TAMINDA SOLAR FARM

Reflective and Illumination Glare

Prepared for:

ELTON Consulting
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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with ELTON Consulting (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.18521-R01-v1.0	18 December 2018	Dr Peter Georgiou	Peter Hayman	Dr Neihad Al-Khalidy

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) has been engaged by ELTON Consulting (ELTON) to carry out a Glare Impact Assessment for the proposed Taminda Solar Farm ("the Project"), a large-scale Solar Photovoltaic (PV) facility to be located adjacent to Tamworth Racecourse, Taminda, approximately 3 km west of the Tamworth central business district.

The 9 MWac facility will comprise 27,648 solar PV panels within a 7.72 ha project site area. The panels, measuring approximately 2.0 m by 1.0 m, will be positioned as currently understood on a proprietary mounting system, the "Belectric Pegging System" ("PEG Frame").

The following potential glare conditions have been considered:

- Daytime Reflective glare (and glint) arising from the solar PV panels within the facility; and
- Night-time Illumination glare from 24/7 operational security lighting within the facility.

In terms of potential glare scenarios, the following has been considered:

- Aviation Sector Reflective Glare; and
- Motorist "Disability" Reflective Glare and Pedestrian "Discomfort" Reflective Glare;
- Rail Operator Reflective Glare;
- Industrial (Critical Machinery) Operator (heavy vehicles, etc) Reflective Glare.
- Residential "Nuisance" Glare from daytime reflections or night-time illumination.

In all cases, the present study has found that the potential for adverse glare from the proposed facility will be minimal, with one potential exception. The lack of glare potential is due to a number of factors, including:

- The distances of receivers (aviation, motorist, rail, residential, etc) from the Project and their respective line of sight relative to solar reflections from the facility, as well as the presence of intervening buildings, vegetation, etc.

Although not formally required by any published criteria, a recommendation based on best practice has been made for a vertical barrier (ranging in height from 0.5 m to 1.5 m above ground level) running along the eastern perimeter of the Project site. This is to protect the amenity of Tamworth Racecourse operations.

There should be negligible impact from the 24/7 lighting required on the site for operational purposes, assuming the lighting design is in accordance with AS 4282-1997 *Control of the Obtrusive Effect of Outdoor Lighting*. This will also address any potential (though unlikely) adverse eco-lighting issues in relation to nocturnal fauna within and surrounding the site.

Once key Project decisions are finalised during detailed design (eg final panel selection, mounting details, etc), the present analysis should be re-visited to confirm the conclusions set out above if key assumptions made in the analysis change significantly.

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1 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been engaged by ELTON Consulting (ELTON) to carry out a Glare Impact Assessment for the proposed Taminda Solar Farm ("the Project"), a large-scale Solar Photovoltaic (PV) facility to be located adjacent to Tamworth Racecourse, Taminda, approximately 3 km west of the Tamworth central business district.

The following potential glare conditions have been considered:

- Daytime Reflective glare (and glint) arising from the solar PV panels within the facility; and
- Night-time Illumination glare from 24/7 operational security lighting within the facility.

1.1 Structure of Report

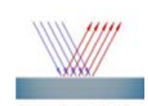
The remainder of this report is structured as follows:

- Section 2 describes the project and surrounding environment;
- Section 3 describes the range of receptors surrounding the site with the potential to experience adverse reflective glare (or glint);
- Section 4 presents the acceptability criteria used for the study;
- Section 5 addresses potential glare impacts from the project;
- Section 6 presents the conclusions of the study along with any associated recommendations.

1.2 Definitions and Terminology

A description of the common terminology used in this study, including illumination definitions taken from *AS 4282-1997 Control of the Obtrusive Effects of Outdoor Lighting* (AS 4282-1997) and *AS 1158.2-2005 Lighting for Roads and Public Spaces* (AS 1158.2-2005), is shown in **Table 1**.

Table 1 Definitions and Lighting Terminology (Consistent with AS 4282-1997 & AS 1158.2-2005)

Terms relevant to Daytime Reflective Glare		
PV Panel	Photovoltaic (PV) panels are designed to absorb solar energy and retain as much of the solar spectrum as possible in order to produce electricity	
Glare	Glare refers to the reflections of the sun off any reflective surface, experienced as a source of excessive brightness relative to the surrounding diffused lighting. Glare covers reflections experienced by both stationary and moving observers (the latter sometimes referred to as "glint") and reflections which are either specular or diffuse	
Specular	A reflection which is essentially mirror-like – there is virtually no loss of intensity or angle dispersion between the incoming solar ray and outgoing reflection	

Diffuse	A reflection in which the outgoing reflected rays are dispersed over a wide ("diffuse") range of angle compared to the incoming (parallel) solar rays, typical of "rougher" surfaces  Diffuse Reflection
KVP	Key View Points (KVPs) are offsite locations where receivers of interest have the potential to experience adverse reflective glare
Terms relevant to Night-Time Illumination	
Obtrusive light	Spill light which, because of quantitative, directional or spectral attributes in a given context, gives rise to annoyance, discomfort, distraction or a reduction in the ability to see essential information, e.g. traffic lights.
Spill light	Light emitted by a lighting installation which falls outside the boundaries of the property on which the installation is sited.
Residential property	Land upon which a dwelling exists or may be developed, e.g. land zoned for residential development.
Dwelling	A building in which people normally reside, especially during the hours of darkness, e.g. house, hotel, motel, hospital.
Luminaire	Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except for the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary circuit auxiliaries together with the means for connecting them to the electrical supply.
Luminous intensity	The concentration of luminous flux emitted in a specific direction. Unit: candela (Cd).
Luminance **AS 1158.2:2005**	This is the physical quantity corresponding to the brightness of a surface (e.g. a lamp, luminaire or reflecting material such as façade glazing) when viewed from a specified direction. Unit: Cd/m^2
Illuminance **AS 1158.2:2005**	This is the physical measure of illumination. It is the luminous flux arriving at a surface divided by the area of the illuminated surface – the unit is lux (lx) … 1 lx = 1 lm/m^2 The term covers both "Horizontal Illuminance" (the value of illuminance on a designated horizontal plane at ground level) and "Vertical Illuminance" (the value of illuminance on a designated vertical plane at a height of 1.5m above ground level).
Glare **AS 1158.2:2005**	Condition of vision in which there is a discomfort or a reduction in the ability to see, or both, caused by an unsuitable distribution or range of luminance, or to extreme contrast in the field of vision. Glare can include: (a) Disability Glare – glare that impairs the visibility of objects without necessarily causing discomfort. (b) Discomfort Glare – glare that causes discomfort without necessarily impairing the visibility of objects.
Threshold Increment (TI) **AS 4282-1997**	TI is the measure of disability glare expressed as the percentage increase in contrast required between an object and its background for it to be seen equally well with a source of glare present. Higher TI values correspond to greater disability glare.

2 PROPOSED TAMINDA SOLAR FARM PROJECT

2.1 Site Description

The Project will be seeking approval for a 9 MWac photovoltaic (PV) solar plant occupying a 7.72 ha area as shown in **Figure 1**.

The proposed land area of the solar farm has been dictated by the solar farm panel quantity needed to meet the 9 MWac capacity and has been subject to various studies and flood modelling.

Figure 1 Taminda Solar Farm Project - Location Map

In relation to **daytime** reflective glare impact, the Project contains the following elements of interest:

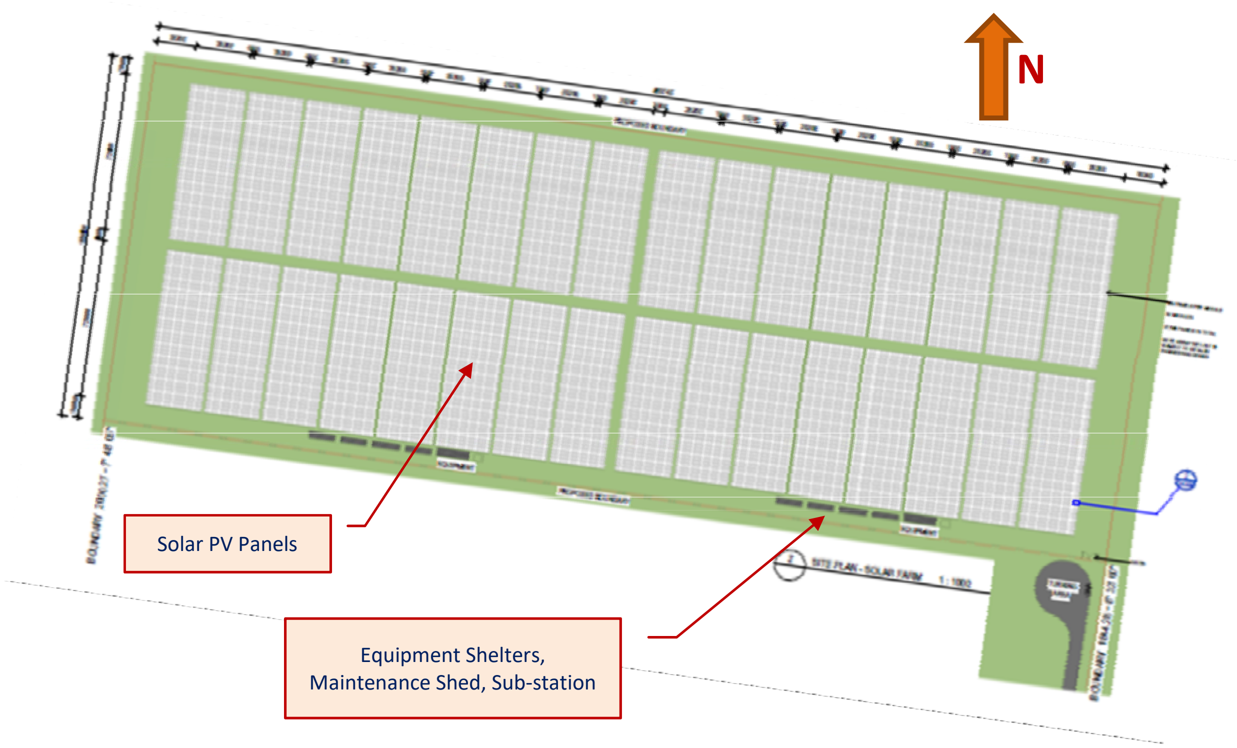
- PV modules using solar panels.

In relation to **night-time** illumination glare impact, the Project contains the following elements of interest:

- Whilst car access into the facility boundary is discouraged, clearance to enable site maintenance, access in case of fire, etc, is required; and
- A control building, maintenance building and substation will be built to facilitate connection to the local grid network.

An indicative site layout for the 9 MWac Project is presented in **Figure 2**.

Figure 2 Taminda Solar Farm Project - Indicative Layout Diagram



2.2 Key Project Components

The key components of the Project from a glare point of view are:

- the photovoltaic (PV) modules in relation to daytime reflective glare; and
- the facility's security/emergency lighting design in relation to night-time illumination glare.

Solar Modules

The Project will utilise 27,648 panels arranged in 32 rectangular grids each measuring 25.2 m by 72 m.

It is expected the Project will use polycrystalline silicon modules approximately 1 m wide by 2 m long. These are standard flat solar panels, essentially the same as deployed on residential properties. They convert energy from the sun into DC electric current that is collected by a DC reticulation system. The final selection of solar module will be made after a techno-economic evaluation during the detailed design phase of the project.

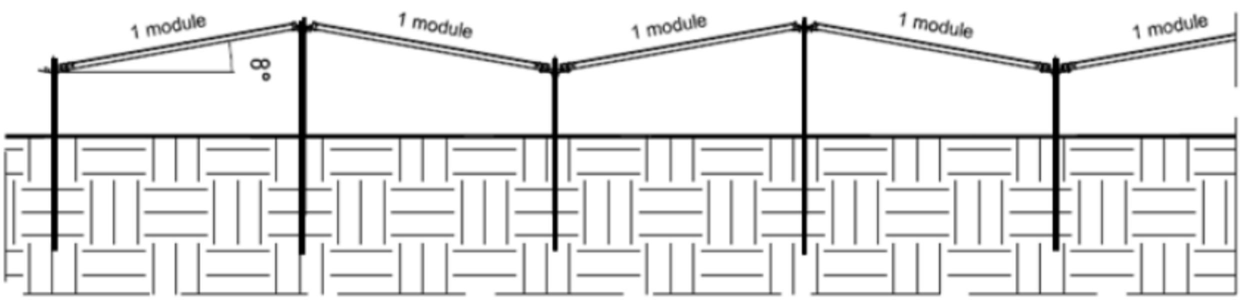
Solar Panel Mounting System

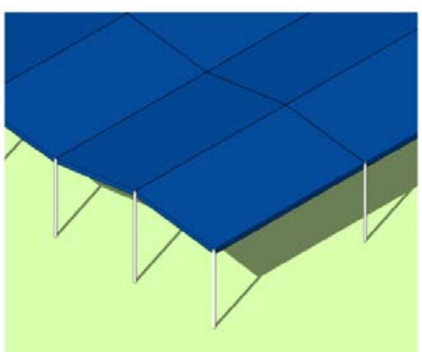
The solar modules will be mounted on a proprietary system known as the "PEG Frame" (Belectric Pegging) mounting system, as illustrated in **Figure 3**.

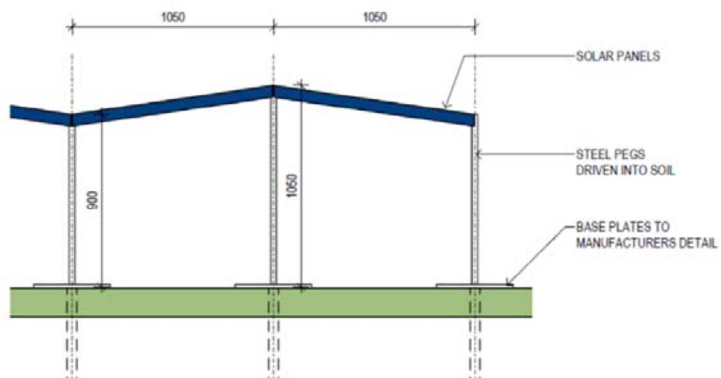
- Pairs of solar panels are mounted on an alternate height framing system as shown in **Figure 3**.
- The primary axis of the PEG Frame (i.e. the main inter-panel ridge lines) will be oriented approximately 8° east of north.
- As a result, half of the panels will have an inclination of approximately 8° in one direction (in this case roughly eastwards) with the other half having an inclination of approximately 8° in the opposite direction (in this case roughly westwards).

Figure 3 PEG Frame System

Vertical cross-sections through PEG Frame System







Panel Installation
(looking northwards)

3 RECEIVERS AND ASSOCIATED IMPACTS

3.1 Receiver Impacts

The issues of concern in relation to daytime reflective glare and night-time illumination glare and the associated receivers of interest are detailed below.

Aircraft and helicopter pilots and airport control tower operators

There have been several documented cases globally, none in Australia, of solar panel installations at airports interfering with Control Tower operations. There is the added potential for reflective glare to impact on pilots especially during the latter approach stages of landing when the line of sight of the pilot is directed downwards.

Motorists using the nearby road network

The issue of concern here is the potential occurrence of Traffic Disability Glare, which most often arises from incoming solar rays striking a reflective surface at a moderately high ("glancing") incident angle (typically greater than 70˚) and an altitude angle less than 25˚ (altitude angles greater than this would be intersected and obstructed by a typical windscreen roof-line).

Train drivers using the nearby rail network

The issue of concern here is the potential impact of reflective glare interfering with or distracting a train operator's activities or the potential for reflections to obscure railway signals.

Industrial critical machinery operators (draglines, heavy trucks, etc)

The issue of concern here is the potential impact of reflective glare interfering with or distracting the operators of critical industrial machinery.

Residents surrounding the project

The issue of concern here is the potential "nuisance" caused by extended periods of reflective glare.

Nearest neighbours may also be impacted by light spill from night-time illumination.

3.2 Nearest Receiver Locations

Receivers of interest relevant to the Project are shown in …

Figure 4 Nearest airfield(s);

Figure 5 Surrounding road network;

Figure 6 Surrounding rail network; and

Figure 7 Nearest representative residential receivers.

Figure 4 Surrounding Airfield(s) – Tamworth Regional Airport

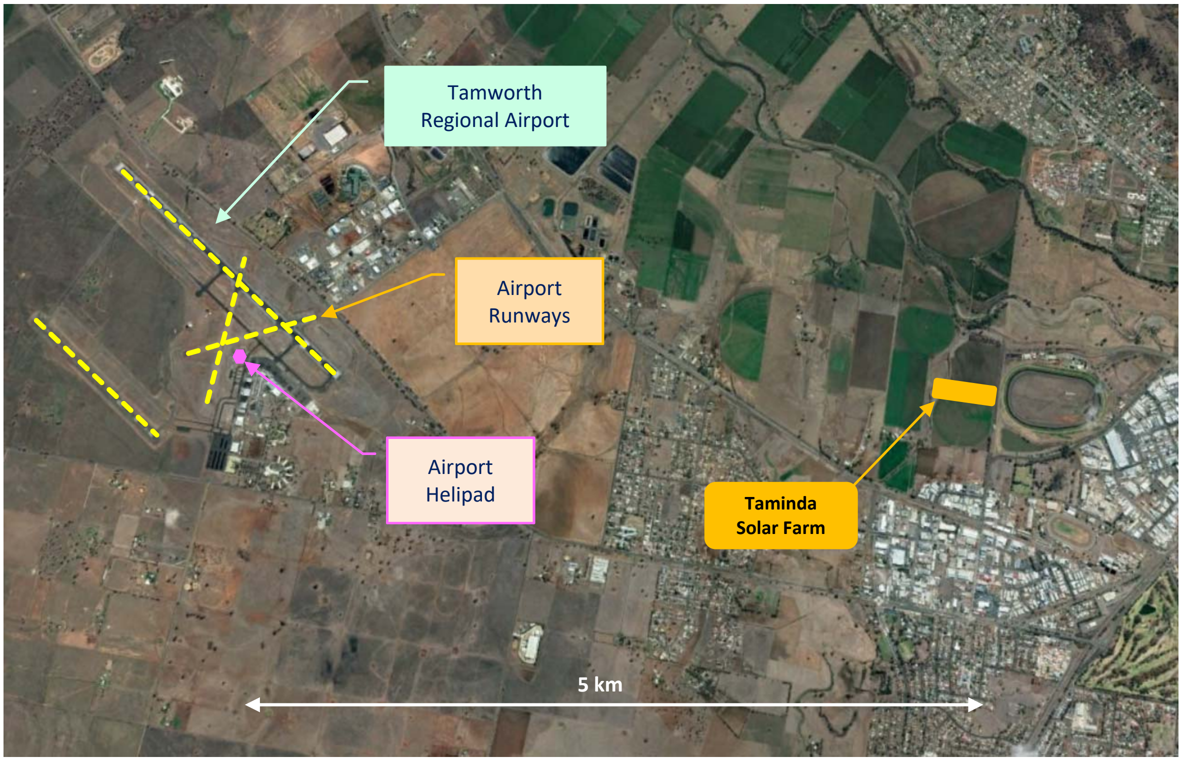


Figure 5 Surrounding Road Network

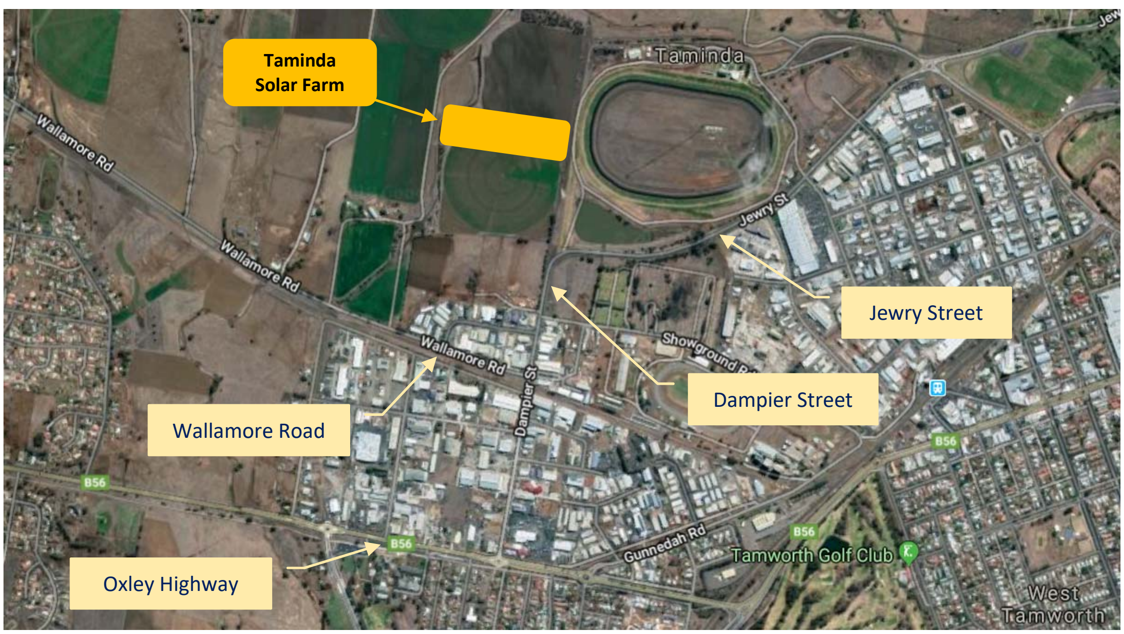


Figure 6 Surrounding Rail Network

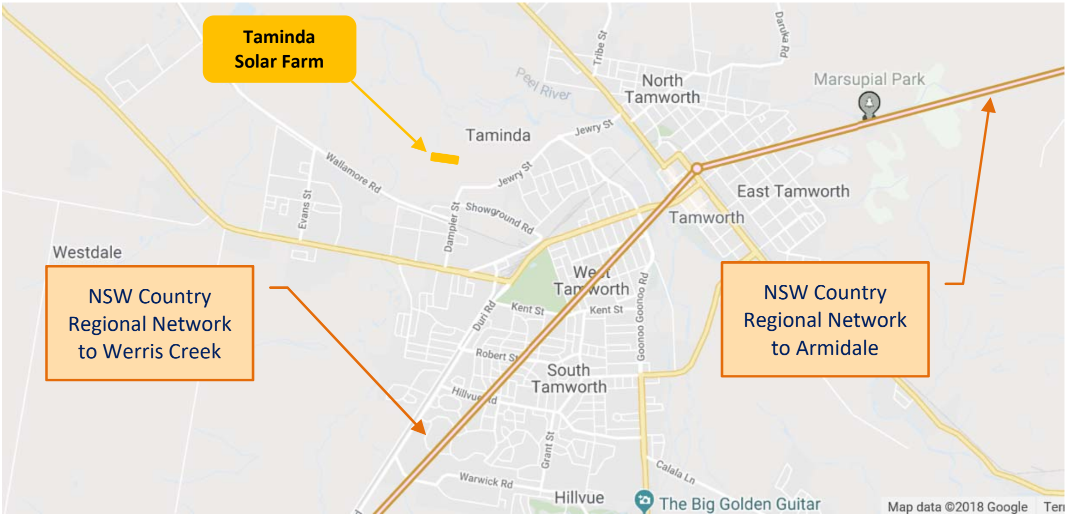
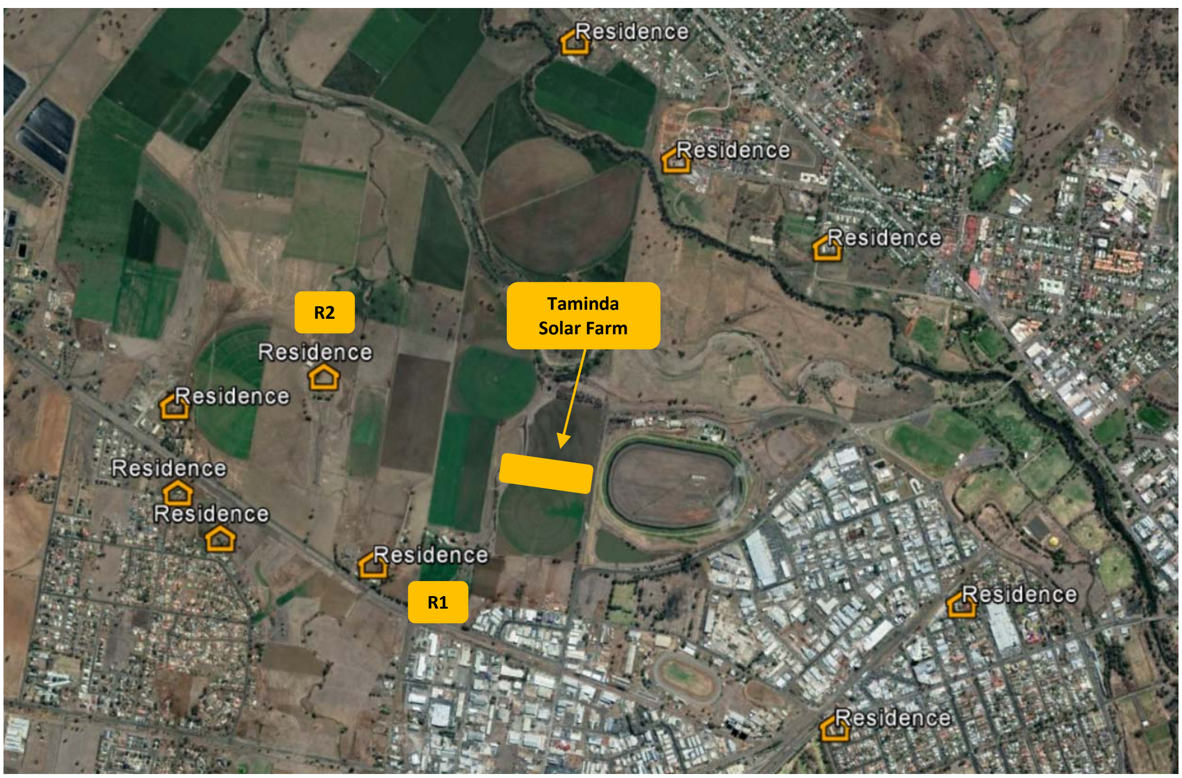


Figure 7 Nearest Representative Residential Receivers



4 GLARE ACCEPTABILITY CRITERIA

4.1 Aviation Sector Reflective Glare

The impact of solar PV systems on aviation activity is something that solar developers today are addressing more and more often, given the (global) proliferation of solar projects located either within or around airport precincts.

Guidance in this area is available from two sources – UK CAA and US FAA.

US FAA

The reader is referred to the following technical references:

- Brumleve (various, 1976-1984), Ho, Ghanbari & Diver (2009, 2010) and Ho & Khalsa (2010)

The FAA regulates and oversees all aspects of American civil aviation. On the basis of the above and other technical R&D references, the FAA issued a Technical Guidance Policy in 2010 and a subsequent (and over-riding) Interim Policy in 2013.

- FAA, *"Technical Guidance for Evaluating Selected Solar Technologies on Airports"*, Federal Aviation Administration, Washington, D.C., November 2010.
- FAA, *"Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports"* Federal Register, Oct. 23, 2013,

In support of the above, the FAA contracted Sandia Labs to develop their **Solar Glare Hazard Analysis Tool** (SGHAT) software tool as the standard for measuring the potential ocular impact of any proposed solar facility on a federally obligated airport. SGHAT utilises the Solar Glare Ocular Hazard Plot to determine and assess the potential for glare. The SGHAT Tool – refer example in **Figure 8** - is described in the following technical reference:

- Ho, C. & Sims, C., *"Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v2.0"*, Sandia National Laboratories, Albuquerque, NM. August 2013.

The criteria specifically state that a proposed solar facility should not create potential for glint or glare (or "after-image") …

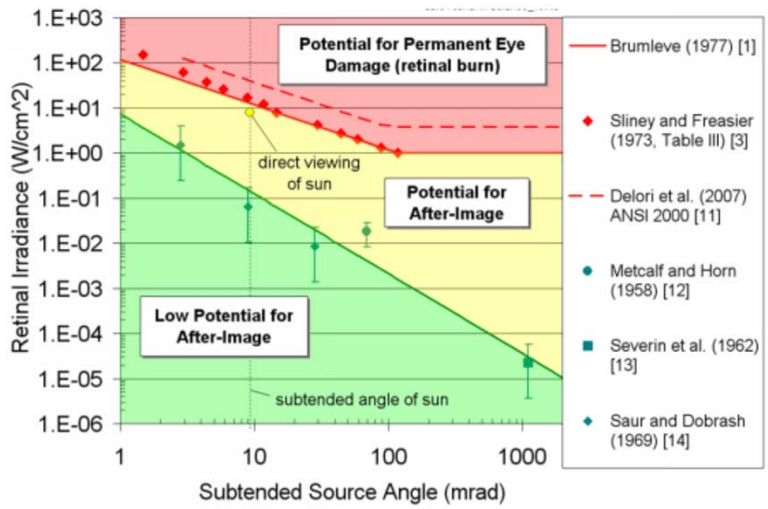
  - in the existing or planned airport traffic control tower (ATCT) cab; or
  - along the final approach path for any existing or future landing thresholds.

As part of the analysis, ocular impact must be examined over the entire calendar year in 1-minute intervals, from sunrise to sunset.

A sample Ocular Hazard Plot is shown in **Figure 8** along with reference sources which contributed to the delineation of various hazard "zones".

For final approach flight paths, an SGHAT analysis result in the "Green" ("Low Potential") zone is deemed acceptable by the FAA. There should be NIL glare for the Aircraft Control Tower.

Figure 8 Example Solar Glare Ocular Plot (SGHAT Software Output)



4.2 Motorist "Disability" Glare and Pedestrian "Discomfort" Glare

The criteria commonly used by Local Government Authorities to assess the acceptability or otherwise of road traffic glare events utilise the so-called **Threshold Increment** (TI) Value of the reflection condition (refer **Table 1**). These acceptability criteria were originally developed to address adverse reflections from the glass curtain wall façade systems of medium and high-rise buildings located close to road carriageways.

- For (Motorist) Traffic Disability Glare, the TI Value should remain:
  - Below 10 for major roads
  - Below 20 for minor roads
- For Pedestrian Discomfort Glare, the TI Value should remain:
  - Below 2 at critical locations such as pedestrian crossings
  - Below 3 for other locations

The TI Value is calculated as the ratio of "veiling" luminance to the overall average carriageway luminance, with the necessary constant and exponent parameters provided in AS 1158.2:2005.

4.3 Rail Operators Reflective Glare

Almost all Australian Rail Authorities have guidelines covering glare in general (ie not specific to solar PV panel glare) aimed at avoiding discomfort/distraction to train operators and obscuring train signals. Most guidelines refer either to Table 2.10 of AS 1158.3.1 for the TI Value criterion and/or Table 3.2 of AS 1158.4 for the Cd (Candela) criterion associated with the control of glare.

- For Rail Traffic Disability Glare, the relevant AS1158 criteria are:
  - The TI Value should remain below 20%
  - The Cd Value at 70° incidence should remain below 6,000.

4.4 Residential "Nuisance" Glare

Instances of documented nuisance glare associated with solar PV panels (grid-scale, industrial or residential) and nearby residential receivers have been relatively infrequent globally, especially given the widespread and rapid increase in the take-up of residential solar panels in Australia and elsewhere.

There are currently no national or state guidelines in Australia governing the acceptability or otherwise of nuisance glare specific to solar PV, although the concepts used for glare acceptability criteria in the preceding sections can assist when dealing with this issue.

The guidance that exists in relation to solar panels from the NSW Government covers installation audits and compliance checks:

NSW Fair Trading
website: www.fairtrading.nsw.gov.au

Additional guidance in relation to compliance with Australia Standards is provided by:

Clean Energy Council
website: www.cleanenergycouncil.org.au

4.5 Industrial Critical Machinery Operations

There are currently no (Australian) national or state guidelines governing the acceptability or otherwise of reflective glare for industrial site critical operations. Instead, the concepts used for acceptability criteria in the preceding sections, in particular Traffic Disability Glare, can assist when dealing with this issue.

The issue most commonly arises in relation to mining operations where machinery operators can be located in elevated locations, eg dragline operations, where a line of sight may be possible to a solar facility located in very close proximity. Ports with their observation towers are another potential source of elevated receivers of interest if located adjacent to a solar facility.

No such industrial operations exist in the present case.

4.6 Observation Regarding Daytime Solar Reflections

One of the challenging issues encountered with daytime solar panel glare is the varying nature of the reflections, whose duration will vary with time of day and day of the year as the sun's rays follow variable incoming angles between the two extremes of …

- summer solstice - sunrise incoming rays from just south of east, maximum angle altitude rays at midday, sunset incoming rays from just south of west
- winter solstice - sunrise incoming rays from the northeast, minimum angle altitude rays at midday, sunset incoming rays from the northwest

Any solar glare analysis must take into account the complete cycle of annual reflection variations noted above.

4.7 Night-Time Illumination Glare

The effect of light spill from outdoor lighting impacting on residents, transport users, transport signalling systems and astronomical observations is governed by AS 4282-1997.

The adverse effects of light spill from outdoor lighting are influenced by a number of factors:

- The topology of the area. Light spill is more likely to be perceived as obtrusive if the lighting installation is located higher up than the observer. Lighting installations are usually directed towards the ground and an observer could hence have a direct view of the luminaire.
- The surrounding area. Hills, trees, buildings, fences and general vegetation have a positive effect by shielding the observer from the light installation.
- Pre-existing lighting in the area. Light from a particular light source is seen as less obtrusive if it is located in an area where the lighting levels are already high, eg in cities. The same lighting installation would be seen as far more bothersome in a less well-lit residential area.
- The zoning of the area. A residential area is seen as more sensitive compared to commercial areas where high lighting levels are seen as more acceptable.

Typical illuminance levels for a variety of circumstances are given in **Table 2** for comparison.

Table 2 Typical Illuminance Levels for Various Scenarios

Lighting Scenario	Horizontal Illuminance (lux)
Moonless overcast night	0.0001
Quarter Moon	0.01
Full Moon	0.1
Twilight	10
Indoor office	300
Overcast day	1,000
Indirect sunlight clear day	10,000-20,000
Direct sunlight	100,000-130,000

Recommended criteria of light technical parameters for the control of obtrusive lighting are given in **Table 3**. The vertical illuminance limits for *curfew hours* apply in the plane of the windows of habitable rooms or dwellings on nearby residential properties. The vertical illuminance criteria for *pre-curfew hours* apply at the boundary of nearby residential properties in a vertical plane parallel to the boundary.

Values given are for the direct component of illuminance, i.e. no reflected light is taken into account.

- Limits for luminous intensity for *curfew hours* apply in directions where views of bright surfaces of luminaires are likely to be troublesome to residents, from positions where such views are likely to be maintained.
- Limits for luminous intensity for *pre-curfew* hours apply to each luminaire in the principal plane, for all angles at and above the control direction.

Table 3 Recommended Maximum Values of Light Technical Parameters (AS4282-1997)

Light Technical Parameter	Time of Operation	Commercial Areas	Residential Areas	
			Light Surrounds	Dark Surrounds
Illuminance in vertical plane (E_v)	Pre-curfew hours	25 lx	10 lx	**10 lx**
	Curfew hours	4 lx	2 lx	**1 lx**
Luminous Intensity emitted by luminaires (I)	Pre-curfew hours	7,500 Cd (for a medium to large area with Level 1 control)	100,000 Cd (for a large area with Level 1 control)	100,000 Cd (for a large area with Level 1 control)
	Curfew hours	2,500 Cd	1,000 Cd	500 Cd

The Project is located within the greater Tamworth area and has the potential to impact on surrounding residential properties – refer **Figure 7**. While these properties are also located within the greater Tamworth area, a number of them are positioned adjacent to rural lands and would therefore be classed as being in a residential area with "Dark Surrounds" (refer **Table 3**).

The applicable limits for adverse spill light will depend on the time of operation for the lighting installation.

For the Project, it is understood that internal access roads and the main equipment buildings in particular, will be required for operational 24/7 access for security, emergency access and maintenance purposes, suggesting the application of the more restrictive limit relevant to *curfew hours*.

Accordingly:

- Light spill from the Project onto the facades of the surrounding residential dwellings should be kept below 1 lux during curfew hours

Finally, it has been known for some time that night-time artificial lighting has the potential to disrupt the natural behaviour of nocturnal fauna species such as arboreal mammals, large forest owls and microbats. The standards mentioned above do not contain limiting lux levels in relation to the mitigation of such eco-lighting impacts. Mitigation recommendations in relation to adverse eco-lighting therefore centre on feasible night-time lighting minimisation, bearing in mind the provision of appropriate health and safety and security conditions given the nature of the site.

5 GLARE IMPACT ASSESSMENT

5.1 Assumptions

The glare assessment discussed in detail in following sections is based on the following assumptions:

- The Project will use the "PEG Frame System" described in **Section 2.2.** The PEG system has its main ("ridge line") axis running 8° east of north.
- The maximum height of the panels will be approximately 1.05 m above ground level.
- As noted previously, pairs of solar panels are mounted on an alternate height framing system. As a result half of the panels will have an inclination of approximately 8° in one direction (in this case roughly eastwards) with the other (alternating) half having an inclination of approximately 8° in the opposite direction (in this case roughly westwards).
- Accordingly, the present assessment has adopted a conservative approach to the analysis of potential solar panel reflections by assuming TWO "worst-case" scenarios.
- The "East" scenario assumes that ALL of the panels have an inclination of 8° directed eastwards (precisely 8° south of east.
- The "West" scenario assumes that ALL of the panels have an inclination of 8° directed westwards (precisely 8° north of west).

5.2 Solar Panel Reflectivity

Solar PV panels are designed to capture (absorb) the maximum possible amount of light within the layers below the front (external) surface. As a consequence, solar PV panels are designed to minimise reflections off the surface of each panel. Reflections are a function of:

- the angle at which the light is incident onto the panel (which will vary depending on the specific location, time of day and day of the year), and
- the index of refraction of the front surface of the panel and associated degree of diffuse (non-directional) versus specular (directional or mirror-like) reflection which is a function of surface texture of the front module (reflecting) surface.

Some typical reflectivity values (given in terms of the "n" refractive index value) are:

- Snow (fresh, flaky) n = 1.98
- Standard Window Glass n = 1.52
- Plexiglass, Perspex n = 1.50
- Solar Glass n = 1.33
- Solar Glass with AR Coating n = 1.25

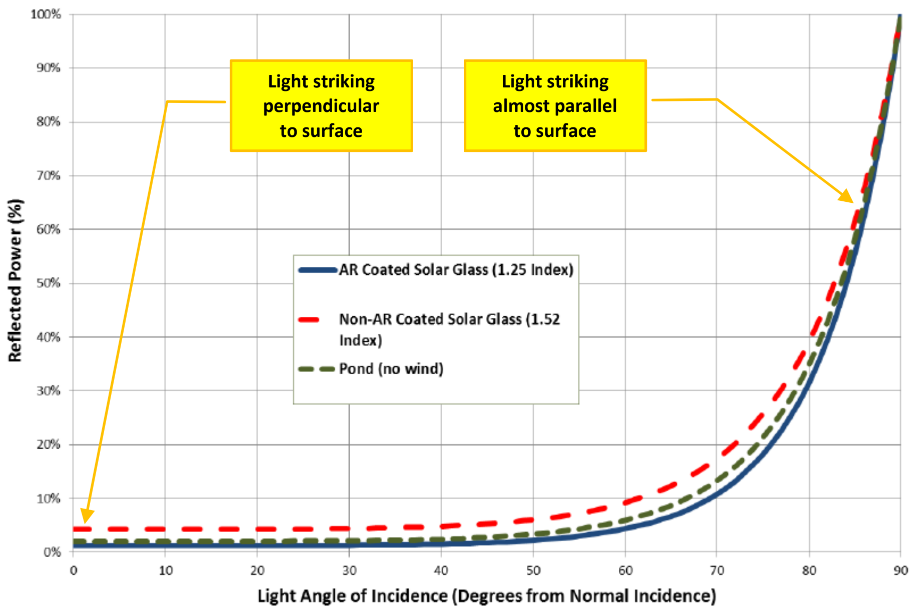
Standard Solar Panels (Solar Glass; Solar Glass with AR Coating)

Representative reflectivity curves are shown in **Figure 9**:

- When an oncoming solar ray strikes the surface of a solar PV panel close to perpendicular to the panel surface (i.e. low "incident" angle), the reflectivity percentage is minimal (less than 5% for all solar panel surface types).

- It is only when an incoming solar ray strikes the panel at a large "incidence" angle, i.e. almost parallel to the panel, that reflectivity values increase. When this happens, reflections become noticeable and potentially at "glare" level for all solar panel surface types. However, in such instances and in particular in the case of motorists, pedestrians, train drivers, etc, it would almost always be the case that the observer would perceive reflections coming from virtually the same direction as the incoming solar rays themselves. Such a condition would not constitute a glare situation as the incoming solar ray intensity would dominate the field of vision perceived by the observer.

Figure 9 Typical Reflectivity Curves as a Function of Incidence Angle



5.3 Tamworth Solar Angles – Annual Variations

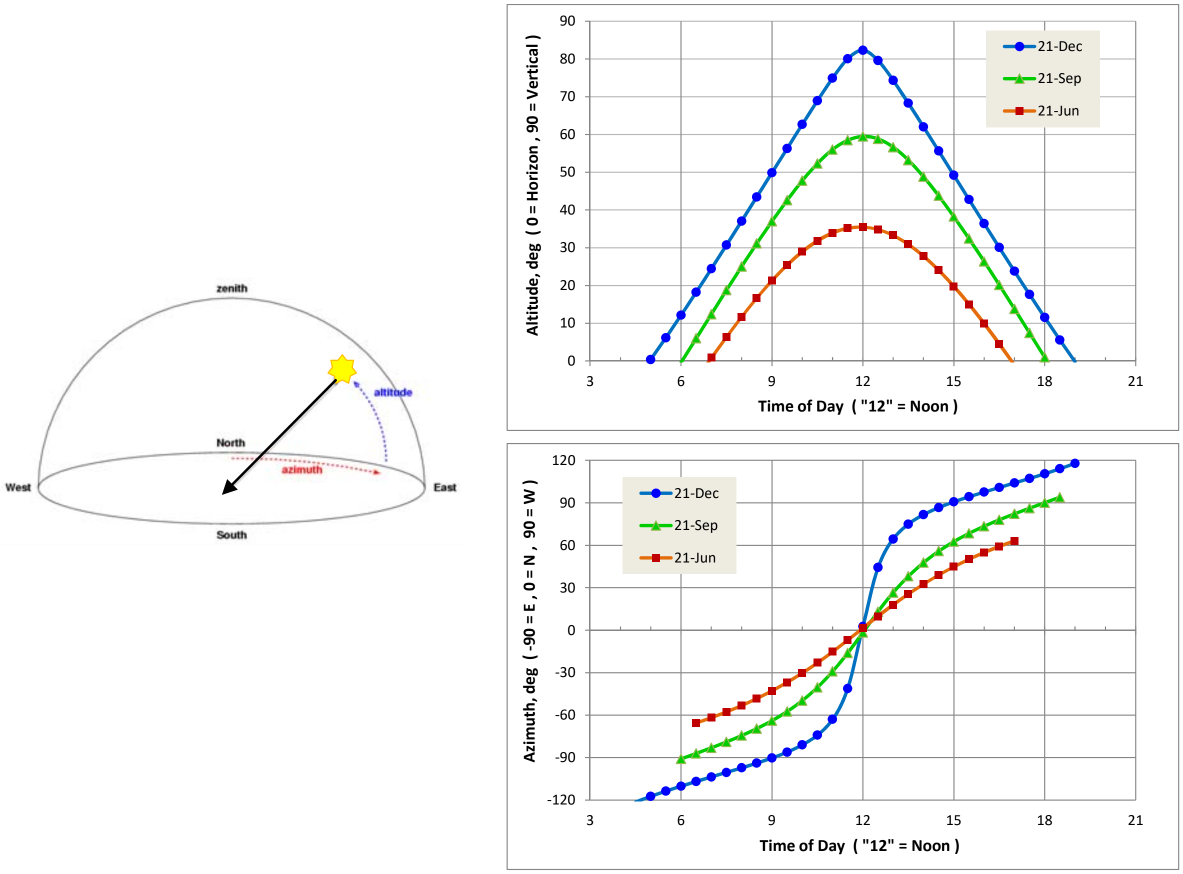
The potential range of incoming solar angles at Tamworth relevant to daytime glare are shown in **Figure 10** with relevant critical angles summarised in **Table 4**.

Table 4 Key Annual Solar Angle Characteristics for Tamworth

Day of Year	Sunrise	Sunset	Azimuth Range	Highest Altitude
Summer Solstice	5:58 am [1]	7:59 pm [1]	118° E of North to 118° W of North	82°
Equinox	6:02 am	6:05 pm	90° DUE EAST to 90° DUE WEST	59.5°
Winter Solstice	6:55 am	4.54 pm	62° E of North to 62° W of North	35.5°

Note 1: Time takes into account Eastern Daylight Savings Time

Figure 10 Tamworth Incoming Solar Angle Variations



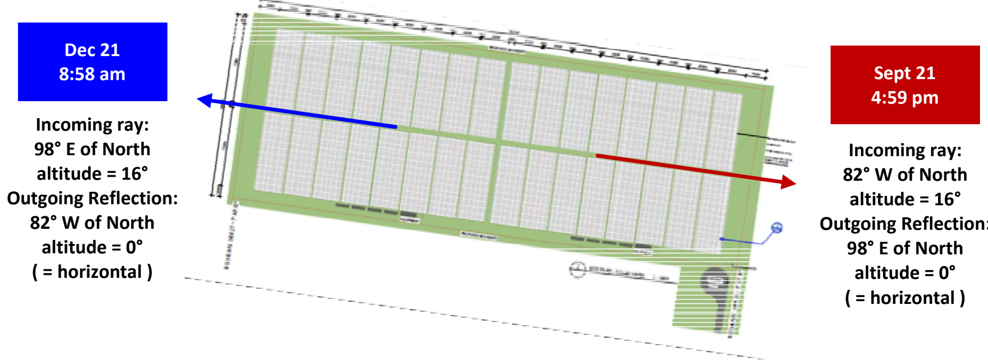
5.4 Project Solar Reflections

As a result of the panel mounting system and the fixed eastwards and westwards inclination of the panels, solar reflections throughout the year will have the potential to be directed downstream of the facility in a particular direction with a range of reflection angles directed upwards, downwards and horizontally. Accordingly, solar reflections will have the potential to be visible by ground-based receivers (traffic and residences) as well as elevated receivers (aviation).

Two examples of potential ground level receiver occurrences are shown in **Figure 11**:

- On the summer solstice, incoming morning rays (arriving from 98° east of north) would be reflected by the facility’s west-inclined panels horizontally towards 82° west of north. These reflections would be potentially noticeable by a downstream stationary receiver for approximately a minute.
- On either of the two equinox days of the year, incoming afternoon rays (arriving from 82° west of north) would be reflected by the facility’s east-inclined panels horizontally towards 98° east of north. These reflections would be potentially noticeable by a downstream stationary receiver for approximately a minute.

Figure 11 Example Solar Angles Generating Horizontal Reflections Downstream of Facility



5.5 Aviation Sector Reflective Glare

Tamworth Regional Airport (IATA: TWM, ICAO: YSTW) is the nearest major airport servicing the area. It is located approximately 5 km west of the Project. The airport is serviced by QANTASLINK (Eastern Australia Airlines) and VIRGIN, as well as general aviation aircraft and helicopters.

- The main 2,200 m long asphalt Runway 12L/30R is oriented roughly northwest-southeast.
- A secondary 1,110 m long asphalt Runway 12R/30L is located 1 km southwest of 12L/30R.
- The airport has two secondary runways: the 1,020 m grass-clay Runway 18/16, oriented roughly north-south and the 842 m grass-clay Runway 06/24, oriented roughly southwest-northeast.

Figure 4 (p.12) shows that none of the airport's four runways is in a direct line of sight towards the Project.

However, there is potential for aircraft approaching some of the runways to have a curved flight track that would see them at least partially in a direct line of sight of the Project prior to their final approach path.

Helicopter flight paths can be highly variable and landing approach paths in the direct line of sight of the Project are possible.

Accordingly, a quantitative analysis was carried out using the Sandia Labs Solar Glare Hazard Analysis Tool (SGHAT) software tool to examine potential worst-case scenario flight path approaches and take-offs and their ability to create adverse and unacceptable glare (and glint) conditions.

- The aircraft flight paths are all for landing scenarios (worst-case with the pilot looking downwards);
- The helicopter flight paths are for both landing and take-off in the same direction (as required by the SGHAT analysis protocol).

As previously noted, a conservative approach was taken by looking at TWO panel scenarios:

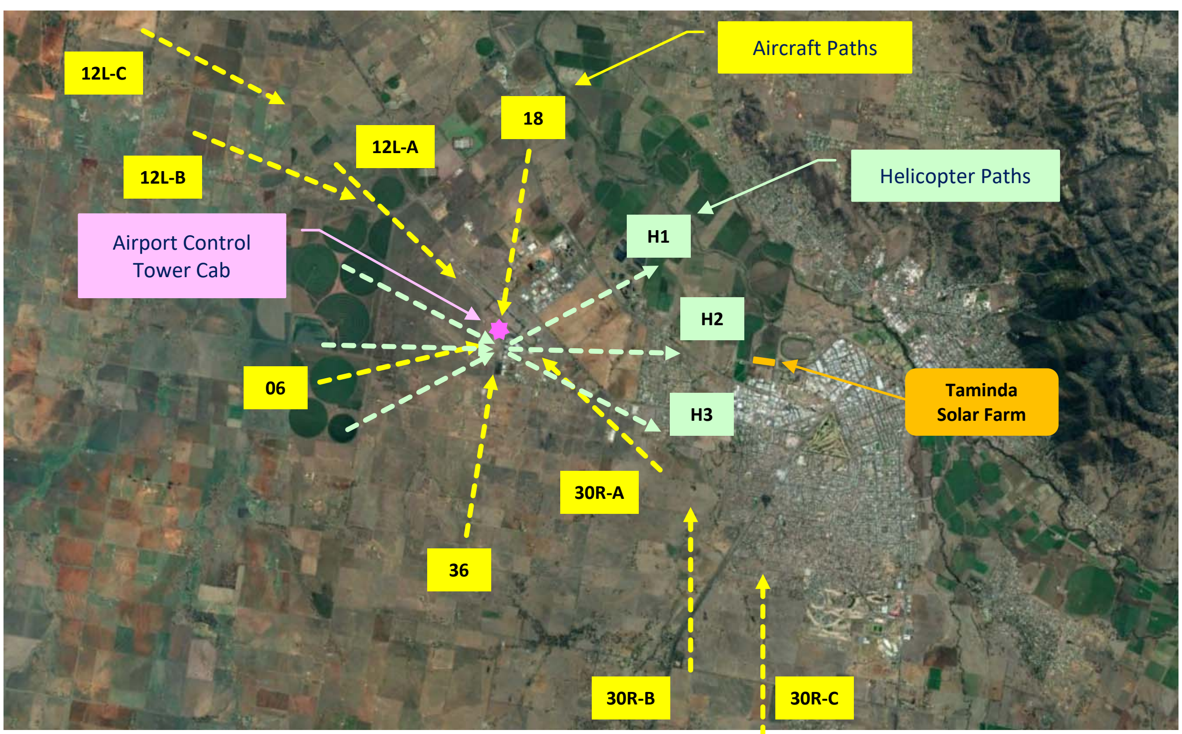
- "East" scenario: ALL panels have a vertical inclination of 8° directed (horizontally) 8° south of east.
- "West" scenario: ALL panels have a vertical inclination of 8° directed (horizontally) 8° north of west.

The flights paths assessed for the Project are shown in **Figure 12**.

Figure 12 Flight Path Geometry for SGHAT Analysis (Aircraft and Helicopters)

SGHAT Modelling Assumptions:

- All runways were examined.
- A range of worst-case flight path scenarios has been assessed, named after their respective runway designations.
- In addition to the straight runway-aligned flight paths for Runway 16L/34R, additional upstream paths were examined with a direct line of sight to the Project.
- All aircraft flight paths are 2 miles in length. For each flight path, aircraft were assumed to be in landing mode, flying with a 3° glide path.
- Helicopter flight paths are also 2 miles in length and cover both landing and take-off in the same direction. Worst-case paths were assumed ranging about a direct line of sight to the Project.
- The SGHAT analysis examines ALL possible solar angles throughout the year
- The reflectivity of the PV panels was assumed to be the same as that shown in the standard solar glass shown in **Figure 9**.



SGHAT Results

The SGHAT Ocular Plots results for all of the flight paths shown in **Figure 12** are shown in **Table 5** (all results) and in **Appendix A** (SGHAT Plots only for the NON-NIL results).

The numbers in **Table 5** in brackets refer to the number of minutes per annum that solar panel reflections are visible within any relevant SGHAT "zone". The two numbers presented per analysis are for the "West" facing and "East" facing panel inclination scenarios.

It will be recalled that solar panel reflections (glint and glare) are acceptable according to the FAA-SGHAT protocol if:

- There are no "Yellow" zone or "Red" zone results for aircraft or helicopter flight paths; and
- There are no "Green", "Yellow" or "Red" zone results for the Airport Control Tower Cab.

Table 5 SGHAT Analysis Results

Flight Path		SGHAT "Green" Zone	SGHAT "Yellow" Zone	SGHAT "RED" Zone
12L-A	final approach	[153 , 0] [1]	[0 , 0]	[0 , 0]
12L-B	prior path towards Project	[0 , 0]	[0 , 0]	[0 , 0]
12L-C	upstream prior path towards Project	[0 , 0]	[0 , 0]	[0 , 0]
30R-A	final approach	[0 , 0]	[0 , 0]	[0 , 0]
30R-B	prior path looking northwards	[0 , 0]	[0 , 0]	[0 , 0]
30R-C	upstream prior path towards Project	[0 , 0]	[0 , 0]	[0 , 0]
18	final approach	[0 , 0]	[0 , 0]	[0 , 0]
36	final approach	[0 , 0]	[0 , 0]	[0 , 0]
06	final approach	[253 , 0]	[0 , 0]	[0 , 0]
H1	direct line of sight + 30°	[786 , 0]	[0 , 0]	[0 , 0]
H2	direct line of sight	[834 , 0]	[0 , 0]	[0 , 0]
H3	direct line of sight - 30°	[763 , 0]	[0 , 0]	[0 , 0]
Airport Control Tower Cab		[0 , 0]	[0 , 0]	[0 , 0]

Note 1 the two SGHAT results [X1 , X2] refer to the results for the "West" (X1) and "East" (X2) Panel scenarios respectively

The findings of the results shown in **Table 5** are that there is NIL Glare potential for Air Traffic Controllers at Tamworth Airport, NIL Glare for Runways 18/36 and 06/24, "Low Potential for After-Image" for isolated locations along the final approach path to Runway 12L and Runway 06 and "Low Potential for After-Image" for the worst-case helicopter landing and take-off paths directed straight towards the Project.

These findings meet the SGHAT requirements recommended by the FAA for off-airport Solar PV installations and would therefore present no hazard to air navigation.

5.6 Motorist "Disability" Glare and Pedestrian 'Discomfort" Glare

In terms of "major" thoroughfares (refer **Figure 5**) in the immediate vicinity of the site, the Oxley Highway (Route B56) is located over to the south and west of the Project, almost 1.5 km to the south at its closest point and is never aligned in such a way that motorists would be looking directly towards the Project's solar panels.

Furthermore, at locations of interest along the Oxley Highway, ie within a few kilometres of the Project, there is built form, mixed vegetation as well as gentle topographic undulations, which eliminate the potential for direct line of sight to the Project.

In terms of "minor" thoroughfares (refer **Figure 5**) in the immediate vicinity of the site, roads of interest include Wallamore Road, Dampier Street and Jewry Street. In all three cases, the Project would be visible at certain locations along these thoroughfares, although with varying degrees of obstruction from intervening buildings and vegetation – as illustrated in **Figure 13**.

Another factor impacting the magnitude of motorist disability glare is the difference between the line of sight of a driver (i.e. in the direction of the road) and the line of sight towards the incoming reflections. Significant TI values can only occur when this difference is small.

Figure 13 shows that none of the potential road glare scenarios (Wallamore, Dampier, Jewry) include situations where the line of sight of a driver would be the same as a direct line of sight towards the Project (and hence with high reflectivity potential), although in some cases the angle difference is modest.

SLR has undertaken IT Calculations along Wallamore Road, Dampier Street and Jewry Street at the locations shown in **Figure 13**. The relevant IT criteria for all three of these roads would be:

- For (Motorist) Traffic Disability Glare, the TI Value should remain below 20
- For Pedestrian Discomfort Glare, the TI Value should remain below 2 at pedestrian crossings and below 3 for other locations

Table 6 TI Value Results

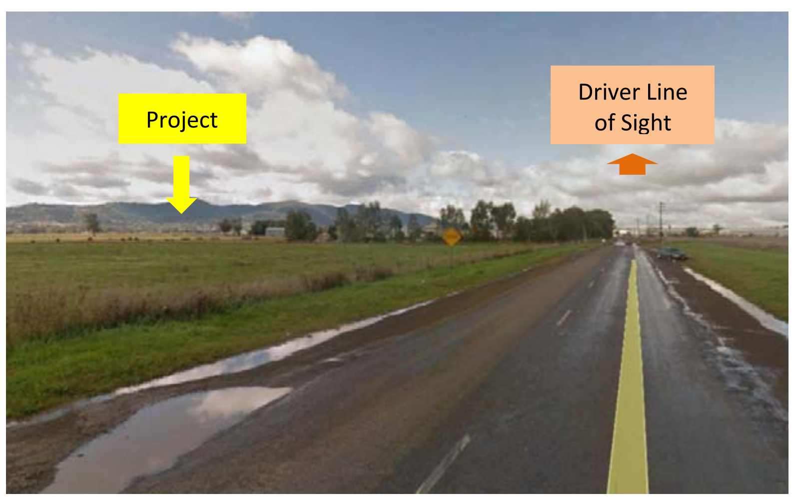
Location	Time of Year	Time of Day	Duration	TI Value
EAST Facing Panel Scenario				
Wallamore Road	nil	nil	nil	nil
Dampier Street	10 May – 01 Aug	3:20 pm - 4:00 pm	5-10 min max	6 max
Jewry Street	03 May – 10 Aug	3:15 pm - 4:00 pm	0-10 min max	12 max
WEST Facing Panel Scenario				
Wallamore Road	15 Feb - 15 Mar 28 Sept – 30 Oct	7:00 am – 7:30 am 6:30 am – 7:00 am	0-5 min max	4 max
Dampier Street	nil	nil	nil	nil
Jewry Street	nil	nil	nil	Nil

Figure 13 View of the Project from Surrounding Thoroughfares

Looking westwards along Jewry Street towards Project

Looking northwards along Dampier Street towards Project

Looking eastwards along Wallamore Road towards Project



The TI calculation results shown in **Table 6** indicate the following:

- TI Values are registered for all three carriageways at various times of the year;
- For the "East" facing panel scenario, TI Values reach a maximum value of TI=12 along Jewry Street just south of the racecourse. TI Values along Wallamore Road for this scenario are non-existent.
- For the "West" facing panel scenario, TI Values reach a maximum value of TI=4 along Wallamore Road. TI Values along Dampier Street and Jewry Street for this scenario are non-existent.

In all cases above the relevant Motorist Traffic Disability Glare criterion (TI Value < 20) is satisfied.

There appear to be no "formal" pedestrian crossings in the areas analysed and accordingly, the relevant Pedestrian Discomfort Glare criterion is also satisfied. While TI Values exceed the TI=3 criterion for pedestrians walking westwards along Jewry Street just south of the racecourse, this is not a regular pedestrian use area (in fact, there is no footpath in this area) and during any instances of infrequent potential glare, pedestrians would have the ability to turn away from any incoming reflections and mitigate the situation.

5.7 Rail Operator Reflective Glare

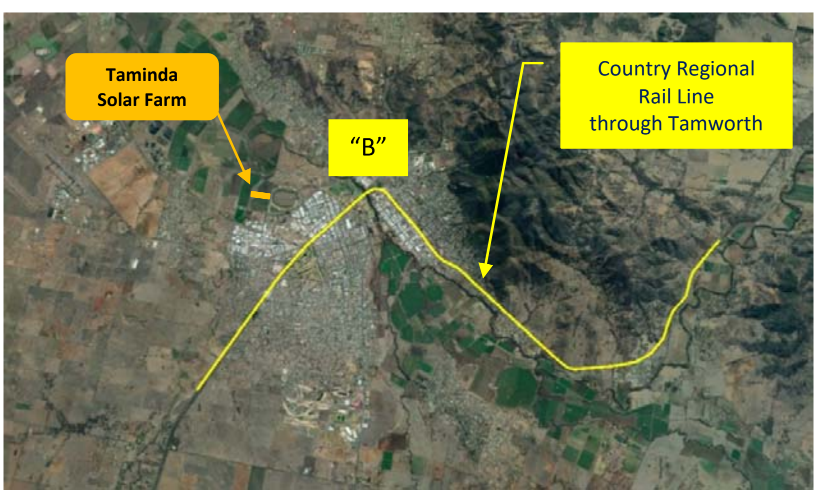
The nearest operational rail line to the project – refer **Figure 14** - is the Country Regional Line running between Werris Creek (to the southwest) through Tamworth and then on to Armidale. It is just over 1.5 km to the southeast at its closest point.

Close to Tamworth, the southern section is not aligned in such a way that a train driver would be looking directly towards the Project's solar panels. This is also the case for the section heading into Tamworth from the east, i.e. Armidale, with the exception of a small section of bend before the elevated rail line crosses the Peel River, marked "B" in **Figure 14**. A review of the intervening topography, built environment and vegetation indicates that there is no direct line of sight from the rail line in this area to the Project and resulting TI Values would be nil.

Finally, we note that ARTC's planned major Inland Rail Project will pass well to the west and north of the Project area.

Accordingly, there are no disability glare issues relevant to rail operations in the area of the Project.

Figure 14 Country Regional Rail Line Path Through Tamworth



5.8 Industrial Critical Machinery Operators

There are no industrial operations in the vicinity of the Project (e.g. mining operations) and none planned (mining or otherwise), with machinery where the relevant operators have the potential to experience reflective glare from the Project.

5.9 Residential "Nuisance" Glare

The nearest residential receivers to the Project are identified in **Figure 7**. The closest receivers, "R1" and "R2", are less than one kilometre to the southwest and approximately 1.5 km to the west-northwest of the Project respectively. Numerous other receivers are located further away with most not having direct visibility to the Project due to the intervening topography, built environment and vegetation, etc.

A review of the intervening terrain between "R1" and the Project indicates that a direct line of sight does not exist because of farm buildings and numerous trees.

Therefore, a TI calculation has been made for receiver "R2" noted above (refer **Figure 7**) based on the following:

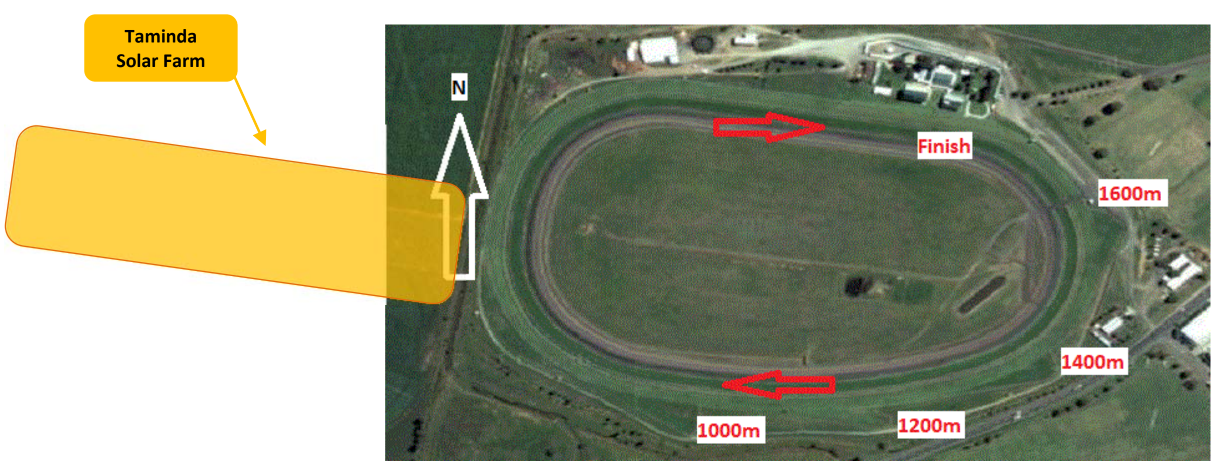
- there is no intervening topography or vegetation that can obscure any reflections from the relevant panels to the receivers, and
- a receiver is looking directly at the nearest PV panels within the Project site.

The TI calculations yield negligible reflective glare at this receiver.

"Special" Receiver Observation and Recommendation

It is noted that the Project is located adjacent to Tamworth Racecourse – refer **Figure 15**. The track is a clockwise running track with its southern straight facing westwards, i.e. almost directly towards the Project. There are also two starting tracks in this area (at the 1,000 m mark and 1,200 m mark) also facing more or less westwards in the line of sight of the Project.

Figure 15 Tamworth Racecourse



SLR has considered a "receiver" located midway along the southern track of the racecourse (2 m above ground level) and determined the relevant TI Values throughout the year:

- Glare from the Project is visible from 21 March to 21 September for the "East" facing panel inclination scenario ;
- The glare would be visible at different times ranging from 3:45 pm to 5:00 pm each day
- The glare would last approximately 10 minutes each day
- TI Values reach a maximum of 14

To provide some additional insight into the glare conditions occurring in this area, the SGHAT software was run for a receiver located 2 m above local ground level. The analysis mode was the same as that run for the Airport Control Tower Cab.

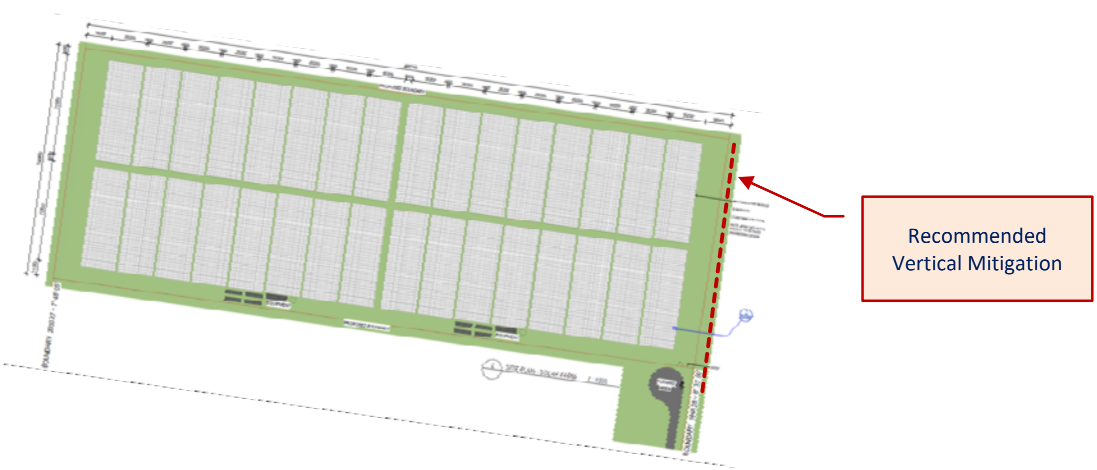
- The SGHAT Ocular Plot result for this calculation was in the "Yellow" zone – corroborating the non-negligible TI Values calculated above.

The frequency occurrence of race days and training days throughout the year at Tamworth Racecourse are not known, but would presumably include the autumn to spring period, during which it would appear likely that glare conditions might occur during the late afternoon, and in particular during the marshalling period for any 1,000 m or 1,200 m distance starts.

While there are no glare or glint criteria established for such racecourse "receivers", the magnitude of the predicted glare suggests mitigation for this occurrence would be prudent. This would most easily be enabled by the vertical obstruction shown in **Figure 16**. This could be in the form of:

- A continuous line of landscaping, 1.5 m in height
- A fence with a solid portion ranging from 0.5 m above ground to 1.5 m above ground

Figure 16 Recommended Glare Mitigation for Project Boundary



5.10 Night-Time Illumination Glare

As noted previously, key areas within the Project (eg equipment buildings, fire access routes and egress, etc) will be operational 24/7. Night-time illumination will therefore be required for all such relevant areas.

The nearest rail lines are located such that the potential for adverse night-time illumination glare from any luminaires chosen for these areas will be zero.

The only potential for night-time illumination glare is associated with the nearest thoroughfares (Dampier Street and Jewry Street) and residential receivers to the Project ("R1" and "R2").

There may also be potentially adverse eco-lighting impacts if there are nocturnal fauna habitats in close proximity to the Project site, eg within any close-by native vegetation areas. SLR understands that this is unlikely due to the historical clearing that has occurred (over a long period) surrounding the site.

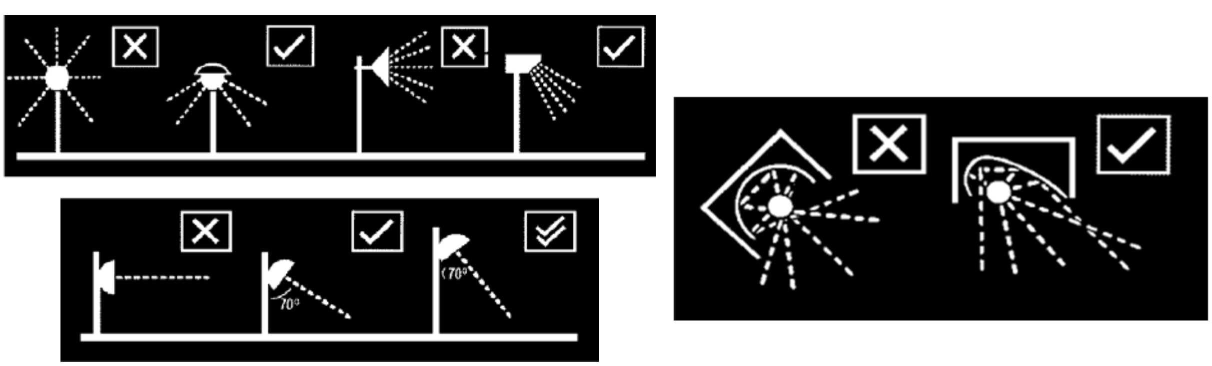
At this stage of the design and given the preliminary nature of the plant layout shown in **Figure 2**, the following recommendations are made to achieve the best lighting performance outcome for the Project (including taking into account safety considerations) while having a minimal impact on the surrounding properties, carriageways and nocturnal fauna.

If implemented correctly, the adopted goal of limiting night-time light spill to no more than 1 lux falling on the nearby residential facades during curfew hours will be achieved. Accordingly, the potential for nuisance glare will be non-existent.

AS4282-1997 Control of the Obtrusive Effect of Outdoor Lighting sets out general principles that should be applied when designing outdoor light to minimise any adverse effect of the light installation.

- Direct lights downward as much as possible and use luminaires that are designed to minimise light spill, e.g. full cut-off luminaires where no light is emitted above the horizontal plane, ideally keeping the main beam angle less than 70°. Less spill-light means that more of the light output can be used to illuminate the area and a lower power output can be used, with corresponding energy consumption benefits, but without reducing the illuminance of the area - refer **Figure 17**.
- Do not waste energy and increase light pollution by over-lighting.
- Wherever possible use floodlights with asymmetric beams that permit the front glazing to be kept at or near parallel to the surface being lit.

Figure 17 Luminaire Design Features that Minimise Light Spill



6 CONCLUSIONS

SLR Consulting Australia Pty Ltd (SLR) has been engaged by ELTON Consulting (ELTON) to carry out a Glare Impact Assessment for the proposed Taminda Solar Farm ("the Project"), a large-scale Solar Photovoltaic (PV) facility to be located adjacent to Tamworth Racecourse, Taminda, approximately 3 km west of the Tamworth central business district.

The 9 MWac facility will comprise 27,648 solar PV panels within a 7.72 ha project site area. The panels, measuring approximately 2.0 m by 1.0 m, will be positioned as currently understood on a proprietary mounting system, the "Belectric Pegging System" ("PEG").

The following potential glare conditions have been considered:

- Daytime Reflective glare (and glint) arising from the solar PV panels within the facility
- Night-time Illumination glare from 24/7 operational security lighting within the facility

In terms of potential glare scenarios, the following has been considered:

- Aviation Sector Reflective Glare; and
- Motorist "Disability" Reflective Glare and Pedestrian "Discomfort" Reflective Glare;
- Rail Operator Reflective Glare;
- Industrial critical machinery operators (heavy vehicles, etc) Reflective Glare.
- Residential "Nuisance" Glare from daytime reflections or night-time illumination;

In all cases, the present study has found that the potential for adverse glare from the proposed facility will be minimal, with one potential exception. The lack of glare potential is due to a number of factors, including:

- The distances of receivers (aviation, motorist, rail, residential, etc) from the Project and their respective line of sight relative to solar reflections from the facility, as well as the presence of intervening buildings, vegetation, etc.

Although not formally required by any published criteria, a recommendation based on best practice has been made for a vertical barrier (ranging in height from 0.5 m to 1.5 m above ground level) running along the eastern perimeter of the Project site. This is to protect the amenity of Tamworth Racecourse operations.

There should be negligible impact from the 24/7 lighting required on the site for operational purposes, assuming the lighting design is in accordance with AS 4282-1997 *Control of the Obtrusive Effect of Outdoor Lighting*. This will also address any potential (though unlikely) adverse eco-lighting issues in relation to nocturnal fauna within and surrounding the site.

Once key Project decisions are finalised during detailed design (eg final panel selection, mounting details, etc), the present analysis should be re-visited to confirm the conclusions set out above if key assumptions made in the analysis change significantly.

APPENDIX A

SGHAT Ocular Plots – Tamworth Airport Operations

SGHAT Ocular Plot Simulations

Aircraft Flight Path	Description
12L-A	final approach
12L-B	prior path towards Project
12L-C	upstream prior path towards Project
30R-A	final approach
30R-B	prior path looking northwards
30R-C	upstream prior path towards Project
18	final approach
36	final approach
06	final approach
H1	direct line of sight + 30°
H2	direct line of sight
H3	direct line of sight - 30°
Airport Control Tower Cab	

APPENDIX A

SGHAT Ocular Plots – Tamworth Airport Operations

EAST FACING ARRAYS

12L-A	NIL result
12L-B	NIL result
12L-C	NIL result
30R-A	NIL result
30R-B	NIL result
30R-C	NIL result
18	NIL result
36	NIL result
06	NIL result
H1	NIL result
H2	NIL result
H3	NIL result
Airport Control Tower Cab	NIL result

WEST FACING ARRAYS

12L-A	**see SGHAT Plot**
12L-B	NIL result
12L-C	NIL result
30R-A	NIL result
30R-B	NIL result
30R-C	NIL result
18	NIL result
36	NIL result
06	**see SGHAT Plot**
H1	**see SGHAT Plot**
H2	**see SGHAT Plot**
H3	**see SGHAT Plot**
Airport Control Tower Cab	**see SGHAT Plot**

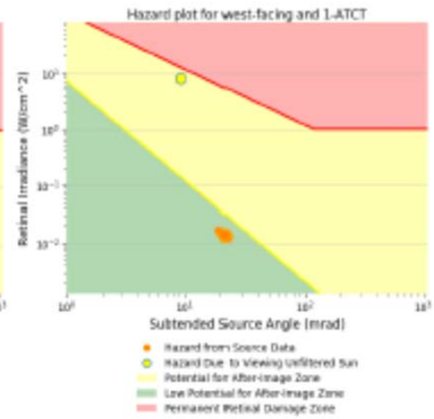
APPENDIX A

SGHAT Ocular Plots – Tamworth Airport Operations

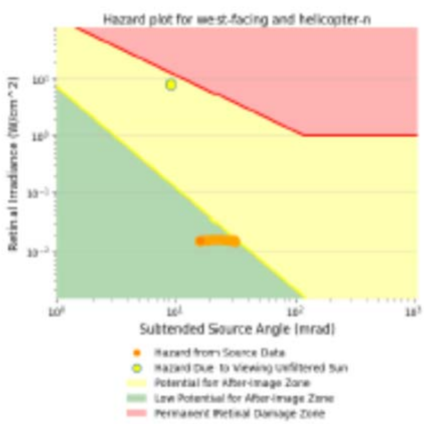
Flight Path 12L-A

Flight Path 06

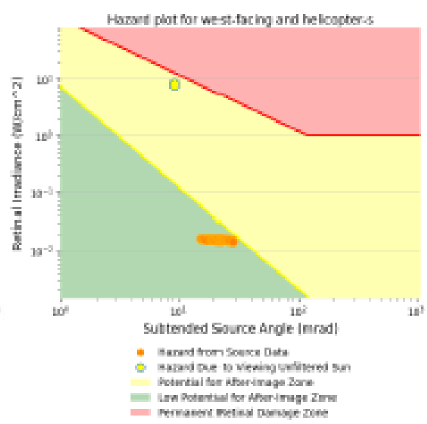
Control Tower



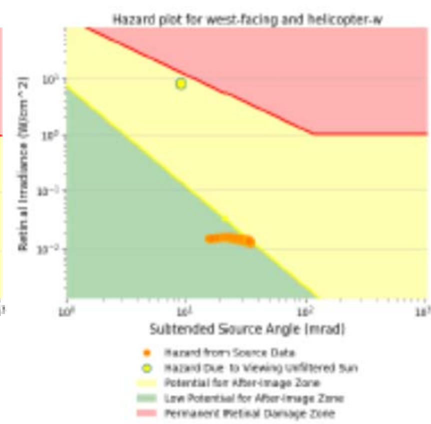
Helicopter Path H1



Helicopter Path H2



Helicopter Path H3



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