GLINT AND GLARE ASSESSMENT

macroworks

Fosterstown North,

Dublin Road/R132,

Swords,

Co. Dublin

iL Registered Landscape Architect

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1   INTRODUCTION

Macro Works Ltd. was commissioned to undertake a glint and glare assessment report for a proposed roof-mounted photovoltaic (PV) panel installation on the roofs of the multiple buildings at the proposed strategic housing development on lands at Fosterstown North, Dublin Road / R132, Swords, Co. Dublin. (Figure 1 refers).

Figure 1: Aerial view indicating the approximate location of the proposed development (red pin).

PV panels are proposed on the roofs of all 10 no. of the proposed buildings (Figure 2 refers). The PV panels will remain in a fixed position throughout the day and year (i.e. they will not rotate to track the movement of the sun). All panels will be tilted with a slope of 13 degrees from the horizontal. Panels on Block 5, 6, 9 and 10 will be orientated in a southerly direction. Panels on Blocks 1, 2, 3, 4, 8 and the larger PV array on Block 7 were analysed as if they will be orientated to both the east and the west, to account for both potential mounting options, while the smaller array on Block 7 will be orientated to the southwest only (Figure 3 and Figure 4 refer). Top of the PV panels will be no more than 400mm from the roof surface on which they are proposed.

Figure 2: Extract from Landscape Masterplan PL21-01, indicating the location of the proposed buildings which are to contain PV panels
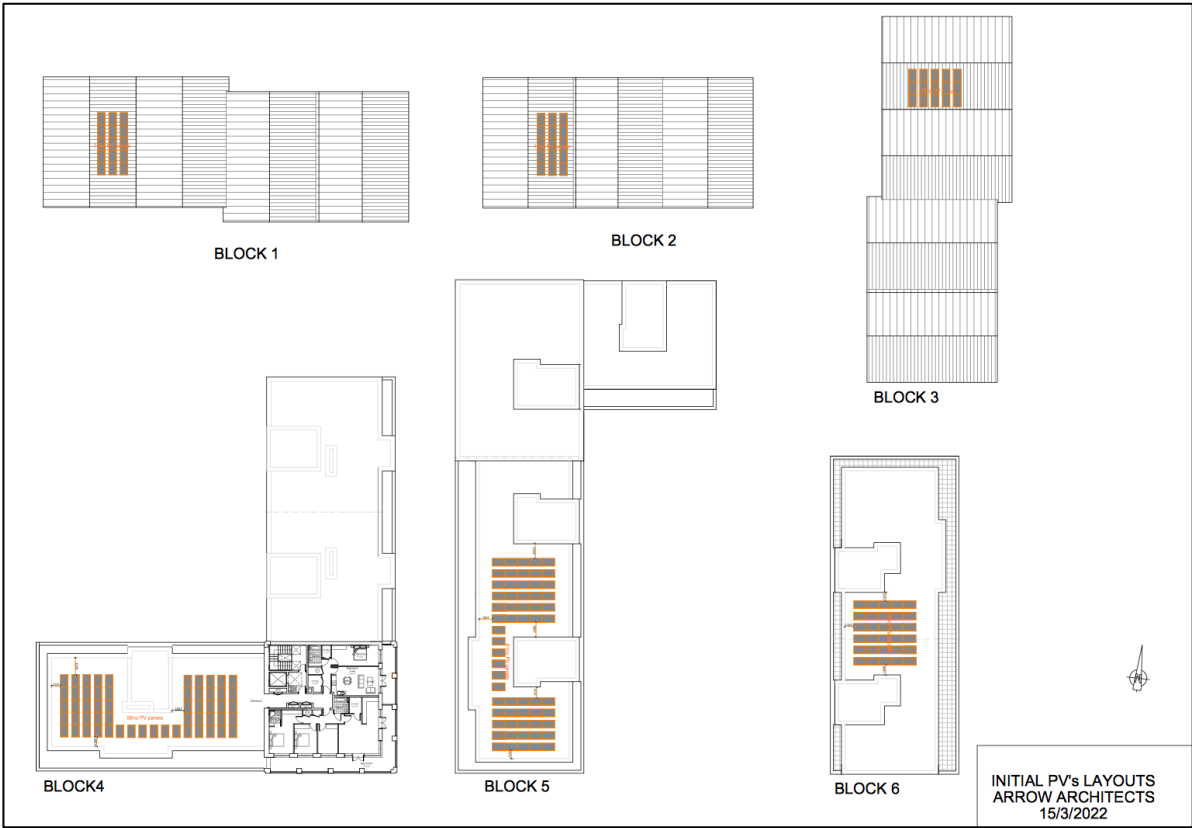
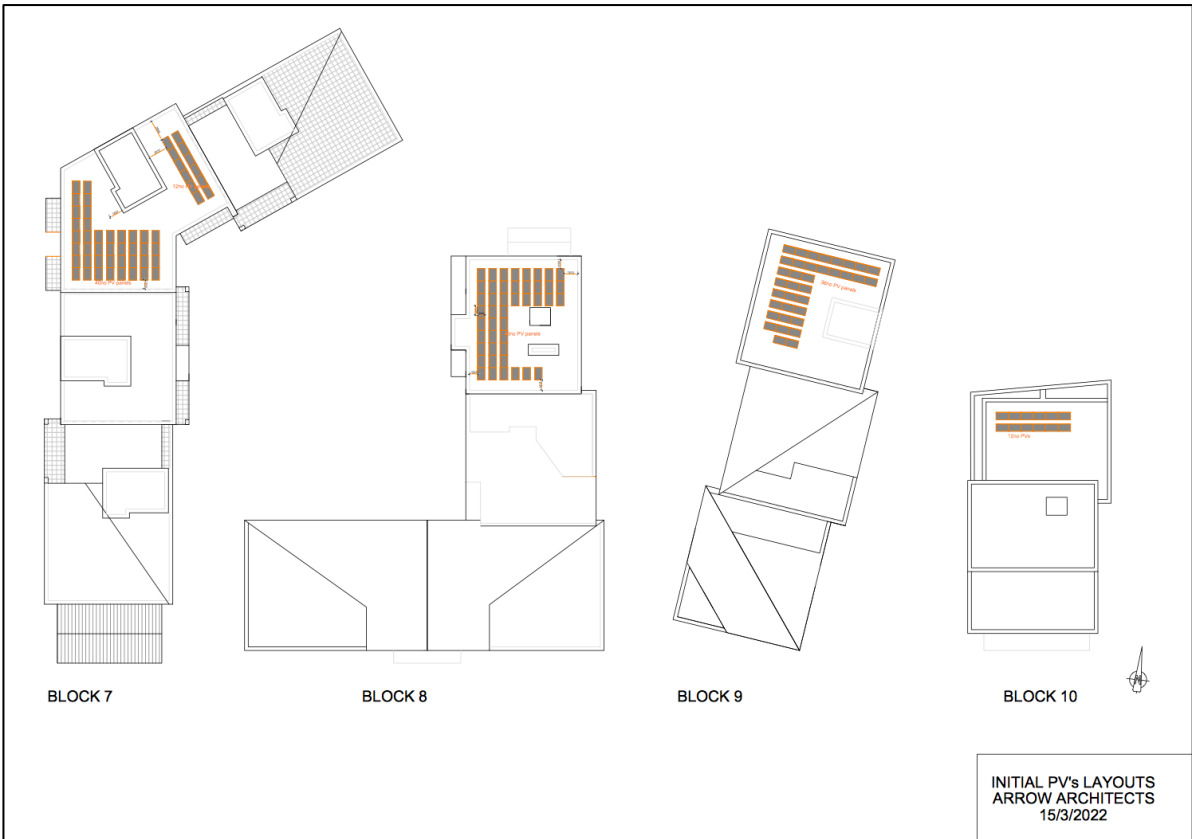**Figure 3: Drawing indicating proposed PV panel arrays on Blocks 1 to 6**

Figure 4: Drawing indicating proposed PV panel arrays on Blocks 7 to 10

2   STATEMENT OF AUTHORITY

Macro Works' relevant experience includes nineteen years of analysing the visual effects of a wide range of infrastructural and commercial development types. This experience includes numerous domestic and international wind and solar energy developments. Macro Works has assessed the effects of glint and glare for many solar development sites throughout Ireland to date.

3   METHODOLOGY

The process for dealing with aviation receptors is as follows:

1. The Federal Aviation Administration (FAA) approved Solar Glare Hazard Analysis Tool (SGHAT) is used to determine if any of these aviation receptors has the potential to theoretically experience glint or glare. This tool also calculates the intensity of such reflectance and whether it is acceptable by FAA standards.
2. SGHAT does not account for terrain screening or screening provided by surface elements such as existing vegetation or buildings, therefore the results of the SGHAT may need to be considered, in conjunction with an assessment of existing intervening screening that may be present, to establish if reflectance can actually be experienced at the receptors.
3. Finally, if necessary, additional assessment is undertaken using Macro Works' bespoke model which would into account any screening provided by any proposed mitigation measures.

4   GUIDANCE

Guidance has been prepared by the Federal Aviation Authority[1] to address the potential hazards that solar developments may pose to aviation activities, and this has been adopted for use by the Irish Aviation Authority. SGHAT was developed in conjunction with the FAA in harmony with this guidance and is commonly regarded as the accepted industry standard by aviation authorities internationally when considering the glint and glare effects upon aviation related receptors.

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[1] Harris, Miller, Miller & Hanson Inc.. (November 2010). Technical Guidance for Evaluating Selected Solar Technologies on Airports; 3.1.2 Reflectivity. *Technical Guidance for Evaluating Selected Solar Technologies on Airports*. Available at: https://www.faa.gov/airports/environmental/policy_guidance/media/airport-solar-guide.pdf

4.1 FEDERAL AVIATION AUTHORITY

Within the FAA's interim policy, a 'Review of Solar Energy System Projects on Federally Obligated Airports'[2] it states:

> "To obtain FAA approval to revise an airport layout plan to depict a solar installation and/or a ''no objection'' to a Notice of Proposed Construction Form 7460–1, the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:
>
> - *No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and*
> - *No potential for glare or ''low potential for after-image'' (shown in green in Figure 1* [Figure 5 refers]*) 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."*

In summary, glare at an ATCT is not acceptable but glare with a *''low potential for after-image''* is acceptable along final approach paths to runways.

4.2 SOLAR GLARE HAZARD ANALYSIS TOOL

The SGHAT was designed to determine whether a proposed solar energy project would result in the potential for ocular impact as depicted on the Solar Glare Hazard Analysis Plot (Figure 5 refers). SGHAT analyses ocular impact over the entire calendar year in one minute intervals from when the sun rises above the horizon until the sun sets below the horizon. One of the principal outputs from the SGHAT report is a glare plot per receptor that indicates the time of day and days per year that glare has the potential to occur. SGHAT plot classifies the intensity of ocular impact as either Green Glare, Yellow Glare or Red Glare. These colour classifications are equivalent to the FAA's definitions regarding the level of ocular impact e.g. 'Green Glare' in the SGHAT is synonymous to the FAA's *''low potential for after-image'','* and so forth. The various correlations are illustrated on the Solar Glare Hazard Analysis Plot**.**

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[2] Federal Aviation Administration (FAA). (2013). Department of Transportation - Federal Aviation Administration. *Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*. Vol 78 (No 205), 63276-63279.
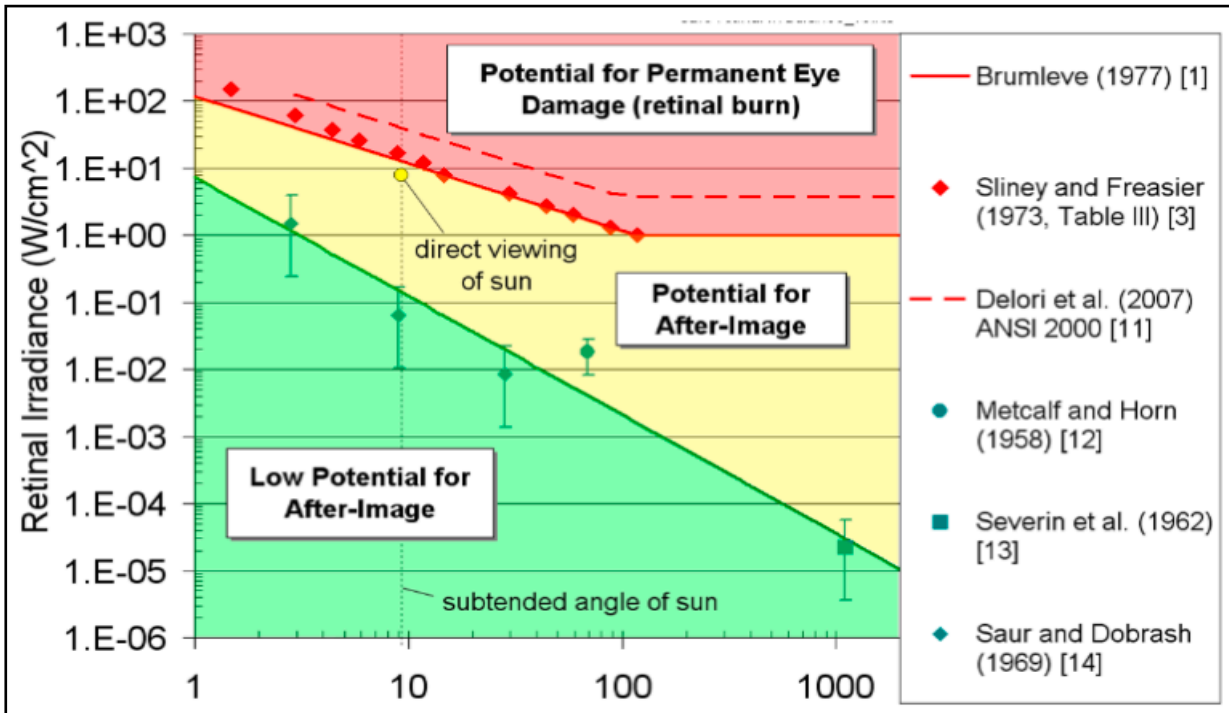
Solar Glare Ocular Hazard Plot: The potential ocular hazard from solar glare is a function of retinal irradiance and the subtended angle (size/distance) of the glare source. It should be noted that the ratio of spectrally weighted solar illuminance to solar irradiance at the earth's surface yields a conversion factor of ~100 lumens/W. Plot adapted from Ho et al., 2011.

Chart References: Ho, C.K., C.M. Ghanbari, and R.B. Diver, 2011, Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation, J. Solar Energy Engineering, August 2011, Vol. 133, 031021-1 – 031021-9.

Figure 5: Figure 1 from the FAA Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports

5   IDENTIFICATION OF RELEVANT RECEPTORS

Dublin Airport is an international airport operated by the Dublin Airport Authority. Its nearest runway is located approximately 1.4km southwest of the proposed development (Figure 6 refers).

Figure 6: Aerial view (Google Earth Pro) showing the location proposed development (red pin) relative Dublin Airport.

5.1 AIR TRAFFIC CONTROL TOWERS

Dublin Airport has a new Air Traffic Control Tower (ATCT) (Ref: '2-ATCT' in SGHAT) located to the west of the main terminal buildings and, with a viewing height of 75.6m Above Ground Level (AGL), is considerably taller than the older ATCT (Ref: '1-ATCT' in SGHAT) at just 21.9m AGL (Figure 7 refers). Both ATCTs were analysed for potential impacts.

Figure 7: Location of the Air Traffic Control Towers at Dublin Airport (red centre icons).

5.2 RUNWAYS

Dublin Airport hosts 2 operational runways 10/28 and 16/34. A 3rd runway 10L/28R is under construction to the north to help accommodate increasing passenger numbers that will run parallel to runway 10/28 to the south. This will render the 16/34 runway as a purely taxiing runway when operational (Figure 8 refers). All 6 runway approaches will be assessed. This includes the recently proposed northern runway (approach 10L and 28R).
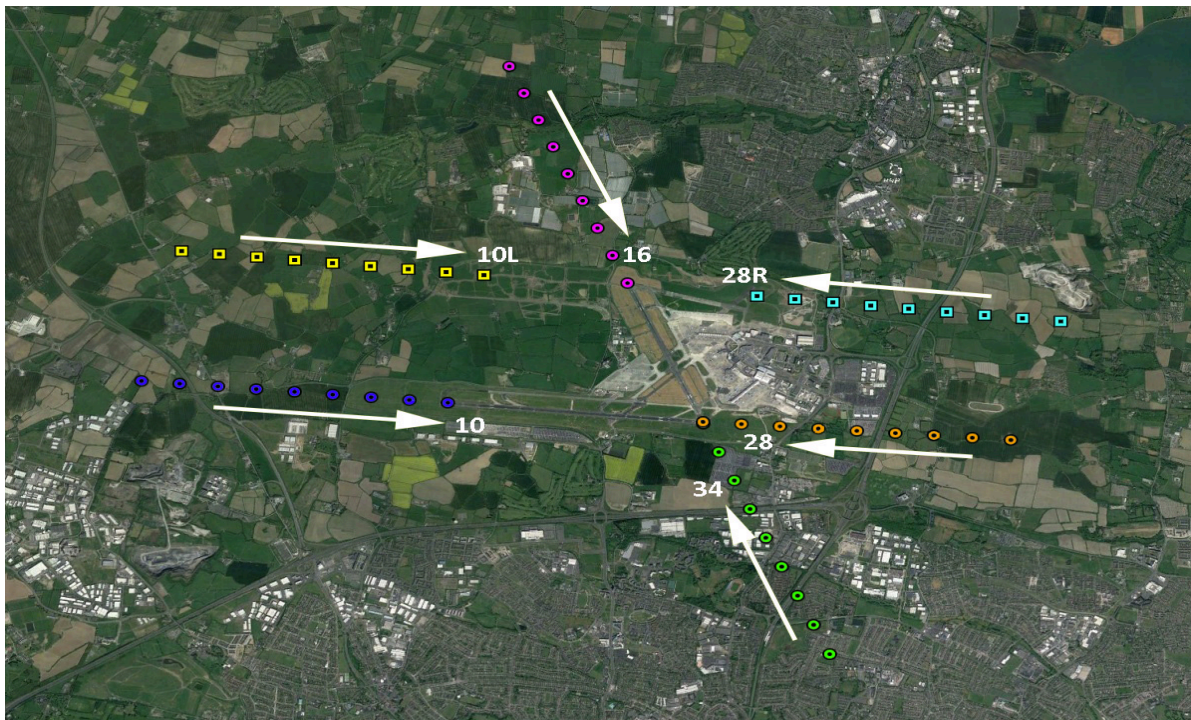

Figure 8: Aerial view (Google Earth Pro) showing 2 mile approach lines to runways at Dublin Airport (at ¼ mile intervals) as assessed by SGHAT. Includes the proposed northern runways 10L and 28R.

6 RESULTS

6.1 RUNWAY APPROACHES

The SGHAT results are contained in Appendix A and show that of the six runway approaches analysed, runway approaches 10L, 10, 16 and 28R at Dublin Airport have the theoretical potential to receive glare. In this instance, SGHAT calculated the potential glare to be '*Green Glare*'. SGHATs '*Green Glare*' classification regarding the intensity of the potential glare is synonymous with FAA's *'low potential for temporary after image'*. *'Green Glare' /* glare with a *'low potential for temporary after image,'* regardless of the number of minutes per year, is considered by the FAA to be an **acceptable level of reflectance effect for runway approaches**.

6.2 AIR TRAFFIC CONTROL TOWERS

The SGHAT results are contained in Appendix A and show no theoretical potential for glare per year at either of the ATCTs in Dublin Airport.

6.3 OVERALL CONCLUSION

From the analysis and discussions contained herein, it is considered that there will not be any hazardous glint and glare effects upon the Dublin Airport aviation receptors identified as a result of the proposed roof-mounted solar PV panels on the roofs of the multiple buildings at the proposed strategic housing development on lands at Fosterstown North, Dublin Road / R132, Swords, Co. Dublin.

APPENDIX A:

SGHAT RESULTS – RUNWAYS APPROACHES AND AIR TRAFFIC CONTROL TOWERS (ATCT)

FORGESOLAR GLARE ANALYSIS

Project: **SGHAT_IRE**

Site configuration: **Fosterstown SHD**

Analysis conducted by Luis Dominguez (luis@macroworks.ie) at 15:23 on 04 Apr, 2022.

U.S. FAA 2013 Policy Adherence

The following table summarizes the policy adherence of the glare analysis based on the 2013 U.S. Federal Aviation Administration Interim Policy 78 FR 63276. This policy requires the following criteria be met for solar energy systems on airport property:

- No "yellow" glare (potential for after-image) for any flight path from threshold to 2 miles
- No glare of any kind for Air Traffic Control Tower(s) ("ATCT") at cab height.
- Default analysis and observer characteristics (see list below)

ForgeSolar does not represent or speak officially for the FAA and cannot approve or deny projects. Results are informational only.

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
2-mile flight path(s)	PASS	Flight path receptor(s) do not receive yellow glare
ATCT(s)	PASS	Receptor(s) marked as ATCT do not receive glare

Default glare analysis parameters and observer eye characteristics (for reference only):

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

FAA Policy 78 FR 63276 can be read at https://www.federalregister.gov/d/2013-24729

SITE CONFIGURATION

Analysis Parameters

DNI: peaks at 1,000.0 W/m^2
Time interval: 1 min
Ocular transmission
coefficient: 0.5
Pupil diameter: 0.002 m
Eye focal length: 0.017 m
Sun subtended angle: 9.3
mrad
Site Config ID: 67103.11293
Methodology: V2
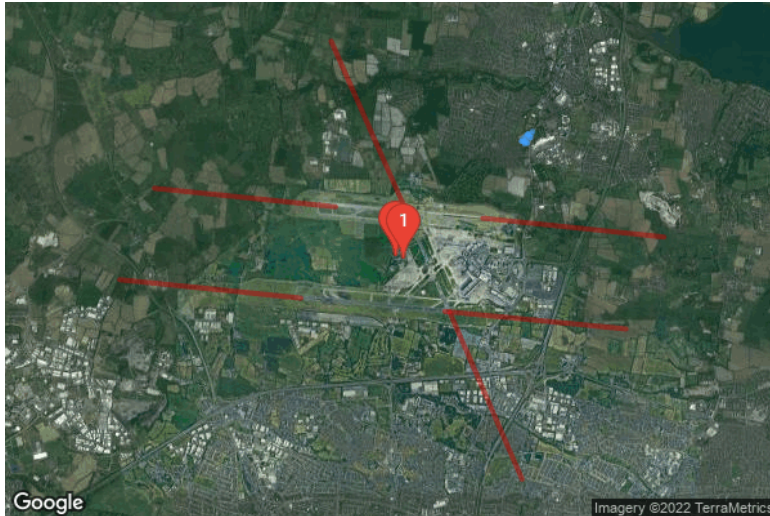
PV Array(s)

Name: Block10
Axis tracking: Fixed (no rotation)
Tilt: 13.0°
Orientation: 202.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.448896	-6.227752	39.50	29.70	69.20
2	53.448863	-6.227611	39.50	29.70	69.20
3	53.448842	-6.227625	39.50	29.70	69.20
4	53.448875	-6.227766	39.50	29.70	69.20
5	53.448896	-6.227752	39.50	29.70	69.20

Name: Block1 E

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 83.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447033	-6.229140	45.00	18.70	63.70
2	53.447036	-6.229079	45.00	18.70	63.70
3	53.446961	-6.229067	45.00	18.70	63.70
4	53.446957	-6.229127	45.00	18.70	63.70
5	53.447033	-6.229140	45.00	18.70	63.70

Name: Block1 W

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 263.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447033	-6.229140	45.00	18.70	63.70
2	53.447036	-6.229079	45.00	18.70	63.70
3	53.446961	-6.229067	45.00	18.70	63.70
4	53.446957	-6.229127	45.00	18.70	63.70
5	53.447033	-6.229140	45.00	18.70	63.70

Name: Block2 E

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 83.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.446987	-6.229913	46.00	18.70	64.70
2	53.446990	-6.229853	46.00	18.70	64.70
3	53.446915	-6.229841	46.00	18.70	64.70
4	53.446912	-6.229901	46.00	18.70	64.70
5	53.446987	-6.229913	46.00	18.70	64.70

Name: Block2 W

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 263.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.446987	-6.229913	46.00	18.70	64.70
2	53.446990	-6.229853	46.00	18.70	64.70
3	53.446915	-6.229841	46.00	18.70	64.70
4	53.446912	-6.229901	46.00	18.70	64.70
5	53.446987	-6.229913	46.00	18.70	64.70

Name: Block3 E

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 83.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447311	-6.230660	46.00	18.70	64.70
2	53.447317	-6.230553	46.00	18.70	64.70
3	53.447272	-6.230546	46.00	18.70	64.70
4	53.447266	-6.230653	46.00	18.70	64.70
5	53.447311	-6.230660	46.00	18.70	64.70

Name: Block3 W

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 263.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447311	-6.230660	46.00	18.70	64.70
2	53.447317	-6.230553	46.00	18.70	64.70
3	53.447272	-6.230546	46.00	18.70	64.70
4	53.447266	-6.230653	46.00	18.70	64.70
5	53.447311	-6.230660	46.00	18.70	64.70

Name: Block4 E

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 83.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447254	-6.229958	45.00	27.15	72.15
2	53.447274	-6.229601	45.00	27.15	72.15
3	53.447349	-6.229613	45.00	27.15	72.15
4	53.447343	-6.229719	45.00	27.15	72.15
5	53.447283	-6.229710	45.00	27.15	72.15
6	53.447275	-6.229854	45.00	27.15	72.15
7	53.447335	-6.229864	45.00	27.15	72.15
8	53.447329	-6.229970	45.00	27.15	72.15
9	53.447254	-6.229958	45.00	27.15	72.15

Name: Block4 W

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 263.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447254	-6.229958	45.00	27.15	72.15
2	53.447274	-6.229601	45.00	27.15	72.15
3	53.447349	-6.229613	45.00	27.15	72.15
4	53.447343	-6.229719	45.00	27.15	72.15
5	53.447283	-6.229710	45.00	27.15	72.15
6	53.447275	-6.229854	45.00	27.15	72.15
7	53.447335	-6.229864	45.00	27.15	72.15
8	53.447329	-6.229970	45.00	27.15	72.15
9	53.447254	-6.229958	45.00	27.15	72.15

Name: Block5

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 162.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447813	-6.230117	44.50	24.00	68.50
2	53.447738	-6.230080	44.50	24.00	68.50
3	53.447721	-6.230176	44.50	24.00	68.50
4	53.447632	-6.230134	44.50	24.00	68.50
5	53.447650	-6.230036	44.50	24.00	68.50
6	53.447588	-6.230006	44.50	24.00	68.50
7	53.447567	-6.230127	44.50	24.00	68.50
8	53.447791	-6.230239	44.50	24.00	68.50
9	53.447791	-6.230239	44.50	24.00	68.50

Name: Block6

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 173.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.448053	-6.229618	44.50	30.30	74.80
2	53.448061	-6.229493	44.50	30.30	74.80
3	53.447983	-6.229480	44.50	30.30	74.80
4	53.447976	-6.229605	44.50	30.30	74.80
5	53.448053	-6.229618	44.50	30.30	74.80

Name: Block7

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 235.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.448474	-6.228859	43.50	29.70	73.20
2	53.448400	-6.228772	43.50	29.70	73.20
3	53.448387	-6.228803	43.50	29.70	73.20
4	53.448461	-6.228890	43.50	29.70	73.20
5	53.448474	-6.228859	43.50	29.70	73.20

Name: Block7 E

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 83.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.448400	-6.229064	43.50	29.70	73.20
2	53.448280	-6.229044	43.50	29.70	73.20
3	53.448291	-6.228867	43.50	29.70	73.20
4	53.448351	-6.228877	43.50	29.70	73.20
5	53.448342	-6.229015	43.50	29.70	73.20
6	53.448403	-6.229025	43.50	29.70	73.20
7	53.448400	-6.229064	43.50	29.70	73.20

Name: Block7 W

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 263.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.448400	-6.229064	43.50	29.70	73.20
2	53.448280	-6.229044	43.50	29.70	73.20
3	53.448291	-6.228867	43.50	29.70	73.20
4	53.448351	-6.228877	43.50	29.70	73.20
5	53.448342	-6.229015	43.50	29.70	73.20
6	53.448403	-6.229025	43.50	29.70	73.20
7	53.448400	-6.229064	43.50	29.70	73.20

Name: Block8 E

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 83.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447939	-6.228377	43.50	29.70	73.20
2	53.447911	-6.228207	43.50	29.70	73.20
3	53.447868	-6.228227	43.50	29.70	73.20
4	53.447886	-6.228338	43.50	29.70	73.20
5	53.447813	-6.228372	43.50	29.70	73.20
6	53.447802	-6.228304	43.50	29.70	73.20
7	53.447787	-6.228311	43.50	29.70	73.20
8	53.447808	-6.228438	43.50	29.70	73.20
9	53.447939	-6.228377	43.50	29.70	73.20

Name: Block8 W

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 263.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.447939	-6.228377	43.50	29.70	73.20
2	53.447911	-6.228207	43.50	29.70	73.20
3	53.447868	-6.228227	43.50	29.70	73.20
4	53.447886	-6.228338	43.50	29.70	73.20
5	53.447813	-6.228372	43.50	29.70	73.20
6	53.447802	-6.228304	43.50	29.70	73.20
7	53.447787	-6.228311	43.50	29.70	73.20
8	53.447808	-6.228438	43.50	29.70	73.20
9	53.447939	-6.228377	43.50	29.70	73.20

Name: Block9

Axis tracking: Fixed (no rotation)

Tilt: 13.0°

Orientation: 196.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.448510	-6.228062	43.50	29.70	73.20
2	53.448478	-6.227867	43.50	29.70	73.20
3	53.448456	-6.227877	43.50	29.70	73.20
4	53.448476	-6.227998	43.50	29.70	73.20
5	53.448383	-6.228042	43.50	29.70	73.20
6	53.448391	-6.228090	43.50	29.70	73.20
7	53.448405	-6.228084	43.50	29.70	73.20
8	53.448409	-6.228108	43.50	29.70	73.20
9	53.448510	-6.228062	43.50	29.70	73.20

Flight Path Receptor(s)

Name: 10L Runway
Description: None
Threshold height: 15 m
Direction: 95.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.436880	-6.280253	71.90	15.20	87.10
Two-mile	53.439822	-6.328592	74.90	180.90	255.80

Name: 10 Runway
Description: None
Threshold height: 15 m
Direction: 95.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°
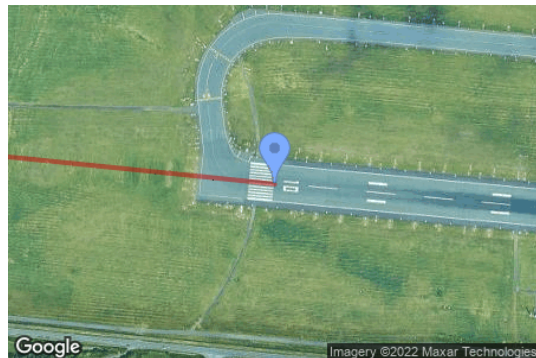
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.422405	-6.289520	74.00	15.30	89.30
Two-mile	53.425327	-6.337846	80.30	177.60	257.90

Name: 16 Runway
Description: None
Threshold height: 15 m
Direction: 156.1°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.436699	-6.261764	66.50	15.20	81.70
Two-mile	53.463138	-6.281428	69.70	180.70	250.40

Name: 28R Runway

Description: None

Threshold height: 15 m

Direction: 275.9°

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.435084	-6.240975	65.50	15.30	80.80
Two-mile	53.432097	-6.192645	34.00	215.50	249.50

Name: 28 Runway

Description: None

Threshold height: 15 m

Direction: 275.5°

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.420299	-6.251111	62.00	15.20	77.20
Two-mile	53.417517	-6.202763	41.90	204.00	245.90

Name: 34 Runway

Description: None

Threshold height: 15 m

Direction: 336.6°

Glide slope: 3.0°

Pilot view restricted? Yes
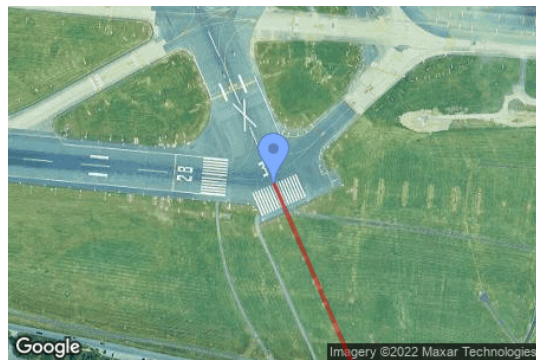
Vertical view: 30.0°

Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.420211	-6.249810	62.20	15.30	77.50
Two-mile	53.393680	-6.230504	49.00	197.10	246.10

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	53.428489	-6.262201	65.90	21.90
2-ATCT	2	53.428937	-6.264259	65.60	75.60

Map image of 1-ATCT
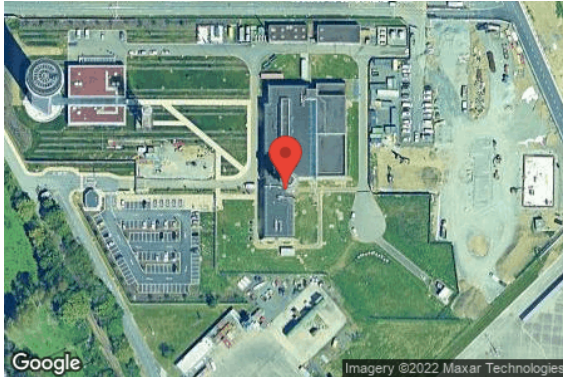
Map image of 2-ATCT
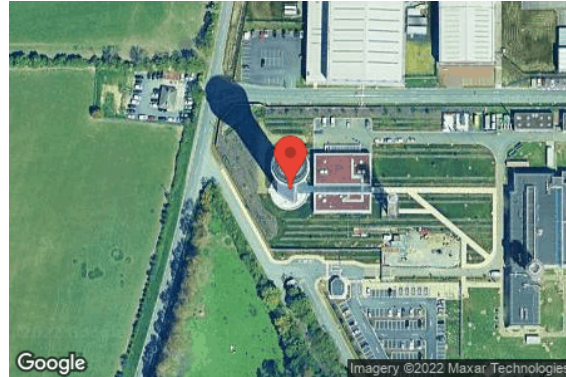
GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt	Orient	"Green" Glare	"Yellow" Glare	Energy
	(°)	(°)	min	min	kWh
Block10	13.0	202.0	8,954	0	-
Block1 E	13.0	83.0	0	0	-
Block1 W	13.0	263.0	5,658	0	-
Block2 E	13.0	83.0	0	0	-
Block2 W	13.0	263.0	5,726	0	-
Block3 E	13.0	83.0	0	0	-
Block3 W	13.0	263.0	5,690	0	-
Block4 E	13.0	83.0	0	0	-
Block4 W	13.0	263.0	5,527	0	-
Block5	13.0	162.0	5,432	0	-
Block6	13.0	173.0	6,976	0	-
Block7	13.0	235.0	6,754	0	-
Block7 E	13.0	83.0	0	0	-
Block7 W	13.0	263.0	5,255	0	-
Block8 E	13.0	83.0	0	0	-
Block8 W	13.0	263.0	5,263	0	-
Block9	13.0	196.0	8,861	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
10L Runway	8485	0
10 Runway	6683	0
16 Runway	54856	0
28R Runway	72	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Results for: Block10

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	2308	0
10 Runway	721	0
16 Runway	5925	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
2308 minutes of green glare
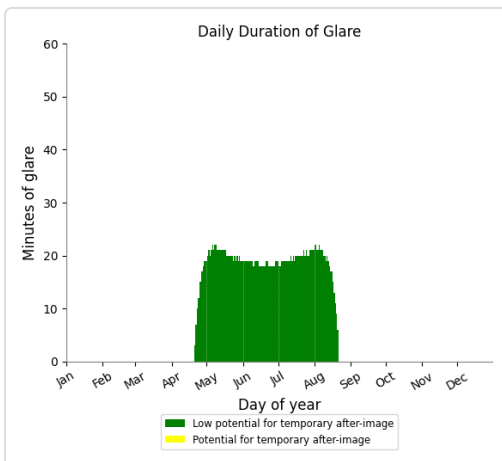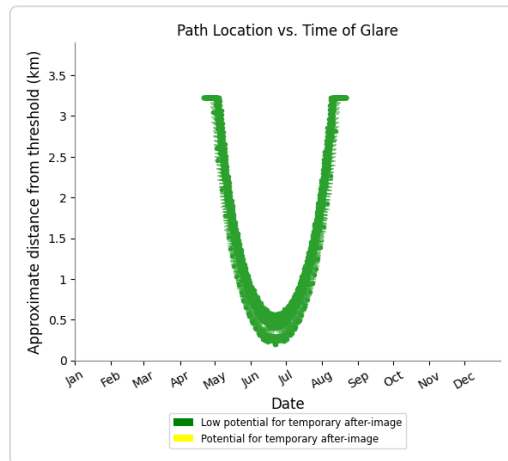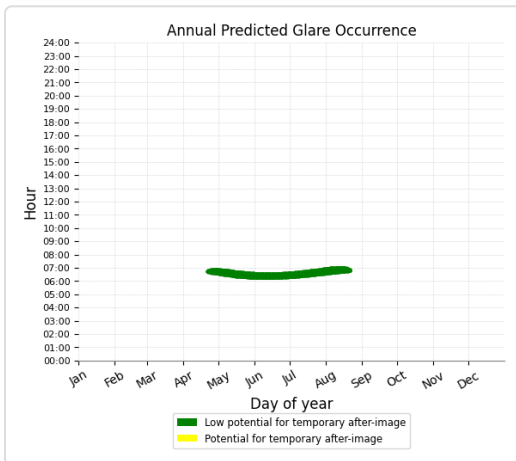
Flight Path: 10 Runway
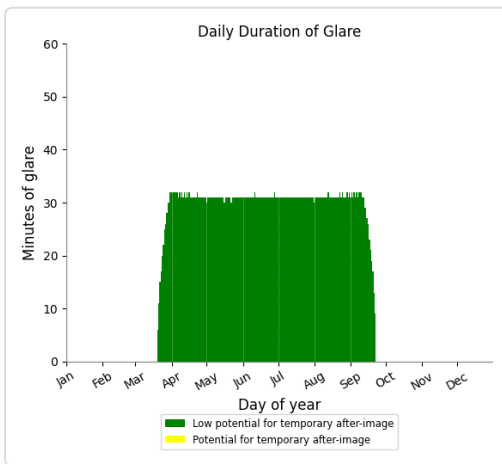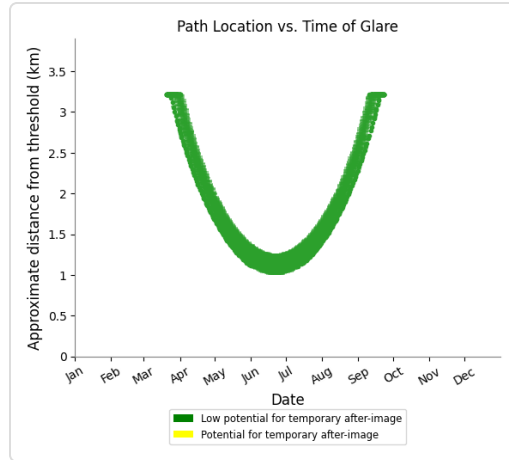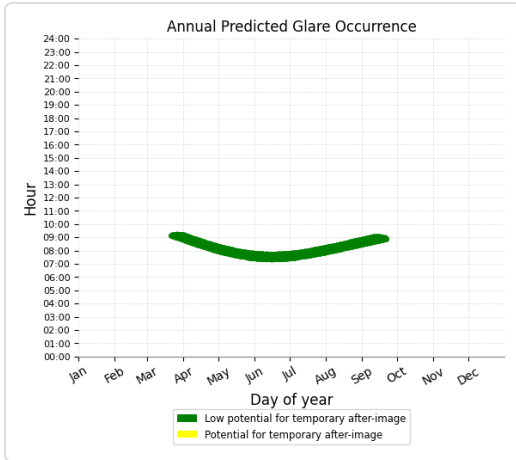
0 minutes of yellow glare

721 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare
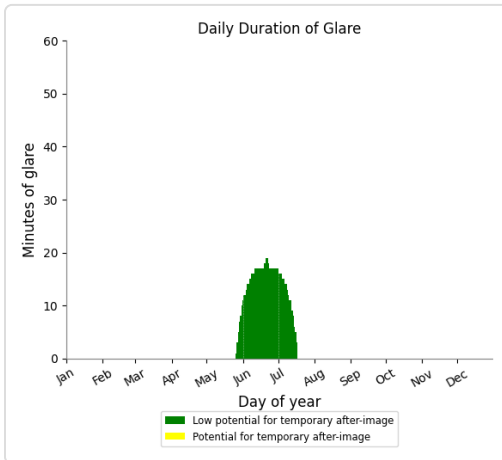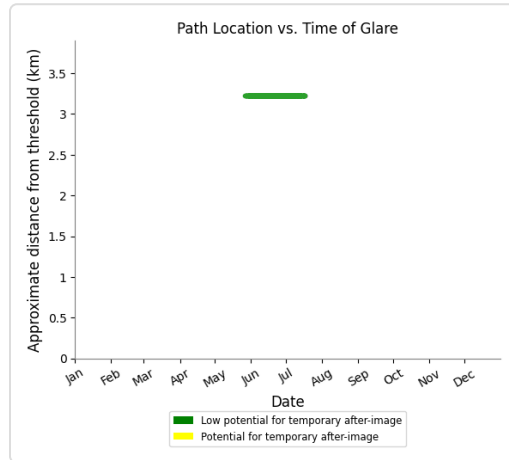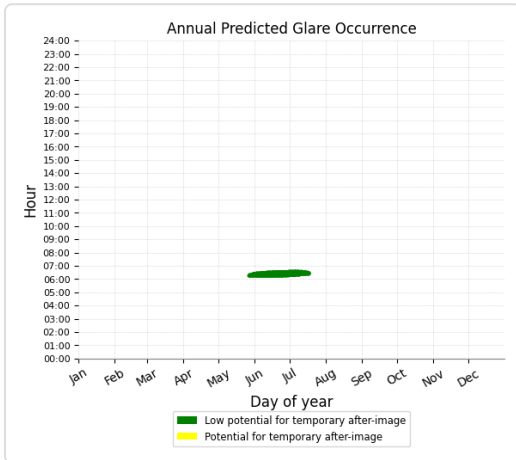
Flight Path: 16 Runway

0 minutes of yellow glare

5925 minutes of green glare
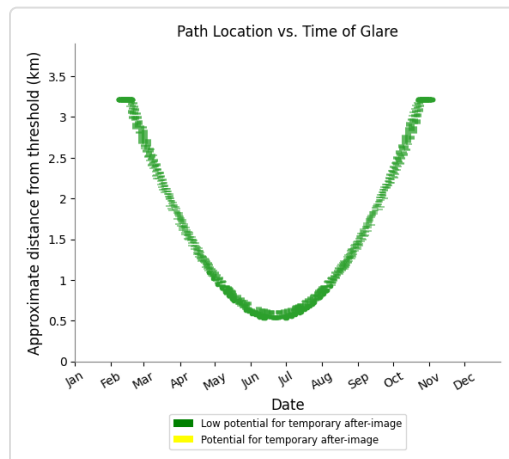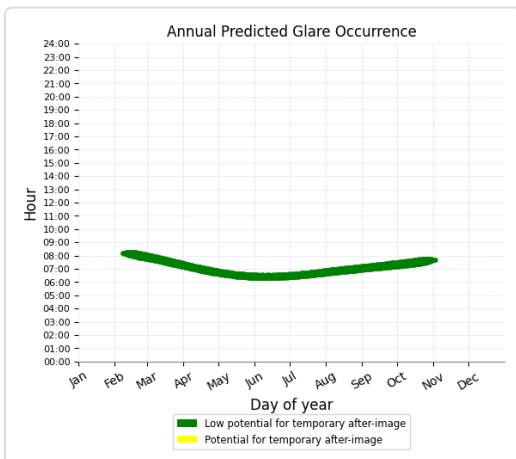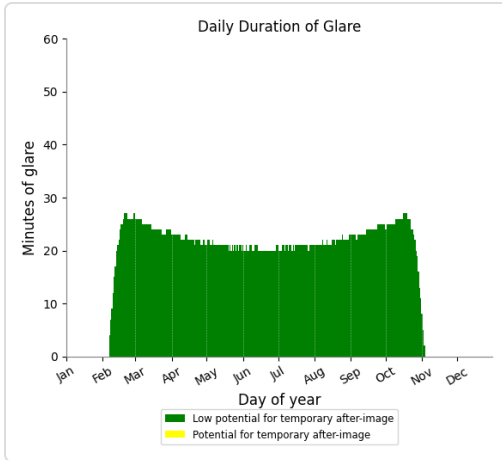
Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

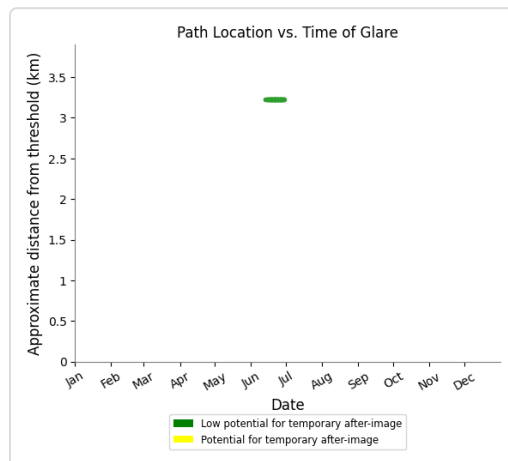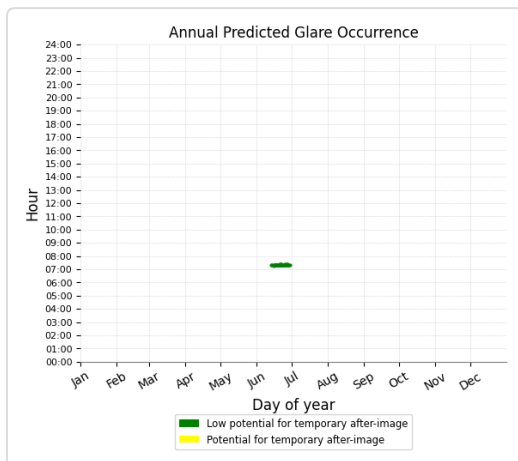0 minutes of yellow glare
0 minutes of green glare

Results for: Block1 E

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0

Receptor	Green Glare (min)	Yellow Glare (min)
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
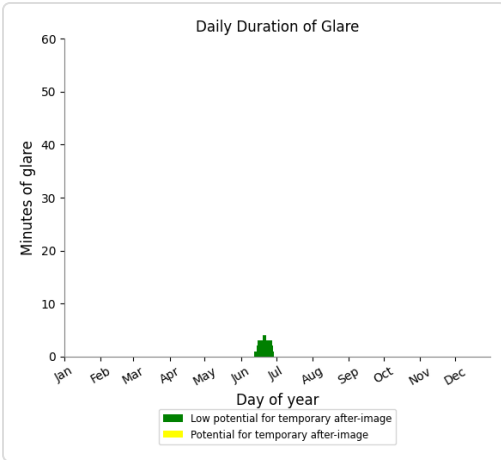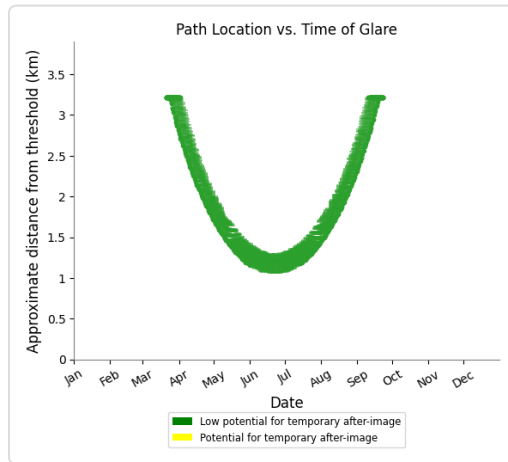0 minutes of green glare

Results for: Block1 W

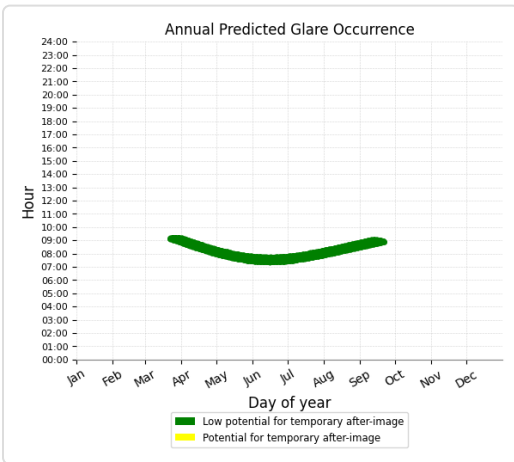| Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	117	0
10 Runway	0	0
16 Runway	5541	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
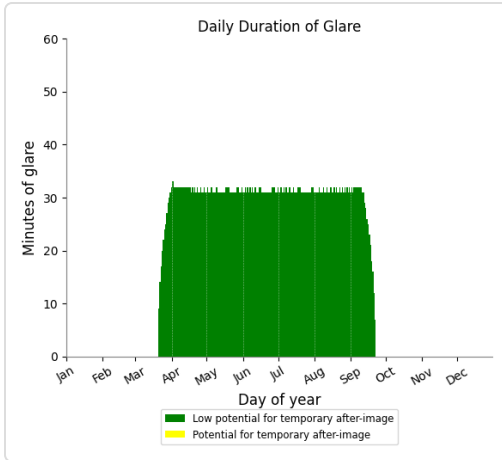
117 minutes of green glare
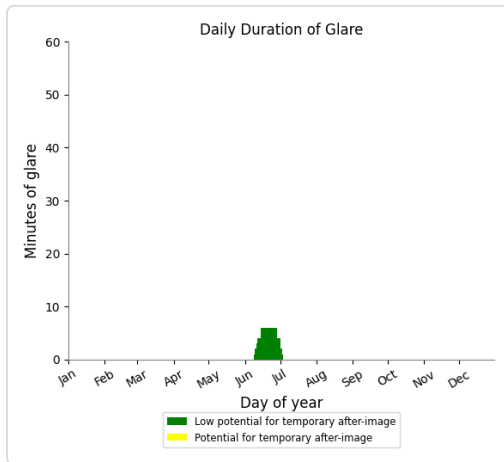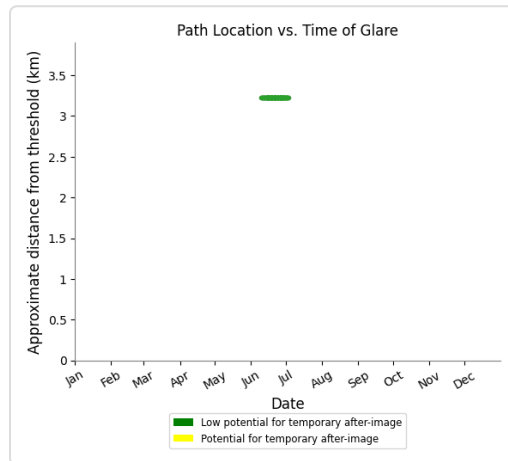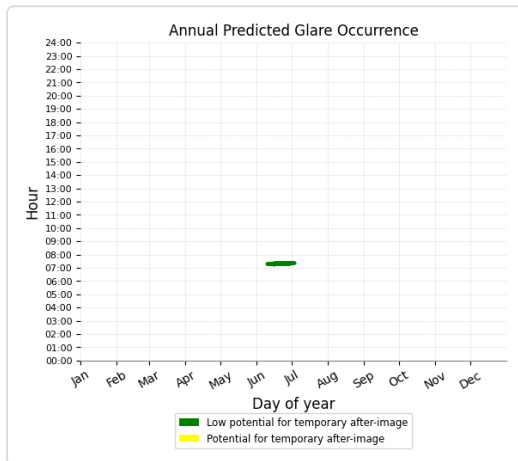
Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
5541 minutes of green glare
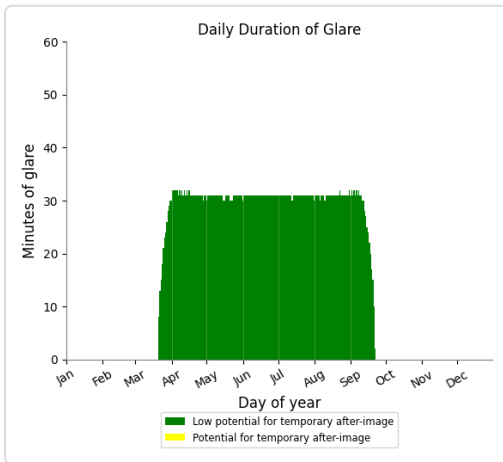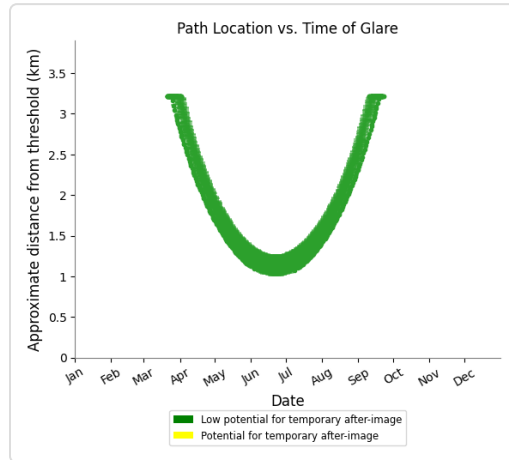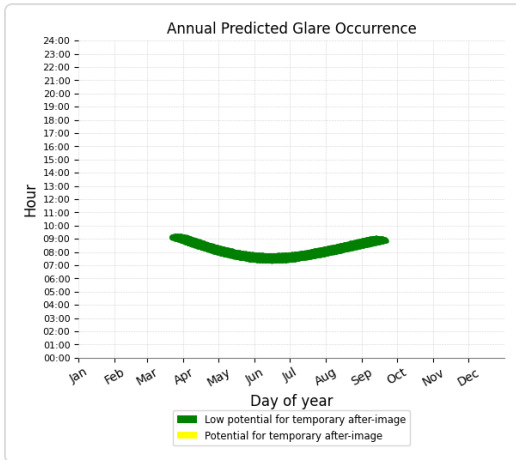
Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Block2 E

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

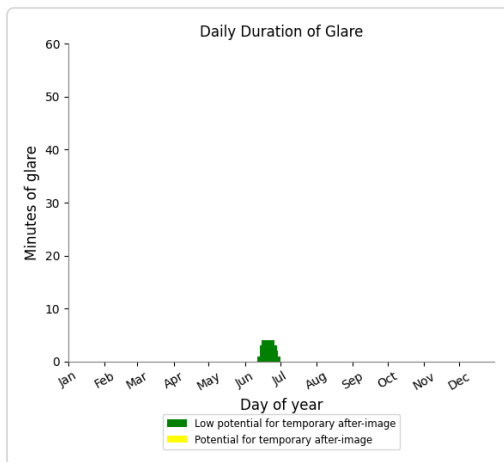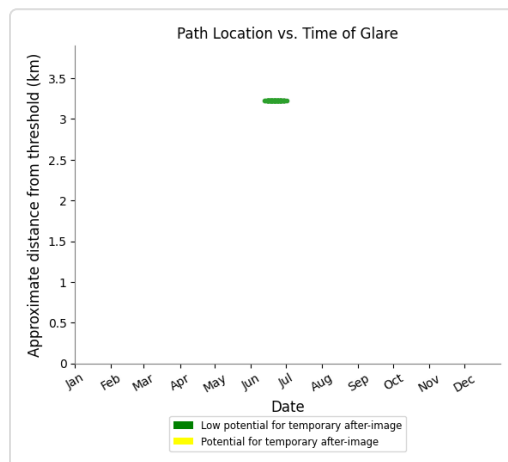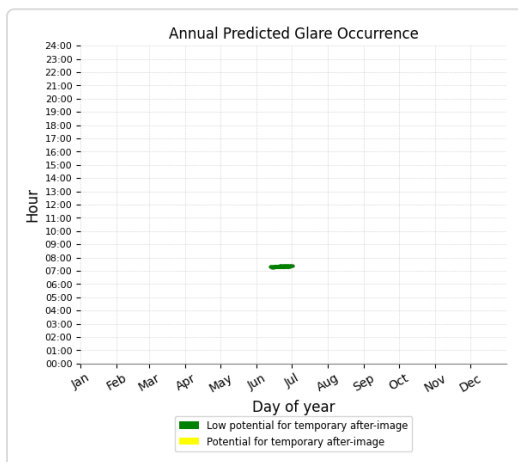0 minutes of yellow glare
0 minutes of green glare

Results for: Block2 W

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	115	0
10 Runway	0	0
16 Runway	5611	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
115 minutes of green glare
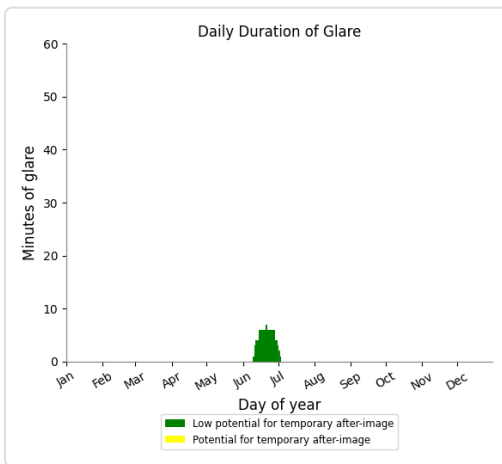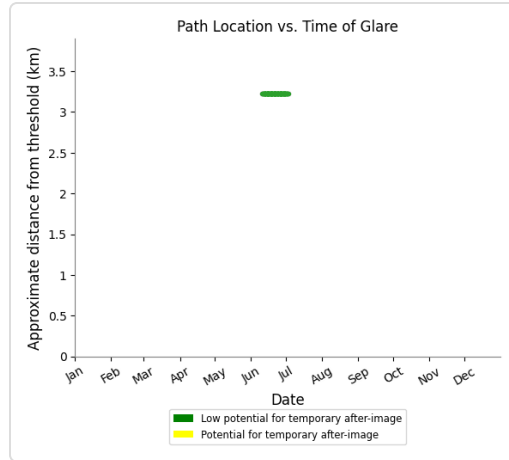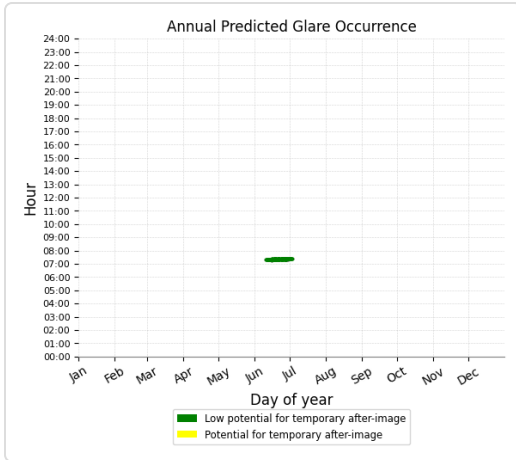
Annual Predicted Glare Occurrence

Legend:
- Low potential for temporary after-image (green)
- Potential for temporary after-image (yellow)

Path Location vs. Time of Glare

Legend:
- Low potential for temporary after-image (green)
- Potential for temporary after-image (yellow)

Daily Duration of Glare

Legend:
- Low potential for temporary after-image (green)
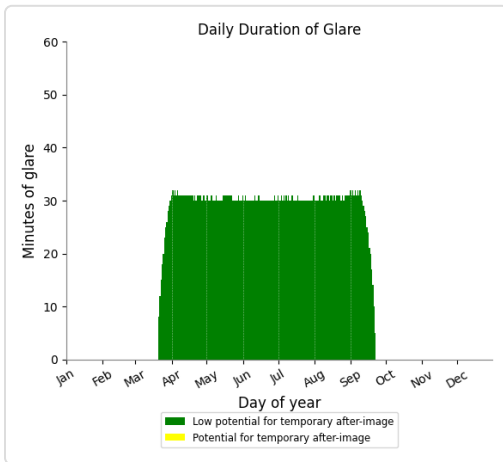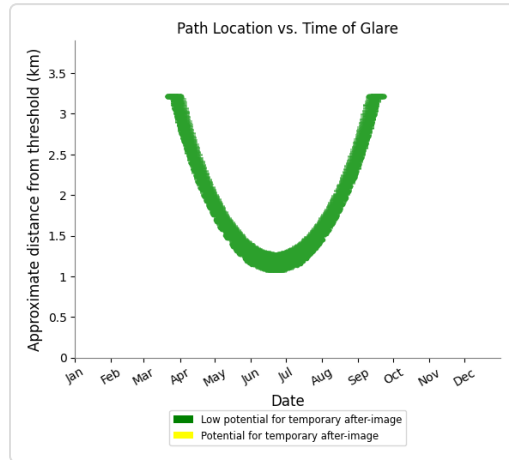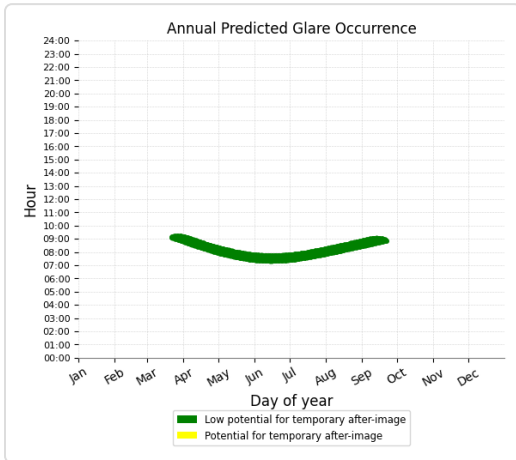- Potential for temporary after-image (yellow)

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
5611 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
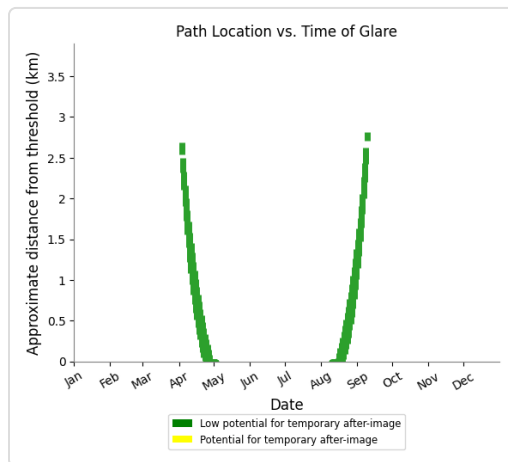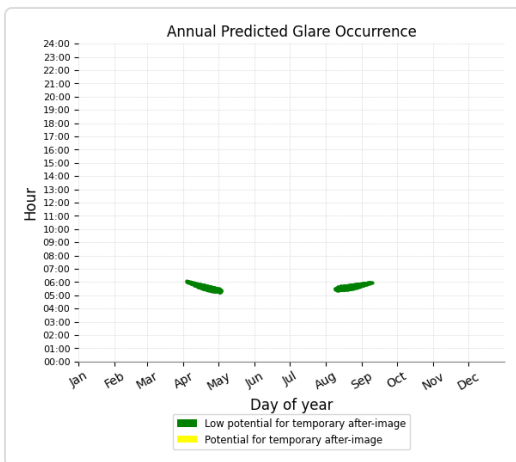0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Block3 E

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
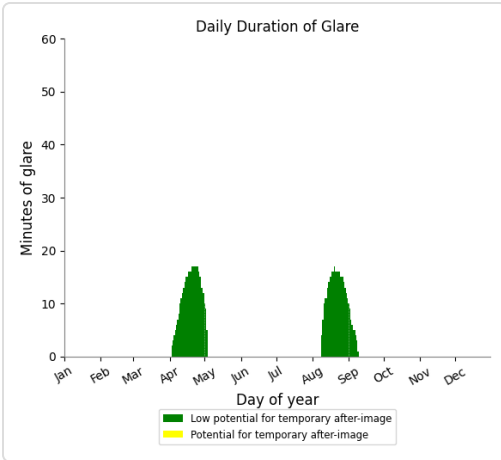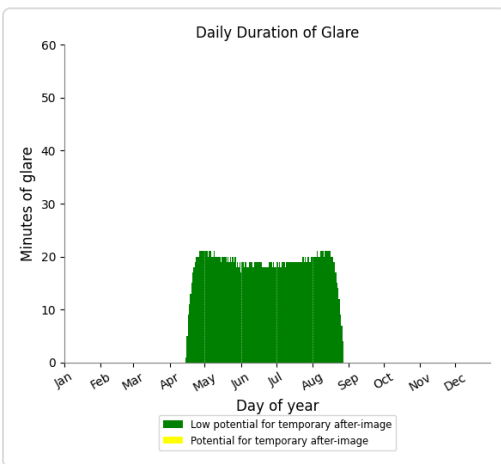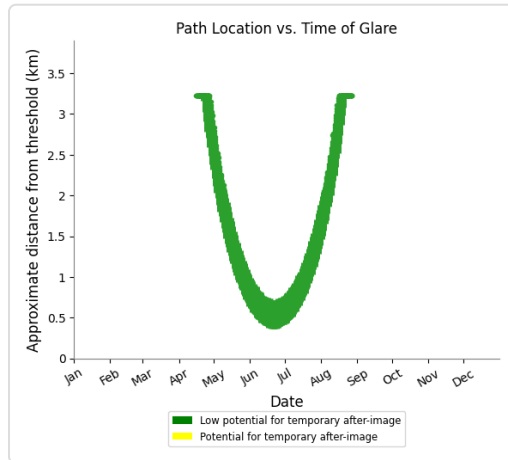0 minutes of green glare

Results for: Block3 W

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	46	0
10 Runway	0	0
16 Runway	5644	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
46 minutes of green glare
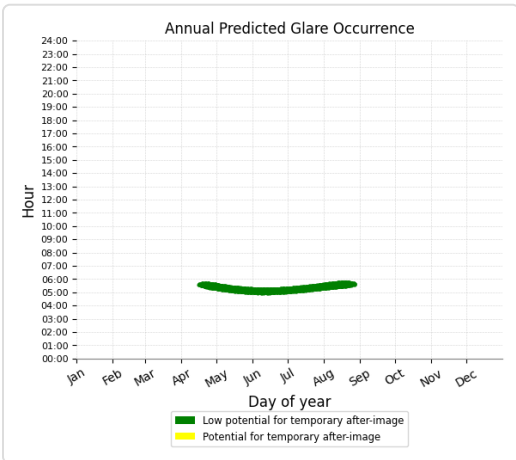
Daily Duration of Glare

Flight Path: 10 Runway

0 minutes of yellow glare
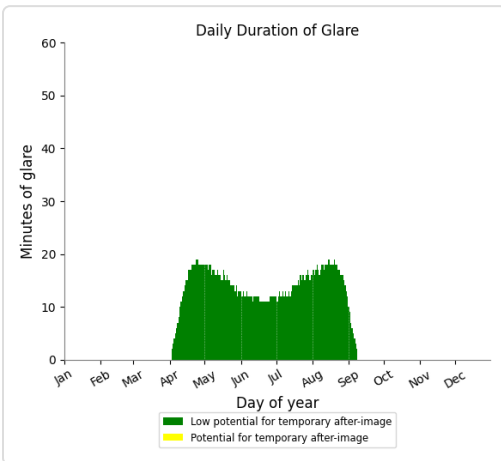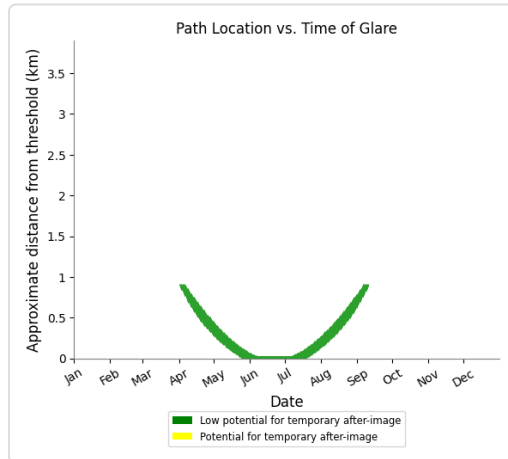
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare

5644 minutes of green glare

Annual Predicted Glare Occurrence

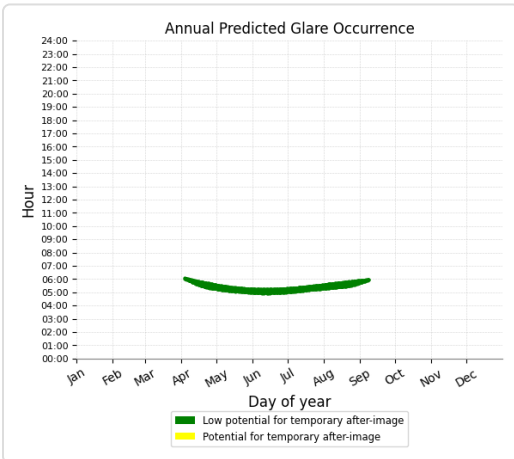Path Location vs. Time of Glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT
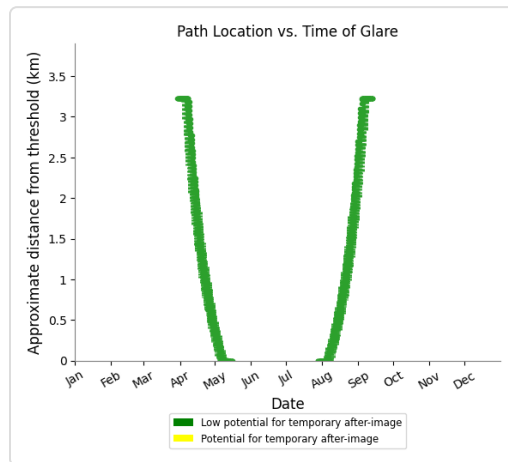
0 minutes of yellow glare
0 minutes of green glare

Results for: Block4 E

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0

Receptor	Green Glare (min)	Yellow Glare (min)
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

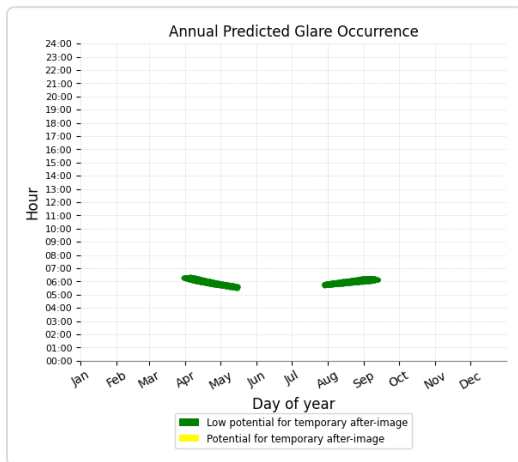0 minutes of yellow glare
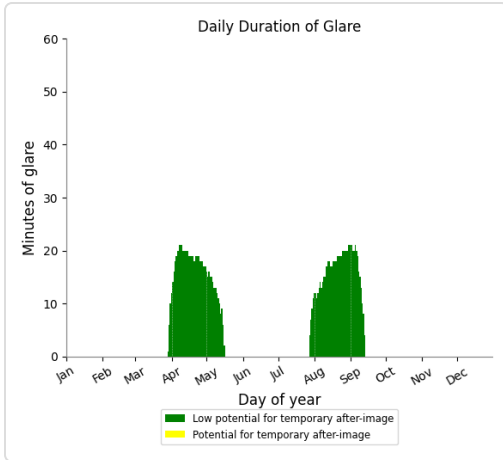0 minutes of green glare

Results for: Block4 W

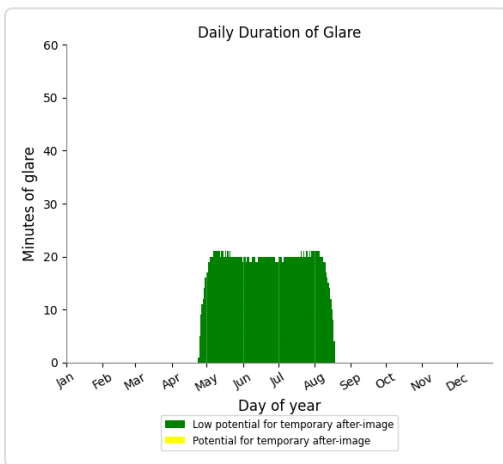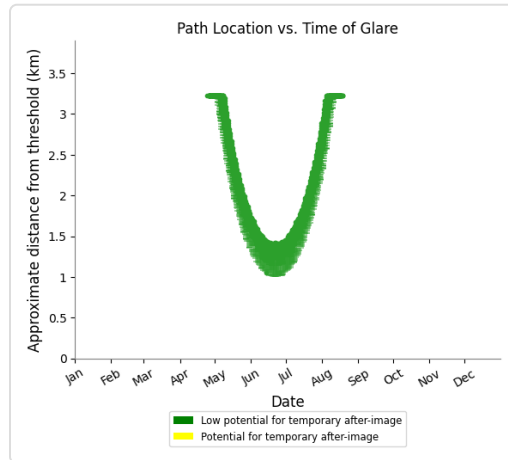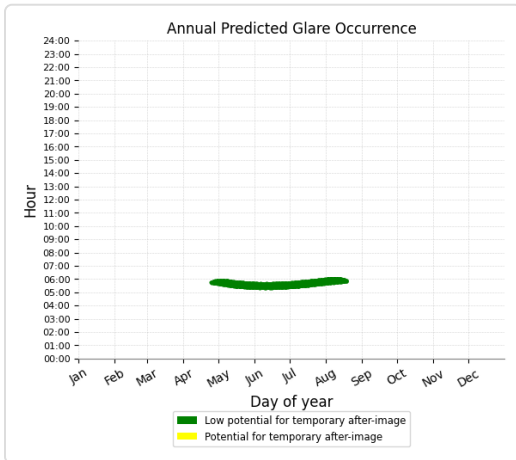| Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	62	0
10 Runway	0	0
16 Runway	5465	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare

62 minutes of green glare
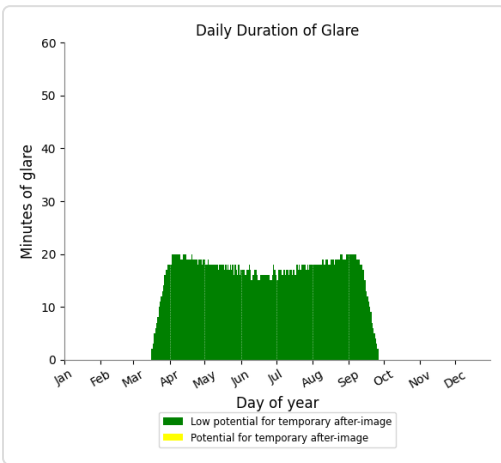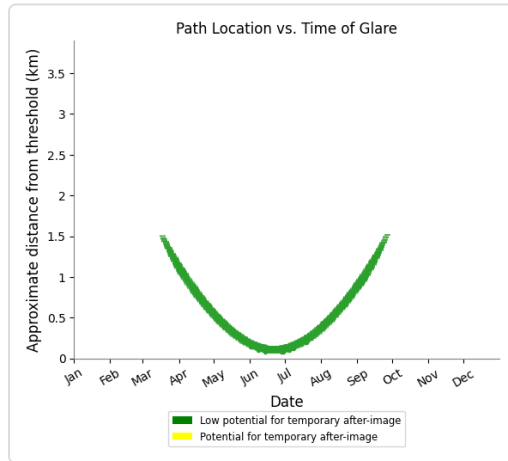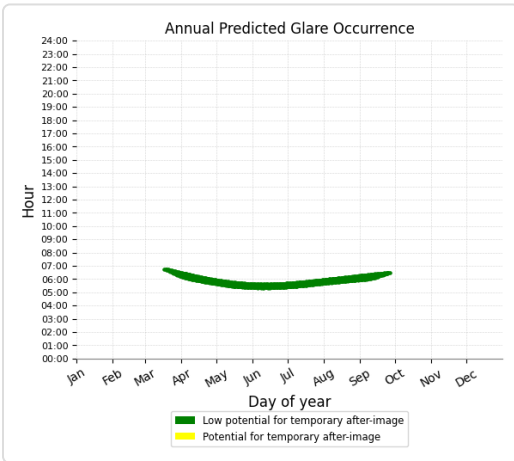
Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
5465 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
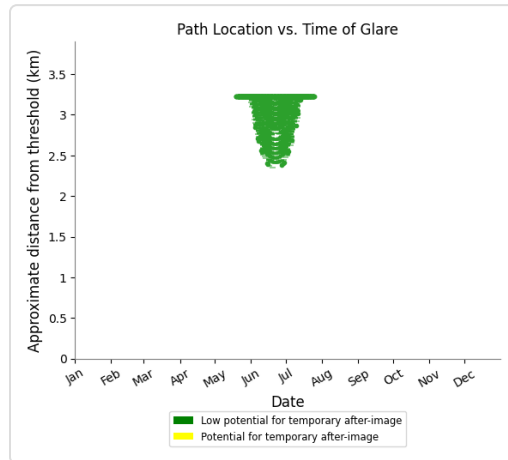0 minutes of green glare

Results for: Block5

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	726	0
10 Runway	2497	0
16 Runway	2209	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
726 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Flight Path: 10 Runway

0 minutes of yellow glare

2497 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare

2209 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
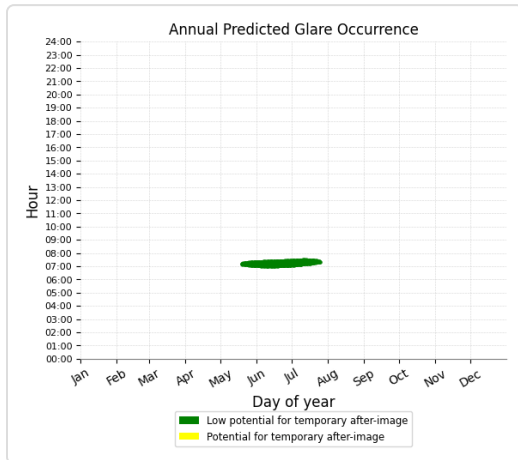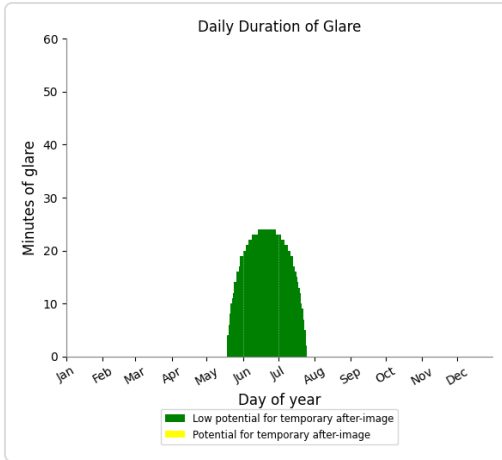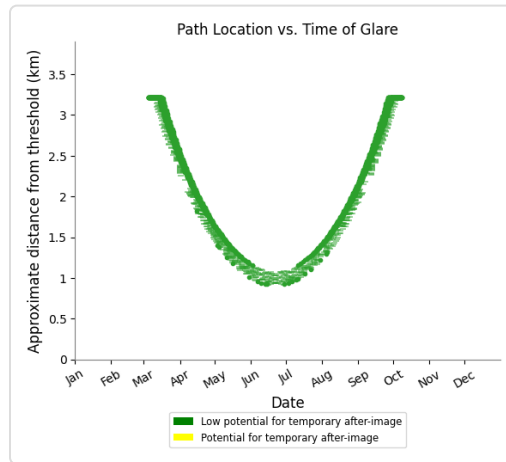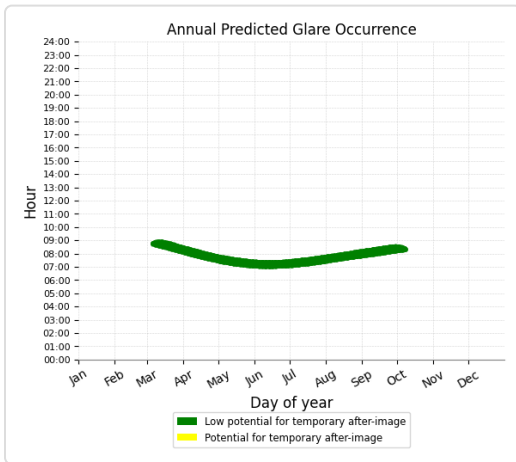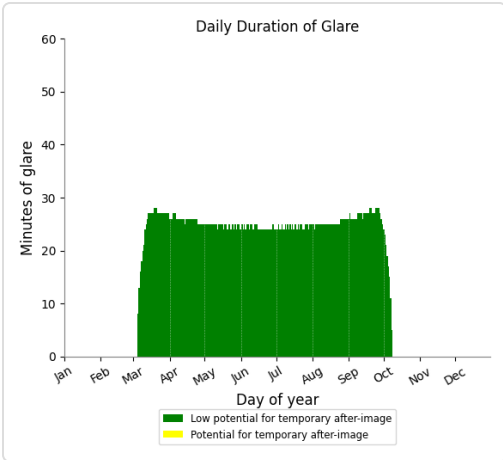0 minutes of green glare

Results for: Block6

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	1525	0
10 Runway	2208	0
16 Runway	3243	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
1525 minutes of green glare

Daily Duration of Glare

Flight Path: 10 Runway

0 minutes of yellow glare

2208 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 16 Runway

0 minutes of yellow glare

3243 minutes of green glare

Annual Predicted Glare Occurrence

Legend:
- Low potential for temporary after-image
- Potential for temporary after-image

Path Location vs. Time of Glare

Legend:
- Low potential for temporary after-image
- Potential for temporary after-image

Daily Duration of Glare

Legend:
- Low potential for temporary after-image
- Potential for temporary after-image
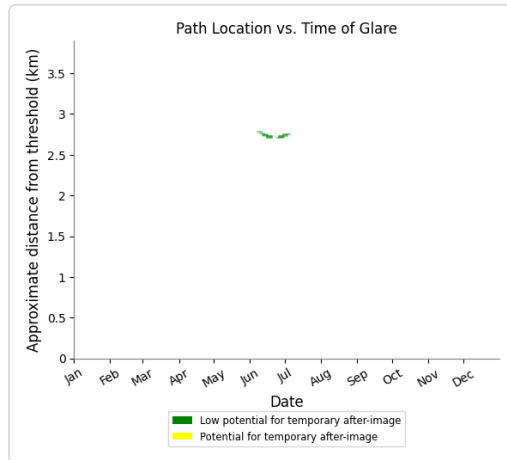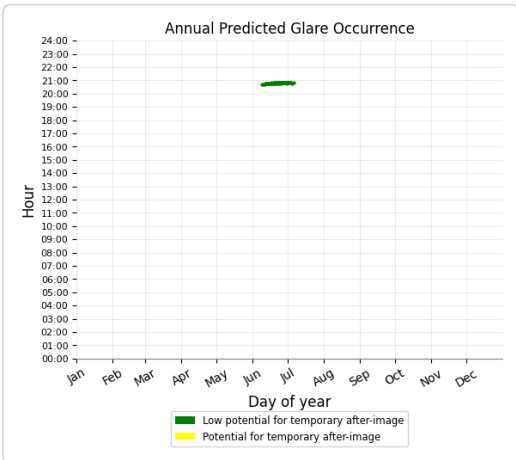
Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Block7

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	1268	0
10 Runway	0	0
16 Runway	5414	0
28R Runway	72	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
1268 minutes of green glare

Daily Duration of Glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
5414 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 28R Runway

0 minutes of yellow glare

72 minutes of green glare
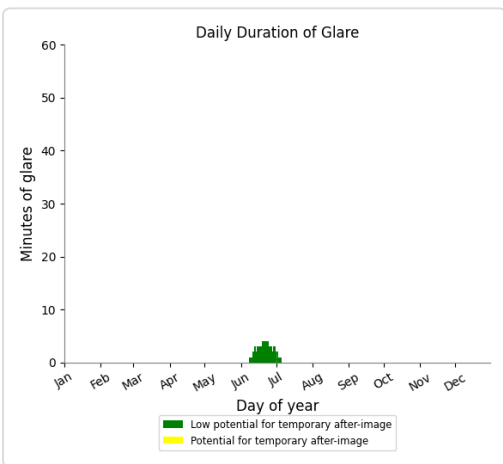
Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 28 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Block7 E

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
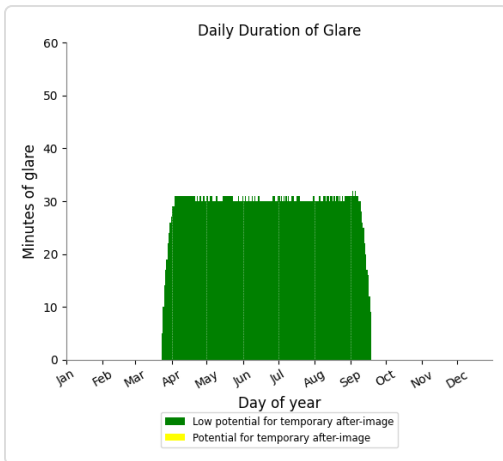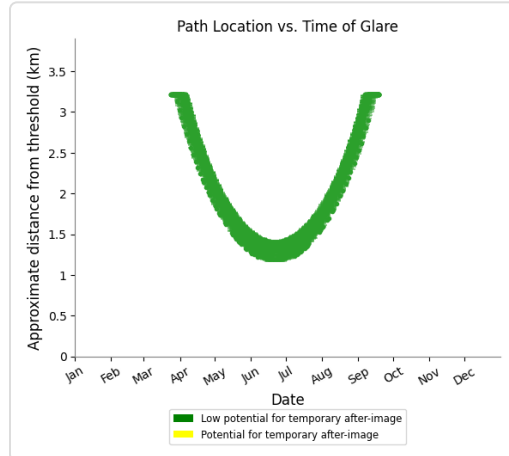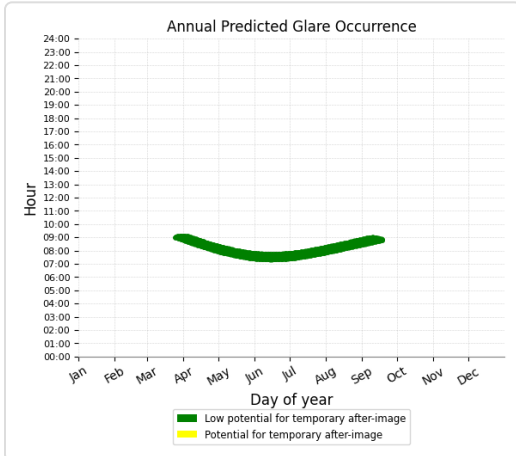0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Block7 W

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	5255	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
5255 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
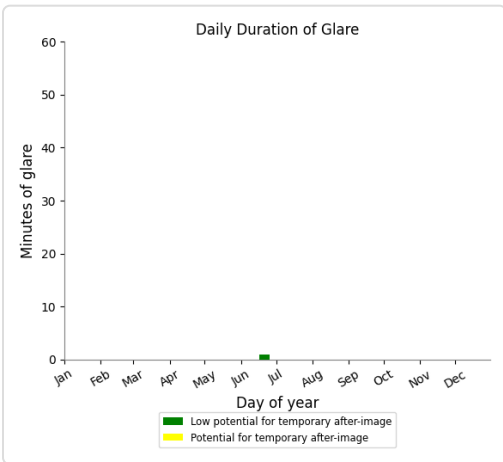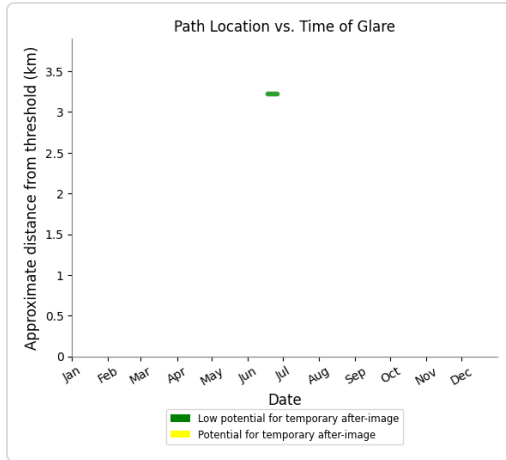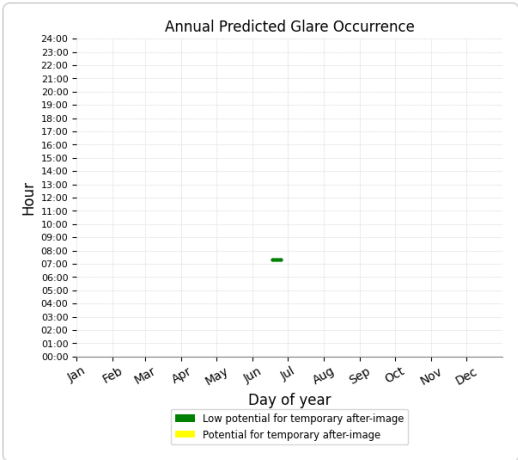0 minutes of green glare

Results for: Block8 E

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
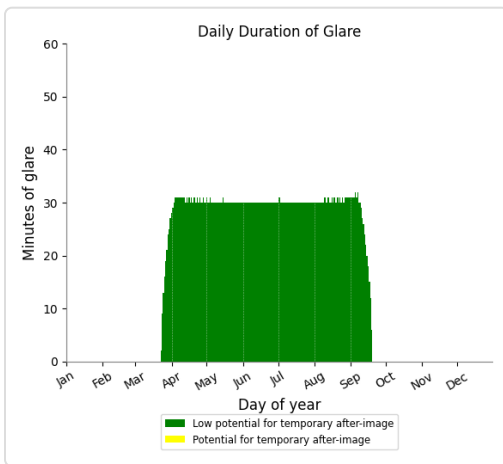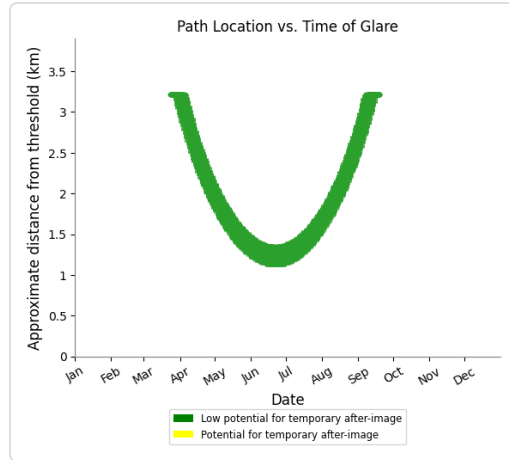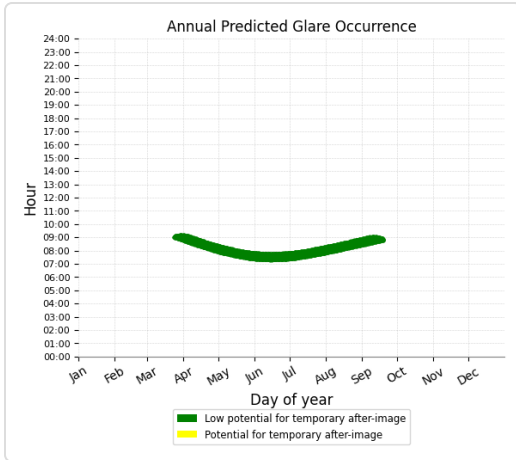0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Block8 W

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	9	0
10 Runway	0	0
16 Runway	5254	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
9 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway

0 minutes of yellow glare
5254 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT
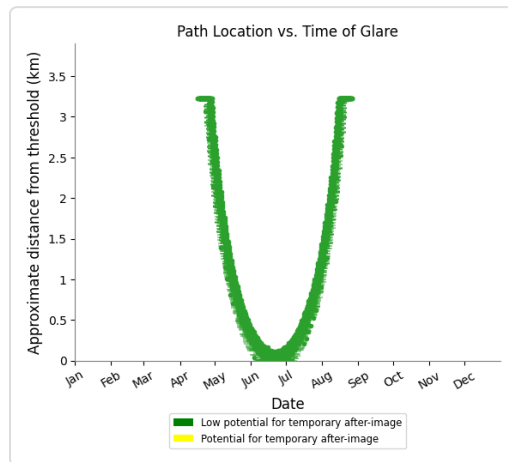
0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

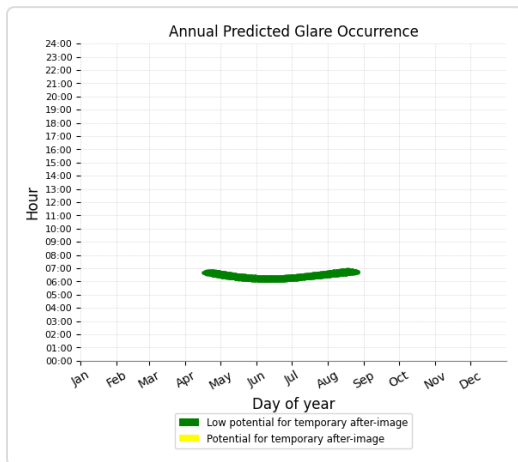0 minutes of yellow glare
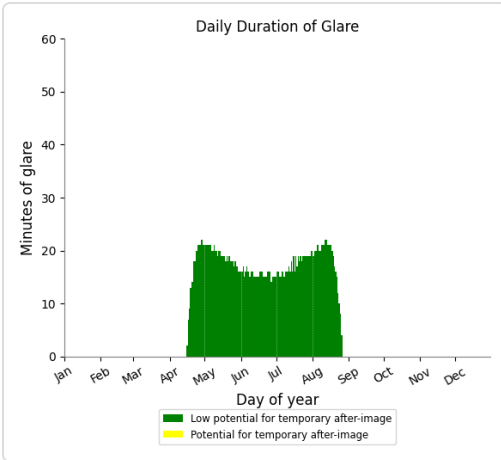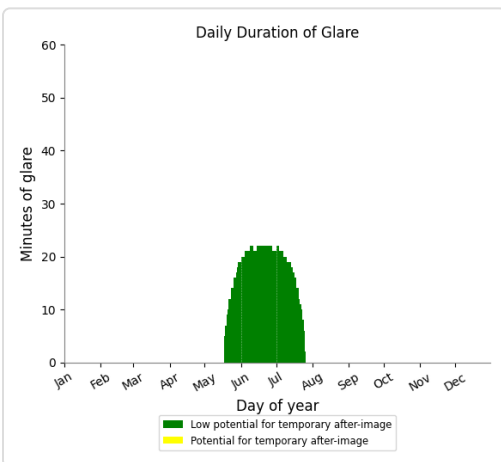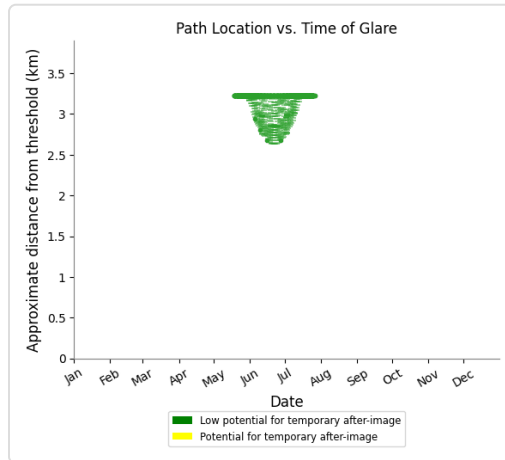0 minutes of green glare

Results for: Block9

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	2309	0
10 Runway	1257	0
16 Runway	5295	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0

Flight Path: 10L Runway

0 minutes of yellow glare
2309 minutes of green glare

Daily Duration of Glare

Flight Path: 10 Runway

0 minutes of yellow glare

1257 minutes of green glare

Annual Predicted Glare Occurrence

Path Location vs. Time of Glare

Daily Duration of Glare
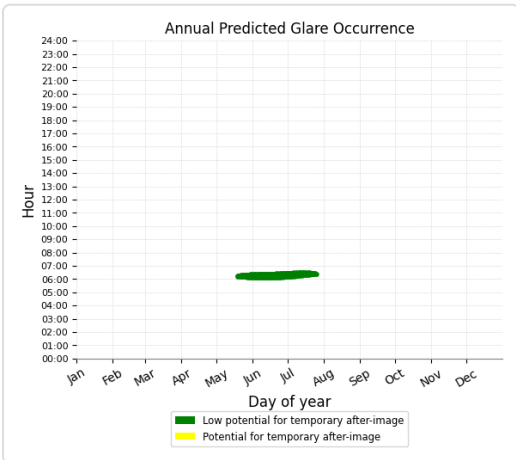
Flight Path: 16 Runway

0 minutes of yellow glare

5295 minutes of green glare

Annual Predicted Glare Occurrence

Low potential for temporary after-image
Potential for temporary after-image

Path Location vs. Time of Glare

Low potential for temporary after-image
Potential for temporary after-image

Daily Duration of Glare

Low potential for temporary after-image
Potential for temporary after-image

Flight Path: 28R Runway

0 minutes of yellow glare
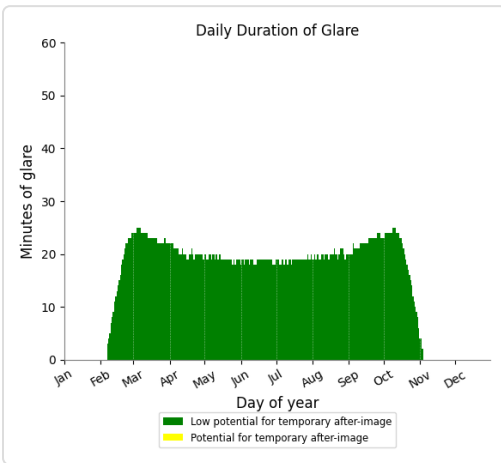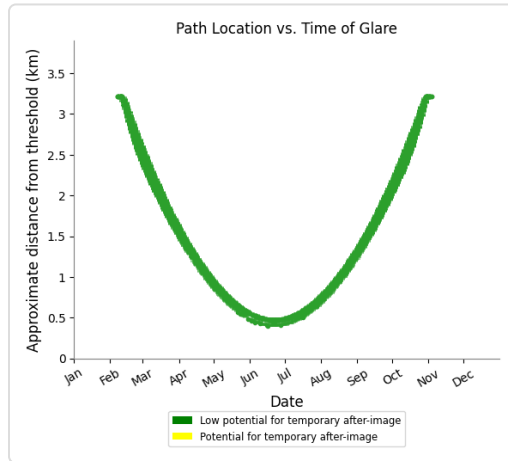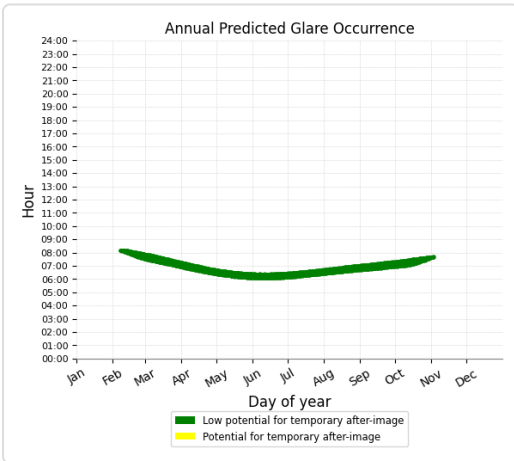0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.

"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.

Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.

Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.

Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to V1 algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.

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.)

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.

The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual results and glare occurrence may differ.

Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.

Refer to the Help page at **www.forgesolar.com/help/** for assumptions and limitations not listed here.