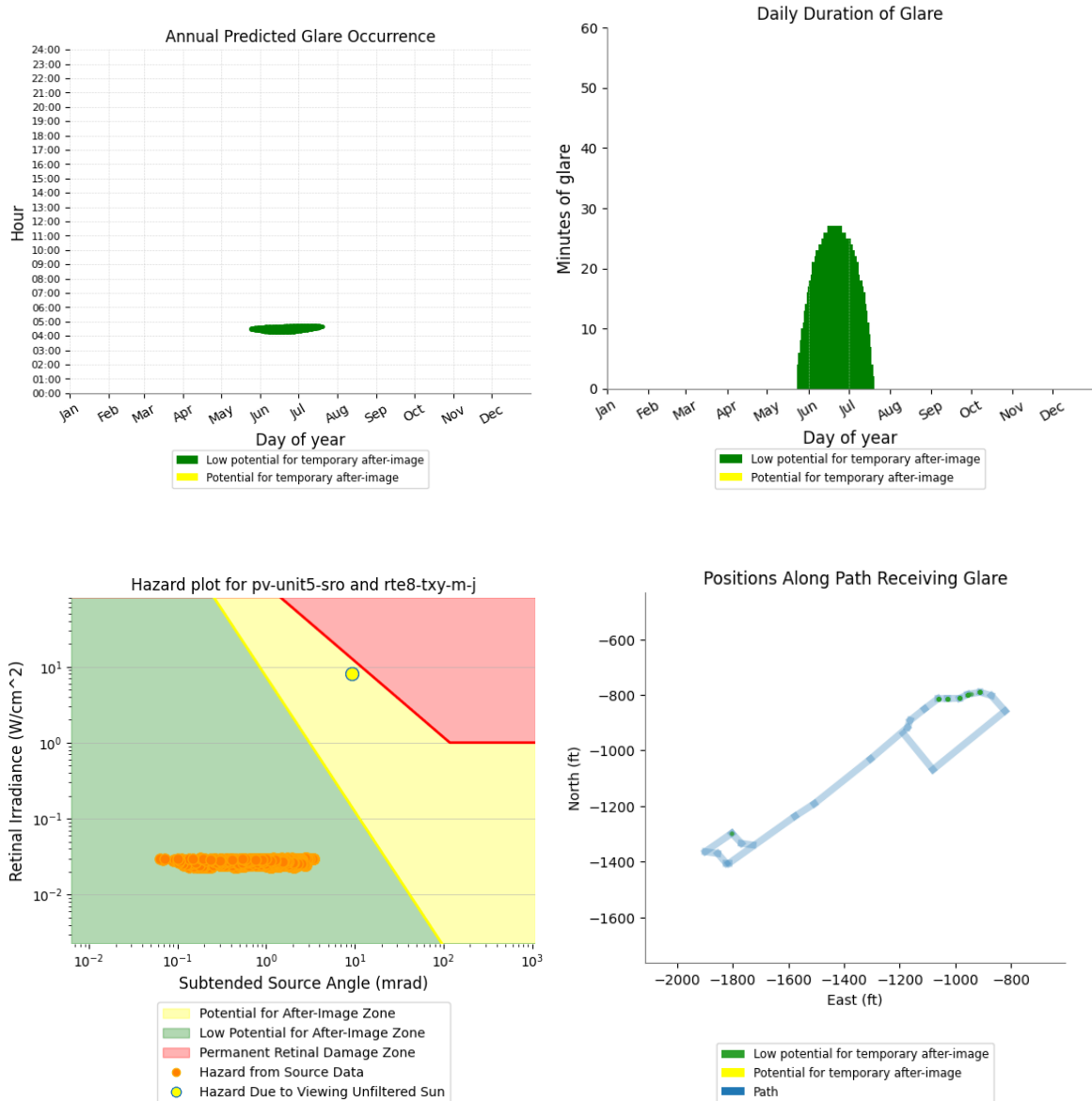
### 3.3.4.5.6 Unit 5 North Roof – South Pitch (Taxiways B, J & M)



The analysis shows that the Unit 5 North roof, South pitch PV array produces 1,013 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways B, J & M between the months of May to July and will last no longer than 25 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4.5.7 Unit 5 South Roof – South Pitch (Taxiways B, J & M)



The analysis shows that the Unit 5 South roof, South pitch PV array produces 1,156 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways B, J & M between the months of May to July and will last no longer than 28 minutes per day, between the hours of 04:00 to 05:00 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

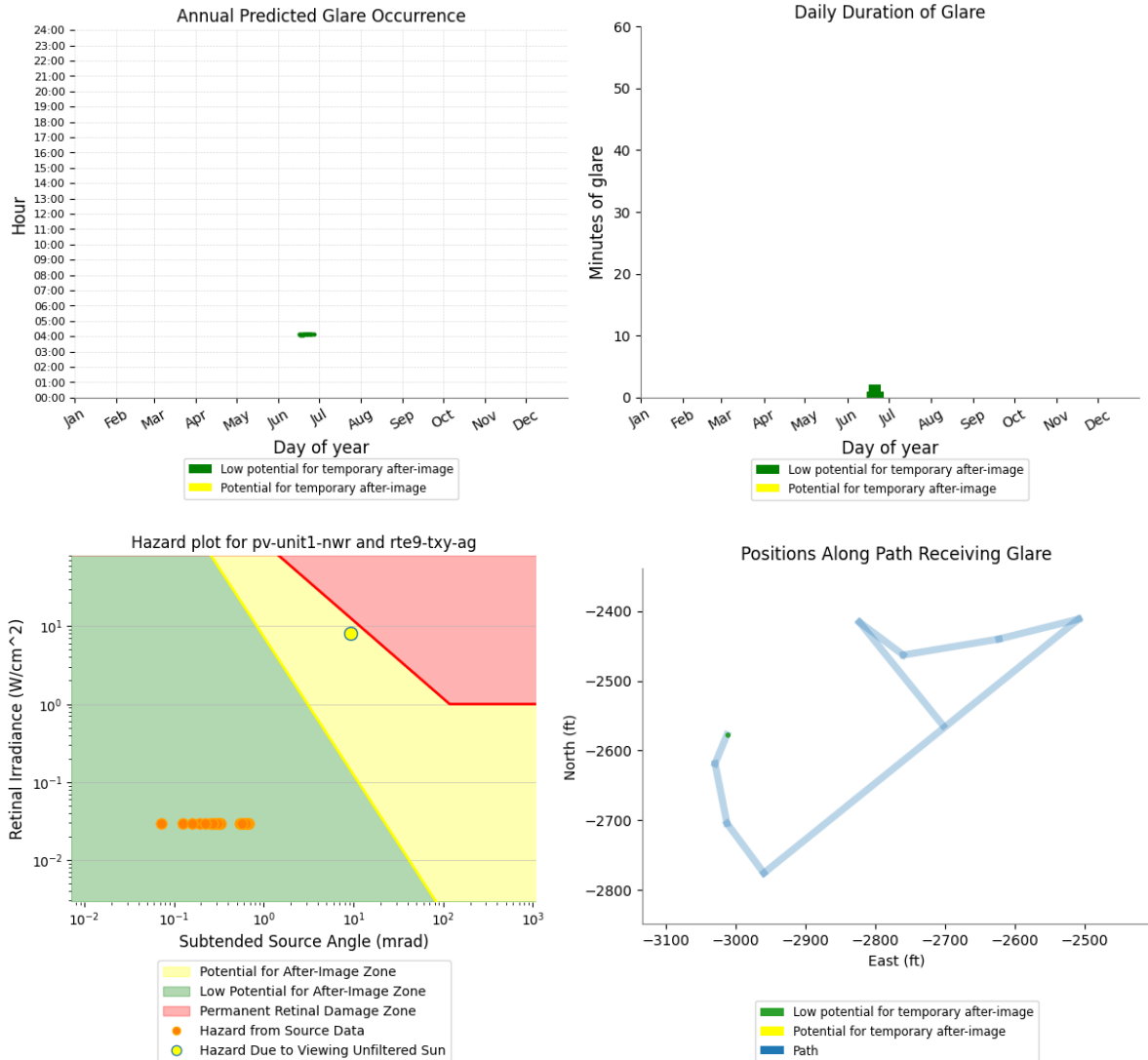
### 3.3.4.6 Route Receptor – PV Array Impacts on Taxiway AE, AF & AG



Figure 17 Route Receptors - Elements of Taxiways AE, AF & AG

Note: Route receptor analysis may not mirror the exact aerodrome plan depiction of taxiway designations. However, a full coverage of the major taxiway network analysis is captured throughout this report.

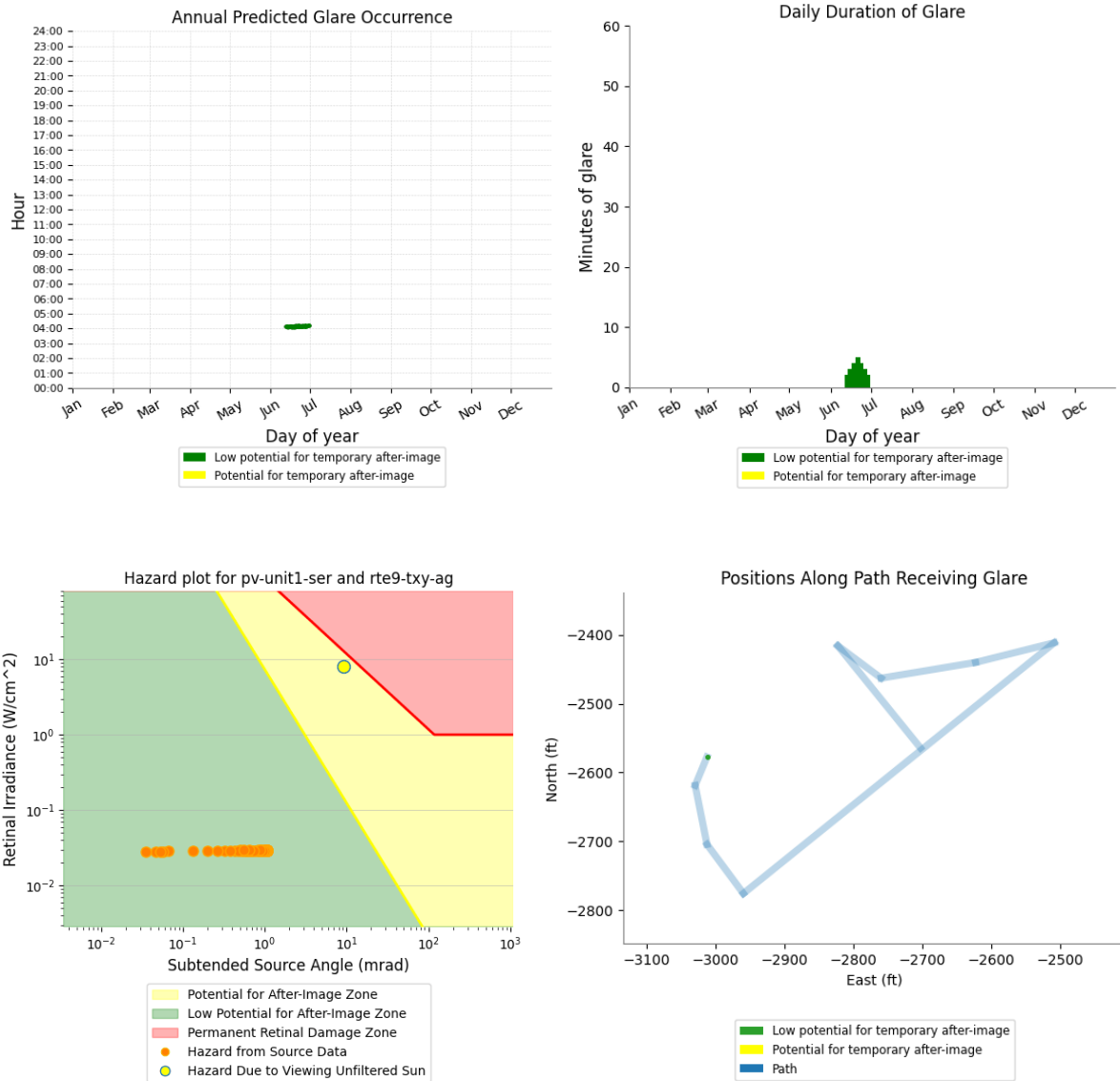
### 3.3.4.6.1 Unit 1 North-West Roof – West Pitch (Taxiway AE, AF & AG)



The analysis shows that the Unit 1 North-west roof, West pitch PV array produces 21 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways AE, AF & AG between the months of June to July and will last no longer than 3 minutes per day, between the hours of 04:00 to 04:30 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

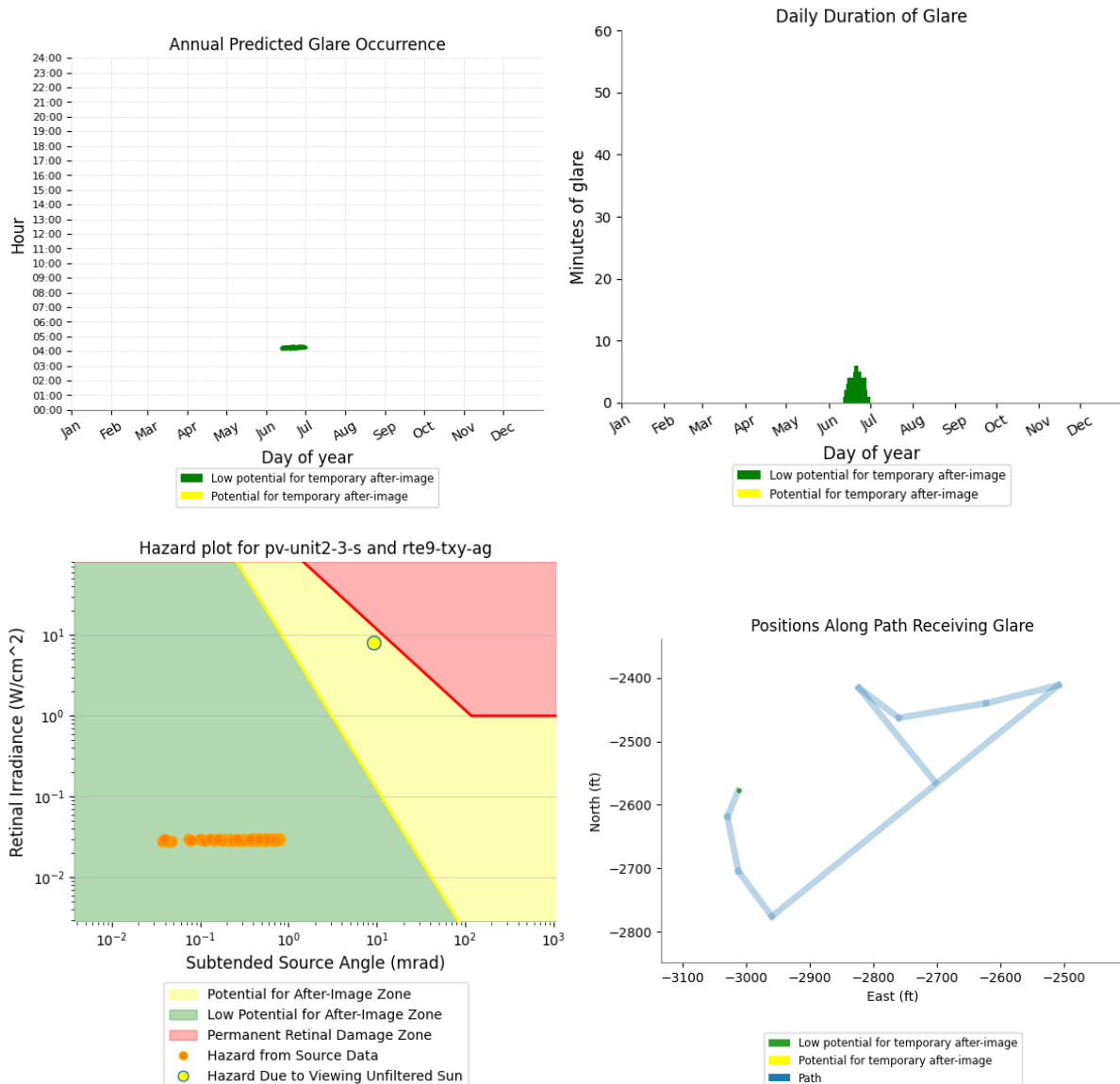
### 3.3.4.6.2 Unit 1 South-East Roof – West Pitch (Taxiway AE, AF & AG)



The analysis shows that the Unit 1 South-east roof, West pitch PV array produces 66 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways AE, AF & AG between the months of June to July and will last no longer than 8 minutes per day, between the hours of 04:00 to 04:30 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

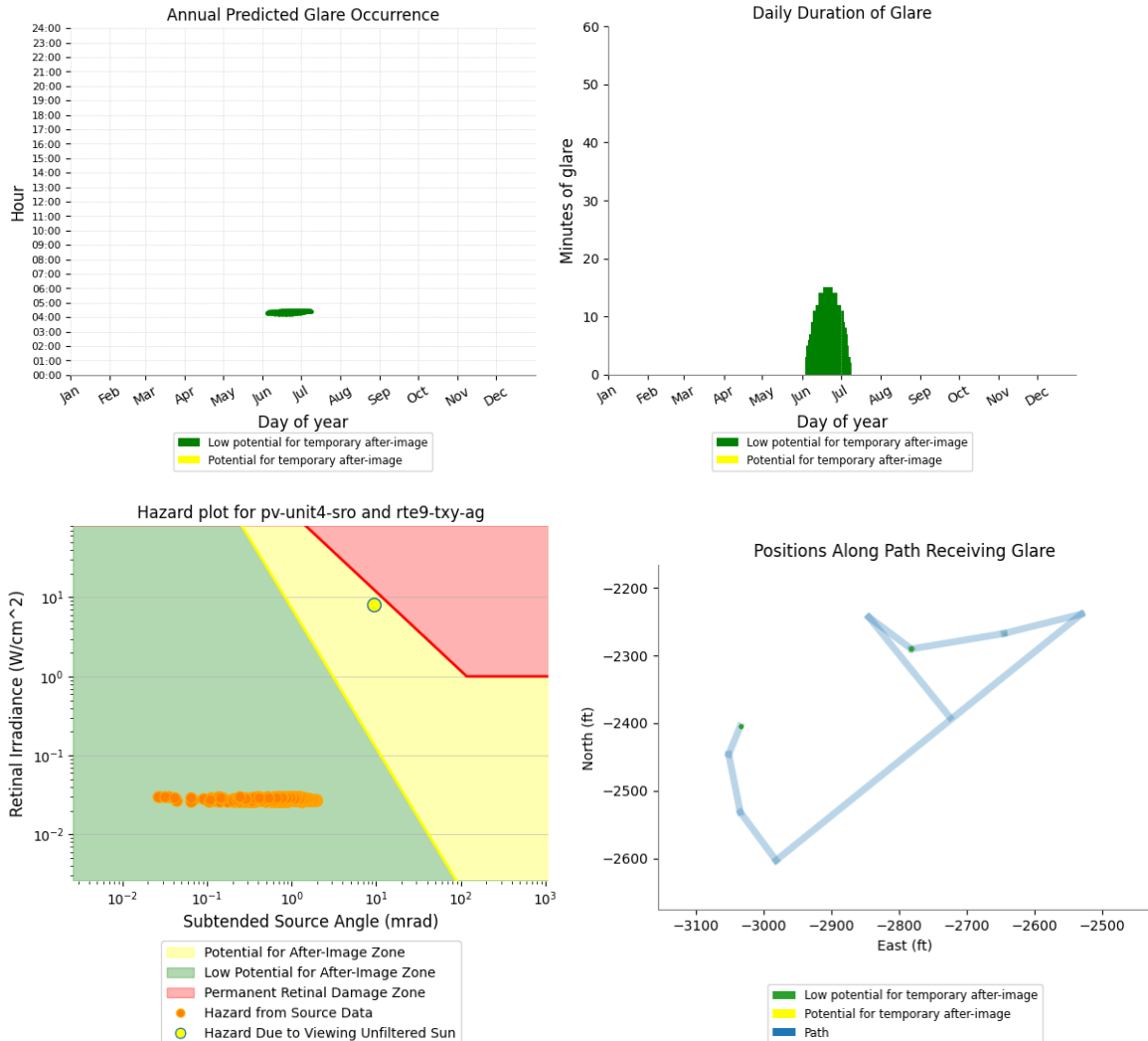
### 3.3.4.6.3 Unit 2 & 3 South Roof Pitch (Taxiway AE, AF & AG)



The analysis shows that the Unit 2 & 3 South roof pitch PV array produces 75 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways AE, AF & AG between the months of June to July and will last no longer than 8 minutes per day, between the hours of 04:00 to 04:40 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

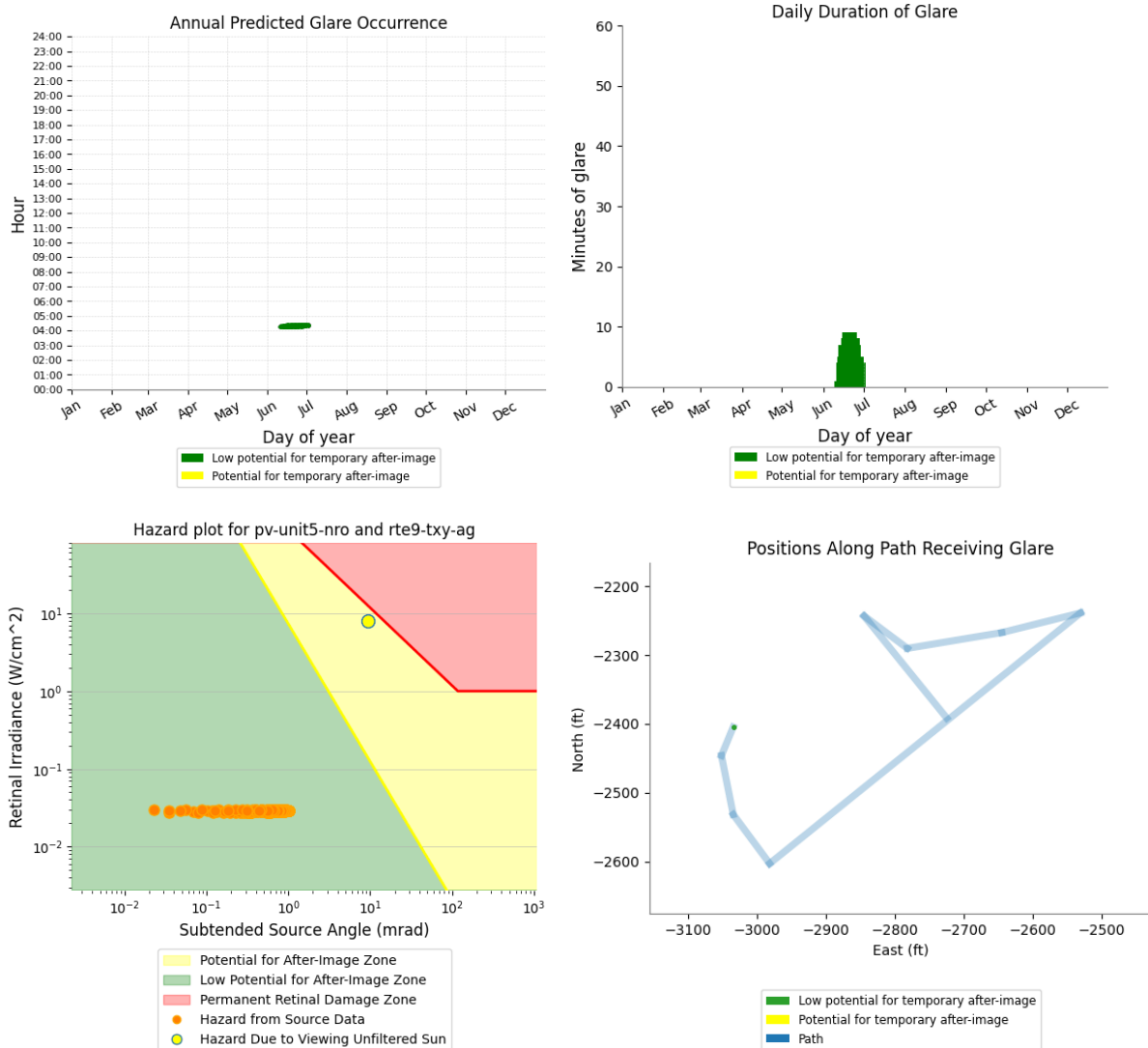
### 3.3.4.6.4 Unit 4 South Roof Pitch (Taxiway AE, AF & AG)



The analysis shows that the Unit 4 South roof pitch PV array produces 394 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways AE, AF & AG between the months of June to July and will last no longer than 15 minutes per day, between the hours of 04:00 to 04:50 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

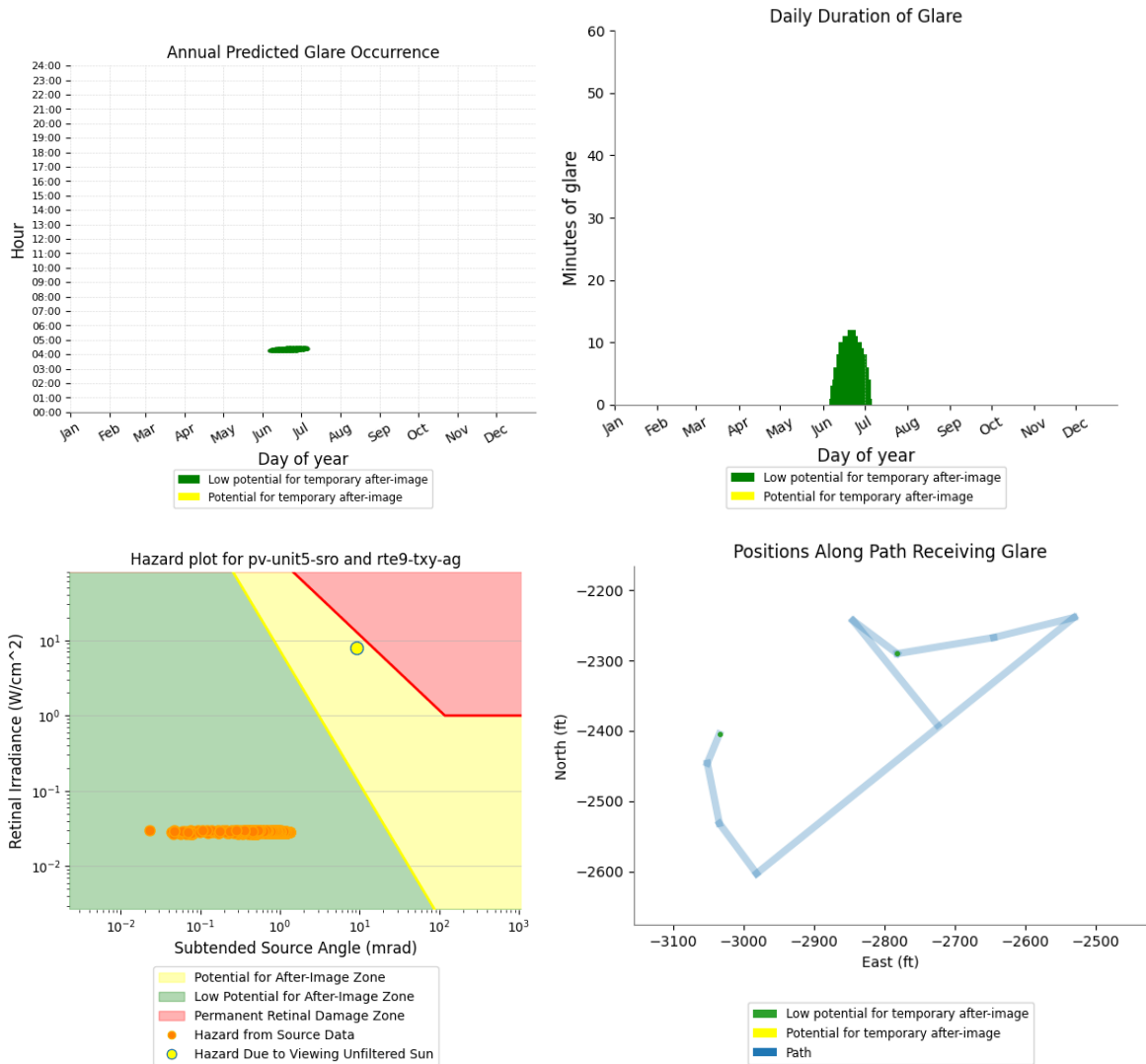
### 3.3.4.6.5 Unit 5 North Roof – South Pitch (Taxiway AE, AF & AG)



The analysis shows that the Unit 5 North roof, South pitch PV array produces 204 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways AE, AF & AG between the months of June to July and will last no longer than 10 minutes per day, between the hours of 04:00 to 04:45 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### 3.3.4.6.6 Unit 5 South Roof – South Pitch (Taxiway AE, AF & AG)



The analysis shows that the Unit 5 South roof, South pitch PV array produces 265 minutes of “green” glare per annum onto this receptor. The glare is evaluated as having a low impact and will only be visible to Taxiways AE, AF & AG between the months of June to July and will last no longer than 12 minutes per day, between the hours of 04:00 to 04:50 UTC.

Manchester International Airport ATS operating timings are open 24 hours (Source: UK Civil AIP dated 01 December 2022).

### **3.3.5 Other Route Receptors**

*No additional Route Receptors (RR), such as motorways, railway lines and carriageways, were included within the scope of this assessment.*

### **3.3.6 Vertical Reflective Surfaces (VS)**

*No requirements for a Vertical Reflective Surface (VS) analysis were included within the scope of this assessment.*

### **3.3.7 Obstructions (OB)**

*No requirements for obstruction (OB) analysis were included within the scope of this assessment.*

## 4 Conclusion

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### 4.1 CAA Information Notice

The following sections provide a summary of the conclusions reached in relation to the proposal to install PV solar panels at the Atlas Business Park site.

#### 4.1.1 Regulatory Requirements

Solar PV developments that are proposed within the licensed aerodrome boundary are to follow the process outlined in CAP 791. This will demonstrate that the necessary safety considerations have been fully addressed, and should include, but not limited to:

- A formal glint/glare or reflectivity assessment.
- An assessment of interference concerning CNS equipment.

The CAA have limited regulatory policy or guidance specific to solar PV developments on or near airfields. As a result, the CAA accepts and advocates the use of the guidance produced by the FAA in the USA to assess the impact of proposed solar PV developments.

Where a solar PV development is being proposed outside of the licensed aerodrome boundary, there is no requirement for the aerodrome operator to consult or notify the CAA in order to seek CAA approval prior to installation. However, in addition to statutory safeguarding obligations via the local planning authority, relevant aeronautical safety issues should be considered prior to any planning application.

#### 4.1.2 Glint and Glare Analysis

It is assessed that it is feasible to locate the proposed PV solar panel array at the proposed Atlas Business Park site located outside the airport boundary (assumed). The entire PV solar array complex within the scope of this report have been assessed, providing a multiple array configuration solution. This means that the client can site PV solar panels within any of the illustrated analysis sections (Figures 9 & 10) at the declared roof pitch angle, without severely impacting MAN operations. The analysis shows that there is no adverse glint or glare affects presenting an impact to the ATC Tower, 2-mile flight paths of runways 05L/23R and 05R/23L, and the taxiways of MAN.

In line with FAA regulator guidance [Ref 4], the ATCT cab is the principal consideration when related to glint & glare effects. The Table below summarises the green glare produced from the Atlas Business Park Development PV solar panel installations that may interact with the ATCT. It should be highlighted again that this assessment evaluated the entire roof surfaces.

In reality, the surface reflection, in accordance with the PV design plans (Figure 3), is likely to return less green glare than declared in the table below. This combined with the assumption that not all days of the year will have cloudless skies and the assessment does not factor in obstructions infringing on the LoS, then the results are favourable in further reducing any potential impacts to aviation at MAN.

| Overview Summary of PV Array Impacts to Manchester Intl Airport ATCT |               |               |                                        |                                         |
|----------------------------------------------------------------------|---------------|---------------|----------------------------------------|-----------------------------------------|
| PV Solar Array                                                       | Time (UTC)    | Period        | Annual Green Glare (Minutes per annum) | Max Duration of Glare (Minutes per day) |
| Unit 1 North-west roof, West pitch PV array                          | 04:00 - 05:00 | May to July   | 1,343                                  | 28                                      |
| Unit 1 South-east roof, West pitch PV array                          |               |               | 1,437                                  | 28                                      |
| Unit 2 & 3 South roof PV array                                       |               |               | 1,830                                  | 30                                      |
| Unit 2 & 3 West roof PV array                                        |               |               | 845                                    | 24                                      |
| Unit 4 South roof PV array                                           |               | May to August | 1,757                                  | 28                                      |
| Unit 5 North roof, South pitch PV array                              |               | May to July   | 1,903                                  | 30                                      |
| Unit 5 South roof, South pitch PV array                              |               |               | 1,964                                  | 30                                      |

Table 7 Overview Summary of Individual PV Array Impacts to MAN ATC-T

Although the analysis shows that some additional glare (green glare) is present (total green glare 48,667 minutes per annum) and the only receptors are the ATC Tower (Table 6) and several taxiways (Table 5) to which there is no regulatory requirement for mitigation of green glare.

## References

| Ref No | Description                                                                                                                                                                                                                               | Source                                  |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| 1      | CAA Information Notice IN-2015/0NN – Solar Photovoltaic Energy System Projects on and in the Vicinity of Aerodromes (Withdrawn)                                                                                                           | UK CAA                                  |
| 2      | CAP 791 – Procedures for Changes to Aerodrome Infrastructure Issue 2, dated August 2016                                                                                                                                                   | UK CAA                                  |
| 3      | FAA Interim Policy, 'FAA Review of Solar Energy System Projects on Federally Obligated Airports' (FAA Doc 78 FR 63276), dated October 2013.                                                                                               | US FAA                                  |
| 4      | FAA Interim Policy, 'FAA Review of Solar Energy System Projects on Federally Obligated Airports' (FAA Doc 86 FR 25801), dated May 2021                                                                                                    | US FAA                                  |
| 5      | FAA Technical Guidance for Evaluating Selected Solar Technologies on Airports, Version 1.1, dated April 2018                                                                                                                              | US FAA                                  |
| 6      | CAP 738 – Safeguarding of Aerodromes Version 3, dated October 2020                                                                                                                                                                        | UK CAA                                  |
| 7      | CAP 168 – Licencing of Aerodromes Version 12 Corr, dated January 2022                                                                                                                                                                     | UK CAA                                  |
| 8      | CAP 670 – Air Traffic Services Safety Requirements Issue 3, dated June 2019                                                                                                                                                               | UK CAA                                  |
| 9      | Yellowhair, J. and C.K. Ho. Assessment of Photovoltaic Surface Texturing on Transmittance Effects and Glint/Glare Impacts. ASME 2015 9th International Conference on Energy Sustainability collocated with the ASME 2015 Power Conference | Science Direct                          |
| 10     | The Air Navigation Order (ANO) 2016 (including Statutory Instrument Amendments 2017 - 2022)                                                                                                                                               | UK Government, Department for Transport |

Table 8 References

## A1 Atlas Business Park PV Array Input Parameters



Figure 18 Atlas Business Park Development Overview Plan *(Source: Client Supplied)*

| Unit 1 North-West Roof, East Pitch – PV Array Parameters |              |                 |                         |                                                                                     |                 |
|----------------------------------------------------------|--------------|-----------------|-------------------------|-------------------------------------------------------------------------------------|-----------------|
| Vertex                                                   | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                               | Total Elev (ft) |
| 1                                                        | 53.371546    | -2.245286       | 232.94                  | 56.82                                                                               | 289.76          |
| 2                                                        | 53.371462    | -2.245634       | 232.69                  | 63.30                                                                               | 295.99          |
| 3                                                        | 53.370920    | -2.245949       | 230.09                  | 63.30                                                                               | 293.39          |
| 4                                                        | 53.370727    | -2.245763       | 231.09                  | 56.82                                                                               | 287.90          |
| SP Axis Tracking                                         | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                                      | 2.9654°      | 109.6°          | correlate with material |                                                                                     |                 |

Table 9 Unit 1 North-West Roof, East Pitch - PV Array Parameters

| Unit 1 North-West Roof, West Pitch – PV Array Parameters |              |                 |                         |                                                                                      |                 |
|----------------------------------------------------------|--------------|-----------------|-------------------------|--------------------------------------------------------------------------------------|-----------------|
| Vertex                                                   | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                                | Total Elev (ft) |
| 1                                                        | 53.371660    | -2.245824       | 232.57                  | 56.82                                                                                | 289.38          |
| 2                                                        | 53.371461    | -2.245633       | 232.69                  | 63.30                                                                                | 295.99          |
| 3                                                        | 53.370919    | -2.245950       | 230.09                  | 63.30                                                                                | 293.39          |
| 4                                                        | 53.370836    | -2.246307       | 230.04                  | 56.82                                                                                | 286.85          |
| SP Axis Tracking                                         | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                                      | 2.9654°      | 289.6°          | correlate with material |                                                                                      |                 |

Table 10 Unit 1 North-West Roof, West Pitch - PV Array Parameters

| Unit 1 South-East Roof, East Pitch – PV Array Parameters |              |                 |                         |                                                                                     |                 |
|----------------------------------------------------------|--------------|-----------------|-------------------------|-------------------------------------------------------------------------------------|-----------------|
| Vertex                                                   | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                               | Total Elev (ft) |
| 1                                                        | 53.371432    | -2.244744       | 232.94                  | 56.82                                                                               | 289.76          |
| 2                                                        | 53.371349    | -2.245099       | 232.94                  | 63.30                                                                               | 296.24          |
| 3                                                        | 53.370808    | -2.245417       | 232.21                  | 63.30                                                                               | 295.51          |
| 4                                                        | 53.370609    | -2.245225       | 231.58                  | 56.82                                                                               | 288.39          |
| SP Axis Tracking                                         | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                                      | 2.9654°      | 109.6°          | correlate with material |                                                                                     |                 |

Table 11 Unit 1 South-East Roof, East Pitch - PV Array Parameters

| Unit 1 South-East Roof, West Pitch – PV Array Parameters |              |                 |                         |                                                                                      |                 |
|----------------------------------------------------------|--------------|-----------------|-------------------------|--------------------------------------------------------------------------------------|-----------------|
| Vertex                                                   | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                                | Total Elev (ft) |
| 1                                                        | 53.371545    | -2.245284       | 232.94                  | 56.82                                                                                | 289.76          |
| 2                                                        | 53.371349    | -2.245099       | 232.94                  | 63.30                                                                                | 296.24          |
| 3                                                        | 53.370808    | -2.245416       | 232.21                  | 63.30                                                                                | 295.51          |
| 4                                                        | 53.370727    | -2.245763       | 231.09                  | 56.82                                                                                | 287.90          |
| SP Axis Tracking                                         | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                                      | 2.9654°      | 109.6°          | correlate with material |                                                                                      |                 |

Table 12 Unit 1 South-East Roof, West Pitch - PV Array Parameters

| Unit 2 & 3 North Pitch Roof – PV Array Parameters |              |                 |                         |                                                                                     |                 |
|---------------------------------------------------|--------------|-----------------|-------------------------|-------------------------------------------------------------------------------------|-----------------|
| Vertex                                            | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                               | Total Elev (ft) |
| 1                                                 | 53.370456    | -2.247156       | 233.82                  | 46.98                                                                               | 280.79          |
| 2                                                 | 53.370201    | -2.247038       | 236.20                  | 55.23                                                                               | 291.43          |
| 3                                                 | 53.369855    | -2.245389       | 231.46                  | 55.23                                                                               | 286.69          |
| 4                                                 | 53.370013    | -2.245039       | 230.61                  | 46.98                                                                               | 277.58          |
| SP Axis Tracking                                  | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                               | 2.9447°      | 19.4°           | correlate with material |                                                                                     |                 |

Table 13 Unit 2 & 3 North Pitch Roof – PV Array Parameters

| Unit 2 & 3 South Pitch Roof – PV Array Parameters |              |                 |                         |                                                                                      |                 |
|---------------------------------------------------|--------------|-----------------|-------------------------|--------------------------------------------------------------------------------------|-----------------|
| Vertex                                            | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                                | Total Elev (ft) |
| 1                                                 | 53.370043    | -2.247397       | 236.22                  | 46.98                                                                                | 283.20          |
| 2                                                 | 53.370201    | -2.247038       | 236.20                  | 55.23                                                                                | 291.43          |
| 3                                                 | 53.369855    | -2.245389       | 231.46                  | 55.23                                                                                | 286.69          |
| 4                                                 | 53.369599    | -2.245279       | 232.57                  | 46.98                                                                                | 279.55          |
| SP Axis Tracking                                  | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                               | 2.9447°      | 199.4°          | correlate with material |                                                                                      |                 |

Table 14 Unit 2 & 3 South Pitch Roof – PV Array Parameters

| Unit 2 & 3 West Pitch Roof – PV Array Parameters |              |                 |                         |                                                                                    |                 |
|--------------------------------------------------|--------------|-----------------|-------------------------|------------------------------------------------------------------------------------|-----------------|
| Vertex                                           | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                              | Total Elev (ft) |
| 1                                                | 53.370456    | -2.247155       | 233.82                  | 46.98                                                                              | 280.79          |
| 2                                                | 53.370200    | -2.247037       | 236.20                  | 55.23                                                                              | 291.43          |
| 3                                                | 53.370042    | -2.247398       | 236.22                  | 46.98                                                                              | 283.20          |
| SP Axis Tracking                                 | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                              | 4.3728°      | 289.4°          | correlate with material |                                                                                    |                 |

Table 15 Unit 2 & 3 West Pitch Roof – PV Array Parameters

| Unit 4 North Pitch Roof – PV Array Parameters |              |                 |                         |                                                                                      |                 |
|-----------------------------------------------|--------------|-----------------|-------------------------|--------------------------------------------------------------------------------------|-----------------|
| Vertex                                        | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                                | Total Elev (ft) |
| 1                                             | 53.369997    | -2.244955       | 230.66                  | 22.40                                                                                | 253.06          |
| 2                                             | 53.369737    | -2.244831       | 231.90                  | 46.98                                                                                | 278.87          |
| 3                                             | 53.369479    | -2.243591       | 227.90                  | 46.98                                                                                | 274.88          |
| 4                                             | 53.369636    | -2.243238       | 226.38                  | 22.40                                                                                | 248.78          |
| SP Axis Tracking                              | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                           | 2.9463°      | 19.1°           | correlate with material |                                                                                      |                 |

Table 16 Unit 4 North Pitch Roof – PV Array Parameters

| Unit 4 South Pitch Roof – PV Array Parameters |              |                 |                         |                                                                                     |                 |
|-----------------------------------------------|--------------|-----------------|-------------------------|-------------------------------------------------------------------------------------|-----------------|
| Vertex                                        | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                               | Total Elev (ft) |
| 1                                             | 53.369582    | -2.245195       | 232.66                  | 22.40                                                                               | 255.06          |
| 2                                             | 53.369738    | -2.244831       | 231.90                  | 46.98                                                                               | 278.87          |
| 3                                             | 53.369479    | -2.243591       | 227.90                  | 46.98                                                                               | 274.88          |
| 4                                             | 53.369222    | -2.243479       | 227.38                  | 22.40                                                                               | 249.78          |
| SP Axis Tracking                              | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                           | 2.9463°      | 199.1°          | correlate with material |                                                                                     |                 |

Table 17 Unit 4 South Pitch Roof – PV Array Parameters

| Unit 5 North Roof, South Pitch – PV Array Parameters |              |                 |                         |                                                                                      |                 |
|------------------------------------------------------|--------------|-----------------|-------------------------|--------------------------------------------------------------------------------------|-----------------|
| Vertex                                               | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                                | Total Elev (ft) |
| 1                                                    | 53.371177    | -2.244183       | 230.72                  | 58.28                                                                                | 230.72          |
| 2                                                    | 53.371278    | -2.243807       | 228.64                  | 65.16                                                                                | 228.64          |
| 3                                                    | 53.370808    | -2.241564       | 223.51                  | 65.16                                                                                | 223.51          |
| 4                                                    | 53.370590    | -2.241381       | 224.56                  | 58.28                                                                                | 224.56          |
| SP Axis Tracking                                     | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                                  | 3.1862°      | 199.1°          | correlate with material |                                                                                      |                 |

Table 18 Unit 5 North Roof, South Pitch – PV Array Parameters

| Unit 5 South Roof, South Pitch – PV Array Parameters |              |                 |                         |                                                                                     |                 |
|------------------------------------------------------|--------------|-----------------|-------------------------|-------------------------------------------------------------------------------------|-----------------|
| Vertex                                               | Latitude (°) | Longitude (°)   | Ground Elev (ft)        | Height Above Gnd (ft)                                                               | Total Elev (ft) |
| 1                                                    | 53.370860    | -2.244377       | 231.57                  | 58.28                                                                               | 289.85          |
| 2                                                    | 53.370956    | -2.243992       | 229.81                  | 65.16                                                                               | 294.97          |
| 3                                                    | 53.370490    | -2.241759       | 225.03                  | 65.16                                                                               | 290.19          |
| 4                                                    | 53.370270    | -2.241564       | 226.09                  | 58.28                                                                               | 284.37          |
| SP Axis Tracking                                     | Tilt (°)     | Orientation (°) | Slope Error (mrad)      |  |                 |
| Fixed (No Rotation)                                  | 3.1862°      | 199.1°          | correlate with material |                                                                                     |                 |

Table 19 Unit 5 South Roof, South Pitch – PV Array Parameters

## A2 Analysis Inputs and Assumptions

### A2.1 PV Panels

| Parameter                      | Input Value                               | Actual/Assumed                                      |
|--------------------------------|-------------------------------------------|-----------------------------------------------------|
| Proposed Solar Panel Locations | See PV array parameter Tables 7 to 17     | Assumed (Based of roof pitch area available)        |
| Axis Tracking                  | Fixed                                     | Actual                                              |
| Module Surface Material        | Smooth Glass without ARC                  | Assumed (based on the most reflective model type)   |
| Slope Error                    | Correlate with material                   | Assumed (As per G&G Tool based on Surface Material) |
| PV Rated Power Category        | 10 to 100 kW<br>(1,000 kW / 8-acre limit) | Assumed                                             |

Table 20 PV Solar Panels Inputs and Assumptions

## A2.2 2-mile Flight Path Receptors

| Flight Path Receptor 1 – Runway 23R                                                                                         |                    |                   |                                                                                     |                          |                      |
|-----------------------------------------------------------------------------------------------------------------------------|--------------------|-------------------|-------------------------------------------------------------------------------------|--------------------------|----------------------|
| Vertical View (°)                                                                                                           | Azimuthal View (°) | Glide Slope (°)   | Pilot view restriction?                                                             | Threshold Height (ft)    | Direction (°)        |
| 30.0° <sup>3</sup>                                                                                                          | 50.0° <sup>3</sup> | 3.0° <sup>2</sup> | Yes                                                                                 | 55 <sup>2</sup>          | 231.0° <sup>2</sup>  |
| Point Description                                                                                                           | Latitude (°)       | Longitude (°)     | Ground Elevation (ft)                                                               | Height above Ground (ft) | Total Elevation (ft) |
| Threshold                                                                                                                   | 53.347557          | -2.287770         | 217.21                                                                              | 55.00                    | 272.21               |
| Two-mile                                                                                                                    | 53.365752          | -2.250086         | 249.42                                                                              | 576.22                   | 825.64               |
| <sup>1</sup> Assumed.<br><sup>2</sup> Actual, as per UK Civil AIP, dated 01 Dec 2022.<br><sup>3</sup> Assumed (By G&G Tool) |                    |                   |  |                          |                      |

Table 21 2-mile Flight Path Receptor 1 – Runway 23R

| Flight Path Receptor 2 – Runway 05L                                                                                         |                    |                   |                                                                                      |                          |                      |
|-----------------------------------------------------------------------------------------------------------------------------|--------------------|-------------------|--------------------------------------------------------------------------------------|--------------------------|----------------------|
| Vertical View (°)                                                                                                           | Azimuthal View (°) | Glide Slope (°)   | Pilot view restriction?                                                              | Threshold Height (ft)    | Direction (°)        |
| 30.0° <sup>3</sup>                                                                                                          | 50.0° <sup>3</sup> | 3.0° <sup>2</sup> | Yes                                                                                  | 57 <sup>2</sup>          | 51.0° <sup>2</sup>   |
| Point Description                                                                                                           | Latitude (°)       | Longitude (°)     | Ground Elevation (ft)                                                                | Height above Ground (ft) | Total Elevation (ft) |
| Threshold                                                                                                                   | 53.361340          | -2.259258         | 252.35                                                                               | 57.00                    | 309.35               |
| Two-mile                                                                                                                    | 53.343141          | -2.296949         | 177.38                                                                               | 685.39                   | 862.78               |
| <sup>1</sup> Assumed.<br><sup>2</sup> Actual, as per UK Civil AIP, dated 01 Dec 2022.<br><sup>3</sup> Assumed (By G&G Tool) |                    |                   |  |                          |                      |

Table 22 2-mile Flight Path Receptor 2 – Runway 05L

| Flight Path Receptor 3 – Runway 23L                                                                                         |                    |                   |                                                                                     |                          |                      |
|-----------------------------------------------------------------------------------------------------------------------------|--------------------|-------------------|-------------------------------------------------------------------------------------|--------------------------|----------------------|
| Vertical View (°)                                                                                                           | Azimuthal View (°) | Glide Slope (°)   | Pilot view restriction?                                                             | Threshold Height (ft)    | Direction (°)        |
| 30.0° <sup>3</sup>                                                                                                          | 50.0° <sup>3</sup> | 3.0° <sup>2</sup> | Yes                                                                                 | 50 <sup>3</sup>          | 231.0° <sup>2</sup>  |
| Point Description                                                                                                           | Latitude (°)       | Longitude (°)     | Ground Elevation (ft)                                                               | Height above Ground (ft) | Total Elevation (ft) |
| Threshold                                                                                                                   | 53.331959          | -2.310731         | 184.70                                                                              | 50.00                    | 234.70               |
| Two-mile                                                                                                                    | 53.350163          | -2.273072         | 237.55                                                                              | 550.58                   | 788.13               |
| <sup>1</sup> Assumed.<br><sup>2</sup> Actual, as per UK Civil AIP, dated 01 Dec 2022.<br><sup>3</sup> Assumed (By G&G Tool) |                    |                   |  |                          |                      |

Table 23 2-mile Flight Path Receptor 3 – Runway 23L

| Flight Path Receptor 4 – Runway 05R                                                                                         |                    |                   |                                                                                      |                          |                      |
|-----------------------------------------------------------------------------------------------------------------------------|--------------------|-------------------|--------------------------------------------------------------------------------------|--------------------------|----------------------|
| Vertical View (°)                                                                                                           | Azimuthal View (°) | Glide Slope (°)   | Pilot view restriction?                                                              | Threshold Height (ft)    | Direction (°)        |
| 30.0° <sup>3</sup>                                                                                                          | 50.0° <sup>3</sup> | 3.5° <sup>2</sup> | Yes                                                                                  | 50 <sup>3</sup>          | 51.0° <sup>2</sup>   |
| Point Description                                                                                                           | Latitude (°)       | Longitude (°)     | Ground Elevation (ft)                                                                | Height above Ground (ft) | Total Elevation (ft) |
| Threshold                                                                                                                   | 53.348175          | -2.277196         | 221.47                                                                               | 50.00                    | 271.47               |
| Two-mile                                                                                                                    | 53.329976          | -2.314875         | 183.73                                                                               | 641.18                   | 824.90               |
| <sup>1</sup> Assumed.<br><sup>2</sup> Actual, as per UK Civil AIP, dated 01 Dec 2022.<br><sup>3</sup> Assumed (By G&G Tool) |                    |                   |  |                          |                      |

Table 24 2-mile Flight Path Receptor 4 – Runway 05R

## A2.3 Route Receptors

| Route 1 – Taxiway A Parameters |                         |               |                                                                                    |                          |                      |
|--------------------------------|-------------------------|---------------|------------------------------------------------------------------------------------|--------------------------|----------------------|
| Path Type                      | Observer View Angle (°) |               |  |                          |                      |
| Two-way (Assumed)              | 50.0° (As per G&G Tool) |               |                                                                                    |                          |                      |
| Vertex                         | Latitude (°)            | Longitude (°) | Ground Elevation (ft)                                                              | Height above Ground (ft) | Total Elevation (ft) |
| 1                              | 53.345289               | -2.292568     | 202.45                                                                             | 0.00                     | 202.45               |
| 2                              | 53.345904               | -2.293298     | 197.77                                                                             | 0.00                     | 197.77               |
| 3                              | 53.346647               | -2.293341     | 195.12                                                                             | 0.00                     | 195.12               |
| 4                              | 53.347211               | -2.292869     | 197.33                                                                             | 0.00                     | 197.33               |
| 5                              | 53.348799               | -2.289650     | 212.05                                                                             | 0.00                     | 212.05               |
| 6                              | 53.350003               | -2.287590     | 221.68                                                                             | 0.00                     | 221.68               |
| 7                              | 53.352898               | -2.281925     | 231.95                                                                             | 0.00                     | 231.95               |
| 8                              | 53.354405               | -2.281554     | 232.92                                                                             | 0.00                     | 232.92               |
| 9                              | 53.355244               | -2.280963     | 235.34                                                                             | 0.00                     | 235.34               |
| 10                             | 53.357473               | -2.276500     | 210.03                                                                             | 0.00                     | 210.03               |

Table 25 Route Receptor 1 - Taxiway A Parameters

| Route 2 –Taxiway B Parameters |              |                         |                       |                                                                                    |                      |
|-------------------------------|--------------|-------------------------|-----------------------|------------------------------------------------------------------------------------|----------------------|
| Path Type                     |              | Observer View Angle (°) |                       |  |                      |
| Two-way (Assumed)             |              | 50.0° (As per G&G Tool) |                       |                                                                                    |                      |
| Vertex                        | Latitude (°) | Longitude (°)           | Ground Elevation (ft) | Height above Ground (ft)                                                           | Total Elevation (ft) |
| 1                             | 53.349380    | -2.279333               | 227.97                | 0.00                                                                               | 227.97               |
| 2                             | 53.351379    | -2.281929               | 225.86                | 0.00                                                                               | 225.86               |
| 3                             | 53.351699    | -2.281993               | 223.48                | 0.00                                                                               | 223.48               |
| 4                             | 53.352916    | -2.281886               | 232.14                | 0.00                                                                               | 232.14               |
| 5                             | 53.356630    | -2.275835               | 223.44                | 0.00                                                                               | 223.44               |
| 6                             | 53.357629    | -2.273732               | 228.38                | 0.00                                                                               | 228.38               |

Table 26 Route Receptor 2 - Taxiway B Parameters

| Route 3 –Taxiways C, D & P Parameters |                         |                                                                                    |                       |                          |                      |
|---------------------------------------|-------------------------|------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------|
| Path Type                             | Observer View Angle (°) |  |                       |                          |                      |
| Two-way (Assumed)                     | 50.0° (As per G&G Tool) |                                                                                    |                       |                          |                      |
| Vertex                                | Latitude (°)            | Longitude (°)                                                                      | Ground Elevation (ft) | Height above Ground (ft) | Total Elevation (ft) |
| 1                                     | 53.354679               | -2.279107                                                                          | 235.98                | 0.00                     | 235.98               |
| 2                                     | 53.358405               | -2.278592                                                                          | 232.34                | 0.00                     | 232.34               |
| 3                                     | 53.358700               | -2.278485                                                                          | 235.07                | 0.00                     | 235.07               |
| 4                                     | 53.358201               | -2.277391                                                                          | 225.45                | 0.00                     | 225.45               |
| 5                                     | 53.356920               | -2.277605                                                                          | 217.76                | 0.00                     | 217.76               |
| 6                                     | 53.355691               | -2.277477                                                                          | 237.70                | 0.00                     | 237.70               |
| 7                                     | 53.355178               | -2.276661                                                                          | 239.87                | 0.00                     | 239.87               |

Table 27 Route Receptor 3 - Taxiways C, D & P Parameters

| Route 4 – Taxiways F & K Parameters |                         |                                                                                    |                       |                          |                      |
|-------------------------------------|-------------------------|------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------|
| Path Type                           | Observer View Angle (°) |  |                       |                          |                      |
| Two-way (Assumed)                   | 50.0° (As per G&G Tool) |                                                                                    |                       |                          |                      |
| Vertex                              | Latitude (°)            | Longitude (°)                                                                      | Ground Elevation (ft) | Height above Ground (ft) | Total Elevation (ft) |
| 1                                   | 53.354632               | -2.281435                                                                          | 233.96                | 0.00                     | 233.96               |
| 2                                   | 53.354593               | -2.277873                                                                          | 237.05                | 0.00                     | 237.05               |
| 3                                   | 53.355720               | -2.275513                                                                          | 236.42                | 0.00                     | 236.42               |
| 4                                   | 53.357321               | -2.272252                                                                          | 250.90                | 0.00                     | 250.90               |
| 5                                   | 53.354568               | -2.268668                                                                          | 255.19                | 0.00                     | 255.19               |

Table 28 Route Receptor 4 - Taxiways F & K Parameters

| Route 5 –Taxiway V Parameters |                         |                                                                                    |                       |                          |                      |
|-------------------------------|-------------------------|------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------|
| Path Type                     | Observer View Angle (°) |  |                       |                          |                      |
| Two-way (Assumed)             | 50.0° (As per G&G Tool) |                                                                                    |                       |                          |                      |
| Vertex                        | Latitude (°)            | Longitude (°)                                                                      | Ground Elevation (ft) | Height above Ground (ft) | Total Elevation (ft) |
| 1                             | 53.357623               | -2.266944                                                                          | 264.46                | 0.00                     | 264.46               |
| 2                             | 53.356841               | -2.266451                                                                          | 257.65                | 0.00                     | 257.65               |
| 3                             | 53.356144               | -2.266204                                                                          | 254.30                | 0.00                     | 254.30               |
| 4                             | 53.355779               | -2.266365                                                                          | 252.71                | 0.00                     | 252.71               |
| 5                             | 53.355535               | -2.266612                                                                          | 255.01                | 0.00                     | 255.01               |
| 6                             | 53.354050               | -2.269669                                                                          | 250.31                | 0.00                     | 250.31               |
| 7                             | 53.347255               | -2.283724                                                                          | 216.54                | 0.00                     | 216.54               |
| 8                             | 53.347037               | -2.284014                                                                          | 216.54                | 0.00                     | 216.54               |
| 9                             | 53.346563               | -2.284379                                                                          | 215.09                | 0.00                     | 215.09               |
| 10                            | 53.343854               | -2.286160                                                                          | 209.44                | 0.00                     | 209.44               |

Table 29 Route Receptor 5 - Taxiway V Parameters

| Route 6 –Taxiways V & S Parameters |                         |               |                                                                                    |                          |                      |
|------------------------------------|-------------------------|---------------|------------------------------------------------------------------------------------|--------------------------|----------------------|
| Path Type                          | Observer View Angle (°) |               |  |                          |                      |
| Two-way (Assumed)                  | 50.0° (As per G&G Tool) |               |                                                                                    |                          |                      |
| Vertex                             | Latitude (°)            | Longitude (°) | Ground Elevation (ft)                                                              | Height above Ground (ft) | Total Elevation (ft) |
| 1                                  | 53.345478               | -2.282809     | 213.21                                                                             | 0.00                     | 213.21               |
| 2                                  | 53.348770               | -2.280534     | 223.64                                                                             | 0.00                     | 223.64               |
| 3                                  | 53.349372               | -2.279311     | 228.07                                                                             | 0.00                     | 228.07               |
| 4                                  | 53.348001               | -2.277638     | 218.63                                                                             | 0.00                     | 218.63               |
| 5                                  | 53.348347               | -2.276886     | 224.19                                                                             | 0.00                     | 224.19               |
| 6                                  | 53.348872               | -2.276586     | 229.15                                                                             | 0.00                     | 229.15               |
| 7                                  | 53.350525               | -2.276994     | 231.52                                                                             | 0.00                     | 231.52               |
| 8                                  | 53.351293               | -2.275363     | 236.75                                                                             | 0.00                     | 236.75               |
| 9                                  | 53.350832               | -2.274934     | 235.22                                                                             | 0.00                     | 235.22               |
| 10                                 | 53.350486               | -2.274891     | 233.82                                                                             | 0.00                     | 233.82               |
| 11                                 | 53.349513               | -2.276736     | 234.55                                                                             | 0.00                     | 234.55               |
| 12                                 | 53.348526               | -2.276543     | 225.91                                                                             | 0.00                     | 225.91               |
| 13                                 | 53.349449               | -2.274569     | 230.71                                                                             | 0.00                     | 230.71               |
| 14                                 | 53.350473               | -2.274848     | 233.77                                                                             | 0.00                     | 233.77               |
| 15                                 | 53.351613               | -2.272445     | 239.78                                                                             | 0.00                     | 239.78               |

Table 30 Route Receptor 6 - Taxiways V & S Parameters

| Route 7 – Taxiways W & Y Parameters |                         |                                                                                    |                       |                          |                      |
|-------------------------------------|-------------------------|------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------|
| Path Type                           | Observer View Angle (°) |  |                       |                          |                      |
| Two-way (Assumed)                   | 50.0° (As per G&G Tool) |                                                                                    |                       |                          |                      |
| Vertex                              | Latitude (°)            | Longitude (°)                                                                      | Ground Elevation (ft) | Height above Ground (ft) | Total Elevation (ft) |
| 1                                   | 53.332125               | -2.310472                                                                          | 185.44                | 0.00                     | 185.44               |
| 2                                   | 53.332638               | -2.311287                                                                          | 185.93                | 0.00                     | 185.93               |
| 3                                   | 53.333086               | -2.311802                                                                          | 183.76                | 0.00                     | 183.76               |
| 4                                   | 53.333368               | -2.311888                                                                          | 183.73                | 0.00                     | 183.73               |
| 5                                   | 53.333701               | -2.311459                                                                          | 183.73                | 0.00                     | 183.73               |
| 6                                   | 53.334470               | -2.309764                                                                          | 183.60                | 0.00                     | 183.60               |
| 7                                   | 53.334355               | -2.309184                                                                          | 183.77                | 0.00                     | 183.77               |
| 8                                   | 53.333880               | -2.308412                                                                          | 187.01                | 0.00                     | 187.01               |
| 9                                   | 53.333432               | -2.307747                                                                          | 187.01                | 0.00                     | 187.01               |

Table 31 Route Receptor 7 - Taxiways W & Y Parameters

### Route 8 - Taxiways B, J & M Parameters

| Path Type         | Observer View Angle (°) |  |                       |                          |                      |
|-------------------|-------------------------|------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------|
| Two-way (Assumed) | 50.0° (As per G&G Tool) |                                                                                    |                       |                          |                      |
| Vertex            | Latitude (°)            | Longitude (°)                                                                      | Ground Elevation (ft) | Height above Ground (ft) | Total Elevation (ft) |
| 1                 | 53.361556               | -2.262778                                                                          | 259.21                | 0.00                     | 259.21               |
| 2                 | 53.360391               | -2.261190                                                                          | 260.49                | 0.00                     | 260.49               |
| 3                 | 53.362286               | -2.257296                                                                          | 250.97                | 0.00                     | 250.97               |
| 4                 | 53.362785               | -2.258036                                                                          | 250.30                | 0.00                     | 250.30               |
| 5                 | 53.362894               | -2.258648                                                                          | 249.60                | 0.00                     | 249.60               |
| 6                 | 53.362824               | -2.259313                                                                          | 247.63                | 0.00                     | 247.63               |
| 7                 | 53.362696               | -2.259753                                                                          | 246.49                | 0.00                     | 246.49               |
| 8                 | 53.362689               | -2.260407                                                                          | 249.54                | 0.00                     | 249.54               |
| 9                 | 53.362689               | -2.260911                                                                          | 251.82                | 0.00                     | 251.82               |
| 10                | 53.362356               | -2.261641                                                                          | 252.62                | 0.00                     | 252.62               |
| 11                | 53.361985               | -2.262424                                                                          | 255.54                | 0.00                     | 255.54               |
| 12                | 53.361754               | -2.262564                                                                          | 257.25                | 0.00                     | 257.25               |
| 13                | 53.360736               | -2.264559                                                                          | 264.36                | 0.00                     | 264.36               |
| 14                | 53.359289               | -2.267595                                                                          | 277.46                | 0.00                     | 277.46               |
| 15                | 53.358886               | -2.268636                                                                          | 282.15                | 0.00                     | 282.15               |
| 16                | 53.357362               | -2.272209                                                                          | 250.93                | 0.00                     | 250.93               |
| 17                | 53.357362               | -2.272348                                                                          | 249.87                | 0.00                     | 249.87               |

|    |           |           |        |      |        |
|----|-----------|-----------|--------|------|--------|
| 18 | 53.357682 | -2.272810 | 241.75 | 0.00 | 241.75 |
| 19 | 53.357740 | -2.273486 | 231.61 | 0.00 | 231.61 |
| 20 | 53.358335 | -2.272048 | 245.72 | 0.00 | 245.72 |
| 21 | 53.358009 | -2.271533 | 256.77 | 0.00 | 256.77 |
| 22 | 53.357958 | -2.270911 | 261.90 | 0.00 | 261.90 |

Table 32 Route Receptor 8 - Taxiways B, J & M Parameters

| Route 9 – Taxiways P & T Parameters |                         |                                                                                     |                       |                          |                      |
|-------------------------------------|-------------------------|-------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------|
| Path Type                           | Observer View Angle (°) |  |                       |                          |                      |
| Two-way (Assumed)                   | 50.0° (As per G&G Tool) |                                                                                     |                       |                          |                      |
| Vertex                              | Latitude (°)            | Longitude (°)                                                                       | Ground Elevation (ft) | Height above Ground (ft) | Total Elevation (ft) |
| 1                                   | 53.350213               | -2.272981                                                                           | 238.21                | 0.00                     | 238.21               |
| 2                                   | 53.353415               | -2.271887                                                                           | 244.26                | 0.00                     | 244.26               |
| 3                                   | 53.353876               | -2.272101                                                                           | 242.07                | 0.00                     | 242.07               |
| 4                                   | 53.356284               | -2.275299                                                                           | 232.03                | 0.00                     | 232.03               |
| 5                                   | 53.356911               | -2.276157                                                                           | 214.05                | 0.00                     | 214.05               |
| 6                                   | 53.357846               | -2.276715                                                                           | 214.58                | 0.00                     | 214.58               |
| 7                                   | 53.358781               | -2.278474                                                                           | 236.13                | 0.00                     | 236.13               |

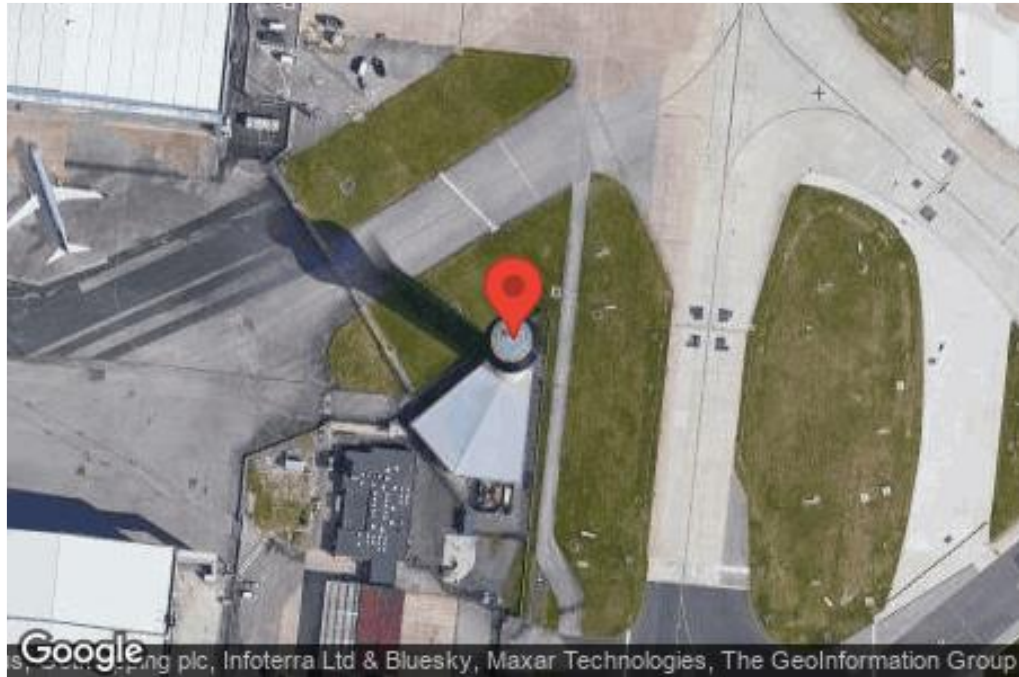
Table 33 Route Receptor 9 - Taxiways P & T Parameters

| Route 10 – Taxiways AE, AF & AG Parameters |                         |                                                                                    |                       |                          |                      |
|--------------------------------------------|-------------------------|------------------------------------------------------------------------------------|-----------------------|--------------------------|----------------------|
| Path Type                                  | Observer View Angle (°) |  |                       |                          |                      |
| Two-way (Assumed)                          | 50.0° (As per G&G Tool) |                                                                                    |                       |                          |                      |
| Vertex                                     | Latitude (°)            | Longitude (°)                                                                      | Ground Elevation (ft) | Height above Ground (ft) | Total Elevation (ft) |
| 1                                          | 53.348512               | -2.285888                                                                          | 218.37                | 0.00                     | 218.37               |
| 2                                          | 53.349844               | -2.287691                                                                          | 220.92                | 0.00                     | 220.92               |
| 3                                          | 53.349421               | -2.286746                                                                          | 218.91                | 0.00                     | 218.91               |
| 4                                          | 53.349626               | -2.284686                                                                          | 222.14                | 0.00                     | 222.14               |
| 5                                          | 53.349883               | -2.282970                                                                          | 230.95                | 0.00                     | 230.95               |
| 6                                          | 53.346616               | -2.289750                                                                          | 204.13                | 0.00                     | 204.13               |
| 7                                          | 53.347257               | -2.290544                                                                          | 204.79                | 0.00                     | 204.79               |
| 8                                          | 53.348025               | -2.290802                                                                          | 208.99                | 0.00                     | 208.99               |
| 9                                          | 53.348397               | -2.290544                                                                          | 210.37                | 0.00                     | 210.37               |

Table 34 Route Receptor 10 - Taxiways AE, AF & AG Parameters

## A2.4 Observer Point Receptors

### Observer Point 1 – ATC Tower Parameters



| Name   | ID | Latitude (°) | Longitude (°) | Elevation (ft) | Height (ft) |
|--------|----|--------------|---------------|----------------|-------------|
| 1-ATCT | 1  | 53.357818    | -2.279611     | 229.65         | 196.85      |

Table 35 Observer Point Receptor – Input and Assumptions

## A2.5 Forge Solar G&G Tool Assumptions and Limitations

The list below highlights the standardised set of assumptions and limitations of the Forge Solar G&G tool utilised to conduct this assessment:

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are retained for two years after analysis completion. Files must be downloaded and saved if additional persistence is required.
3. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
4. Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects V1 analyses of path receptors.
5. Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
6. The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the approximate total heights of the PV vertices. For increased accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
9. The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling

uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

10. The ocular hazard predicted by the tool depends on several environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
11. The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modelling methods.
12. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

*(Source: Forge Solar (Accessed: 08 December 2022))*