AMAROO SOLAR FARM

Reflective Glare Assessment

Prepared for:

Providence Asset Group
704/99 Bathurst Street
SYDNEY NSW 2000

SLR Ref: 631.30013-R03
Version No: -v1.1
May 2021

PREPARED BY

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
Tenancy 202 Submarine School, Sub Base Platypus, 120 High Street
North Sydney NSW 2060 Australia

T: +61 2 9427 8100
E: sydney@slrconsulting.com   www.slrconsulting.com

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 Providence Asset Group (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.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
631.30013-R03-v1.1	25 May 2021	Peter Hayman	Dr Peter Georgiou	Dr Neihad Al-Khalidy

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Providence Asset Group to carry out a Reflective Glare assessment of the proposed Amaroo Solar Farm (the "Project"). The Project is located at Lot 392 DP751780, on Amaroo Drive, Moree, approximately 1.5 km west of the Newell Highway and just under 2.5 km from nearby Moree Airport which lies to the southeast.

The proposed (up to) 5 MWac facility (refer Section 2) will comprise 13,524 solar PV panels within a 15 ha project site area. The 540 W panels, measuring approximately 2.26 m by 1.13 m, will be positioned as currently understood on 161 single-axis trackers oriented north-south with a spacing of 6.4 m.

The following potential glare conditions have been considered:

- Daytime Reflective glare (and glint) arising from the solar PV panels within the facility:
  - Aviation Sector Reflective Glare;
  - Motorist "Disability" and Pedestrian "Discomfort" Reflective Glare;
  - Rail Operator Reflective Glare;
  - Industrial Machinery Operator Reflective Glare; and
  - Residential "Nuisance" Glare.
- Night-time Illumination glare if any 24/7 operational security lighting is incorporated into the Project in the future; none is currently planned.

Aviation-Related Potential Glare

Quantitative analysis using the FAA-SGHAT software tool has shown that there will be nil glare from the Project at Moree Airport with the solar array in normal tracking mode, ie panels tilting ±60°.

If the facility's panels are left horizontal (ie flat), reflections in the SGHAT "Green" zone, which is an acceptable outcome for aviation glare, are likely to be perceived on Runways 19 and 23. Leaving the solar array with a fixed westwards tilt angle of at least 10° eliminates all reflections completely. This should be considered during construction and maintenance periods.

Motorist, Rail Traffic and Residential Glare

There will also be nil glare from the Project in relation to road traffic, rail traffic and surrounding residential receivers under the standard operational ±60° tilt angle scenario.

There is potential for reflection visibility to nearby residential receivers if solar panels are left in a fixed tilt horizontal or with a slight eastwards tilt (eg for maintenance, during construction, under back-tracking mode, etc). This is predicted for several residential receivers located east of the site, although it is noted that this is a conservative estimate, as the predictions did not take into account the benefit of landscaping, trees, etc, in the vicinity of these residences. Again, leaving the solar array with a fixed westwards tilt angle of at least 10° eliminates all of these reflections completely.

Night-time lighting is not currently incorporated into the Project. If 24/7 lighting is required in the future for operational purposes, there should be negligible impact on nearby residential receivers, assuming the lighting design is in accordance with AS 4282-1997 Control of the Obtrusive Effect of Outdoor Lighting. This would also address any potential adverse eco-lighting issues in relation to nocturnal fauna within and surrounding the site, although, as far as is known, no biodiversity issues have been identified in relation to the Project. Any future lighting design should also be checked against CASA's NASF Guidelines (E & F).

EXECUTIVE SUMMARY

When key Project decisions are finalised during detailed design (e.g. 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.

CONTENTS

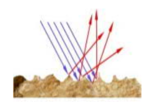
CONTENTS

DOCUMENT REFERENCES

TABLES

FIGURES

Abbreviations and Definitions

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: • Which can be experienced by both stationary and moving observers (the latter referred to as “glint”). • 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.  Specular 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	
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 4282:2019	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.

1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Providence Asset Group to carry out a Reflective Glare assessment of the proposed Amaroo Solar Farm (the "Project"). The Project is located at Lot 392 DP751780, on Amaroo Drive, Moree, approximately 1.5 km west of the Newell Highway and just under 2.5 km from nearby Moree Airport which lies to the southeast.

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

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 the assumptions made in the glare impact analysis.
- Section 6 presents the results of the glare impact analysis of the Project.
- Section 7 presents the conclusions of the study.

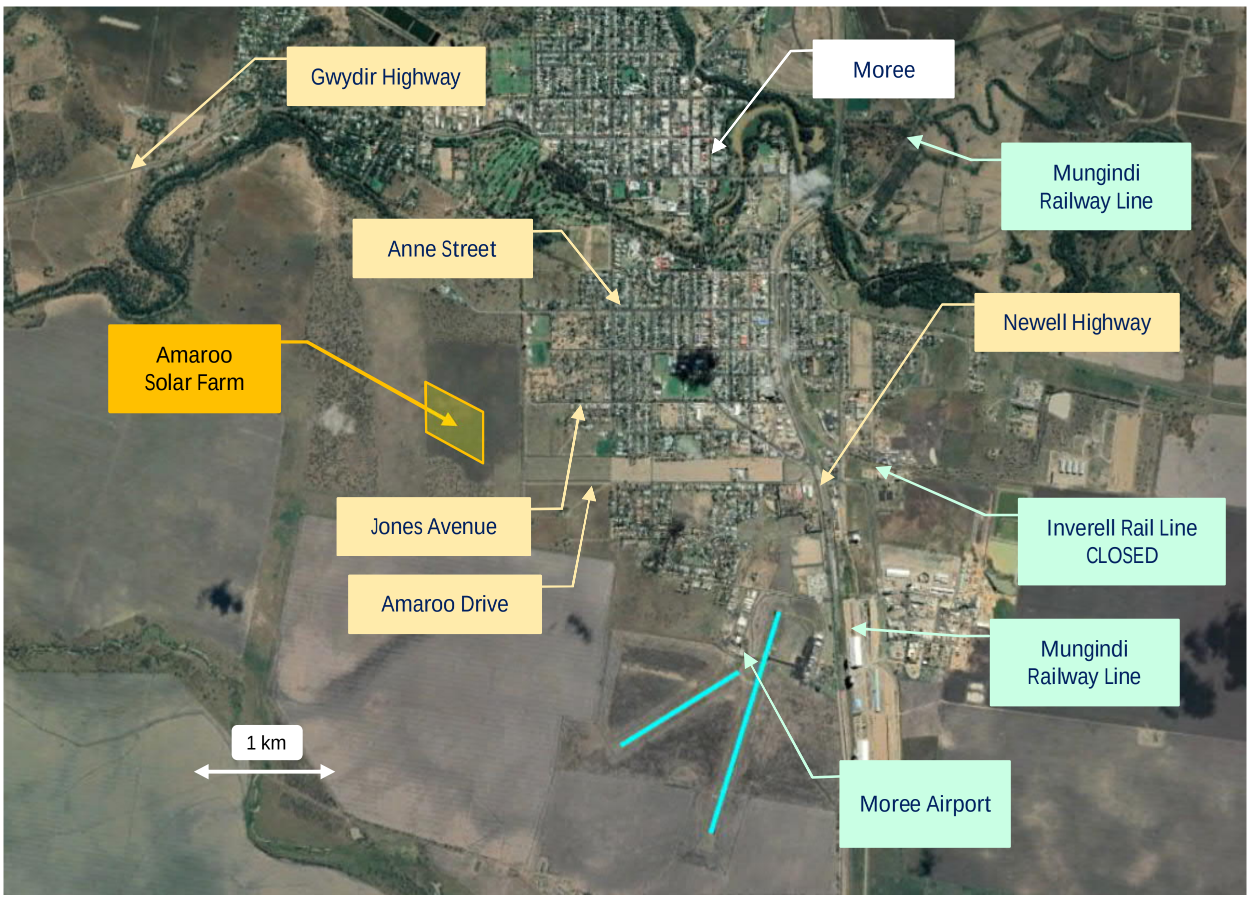
2 PROPOSED AMAROO SOLAR FARM PROJECT

2.1 Site Location

The Project is seeking approval for an (up to) 5 MWac photovoltaic (PV) solar plant occupying a 15 ha area as shown in Figure 1. The Project is located at Lot 392 DP751780, on Amaroo Drive, Moree, approximately 1.5 km west of the Newell Highway and just under 2.5 km from nearby Moree Airport which lies to the southeast.

The land required for the Project has been subject to constraints identified by site investigation, i.e. native vegetation, and areas of cultural or heritage significance. The plan of the Project has been developed following completion of these site investigations and the assessment of any constraints and their impact.

Figure 1 Amaroo Solar Farm - Location Map



2.2 Site Description and Key Project Components

From a Reflective Glare point of view, the key components of the Project are:

- the photovoltaic (PV) modules in relation to their daytime reflective glare potential; and
- the facility's security/emergency lighting design in relation to potential night-time illumination glare issues, if such 24/7 lighting is incorporated into the Project – note: none is currently planned.

Solar Panel Mounted Array – refer Figure 2

The proposed ground-mounted array (refer Figure 2(a)) would consist of 161 trackers oriented in a north-south direction, supporting 540W solar panels (13,524 panels in total);

- The trackers are "single-axis" capable of rotating solar panels to a maximum of ±60° - refer Figure 2(b);
- The trackers are oriented north-south and spaced 6.4 m apart;
- Individual panels (2.26 m x 1.13 m) reach a maximum height above ground of 2.58 m at their full 60° tilt angle

Figure 2 Amaroo Solar Farm Site Layout

(a) Site Layout

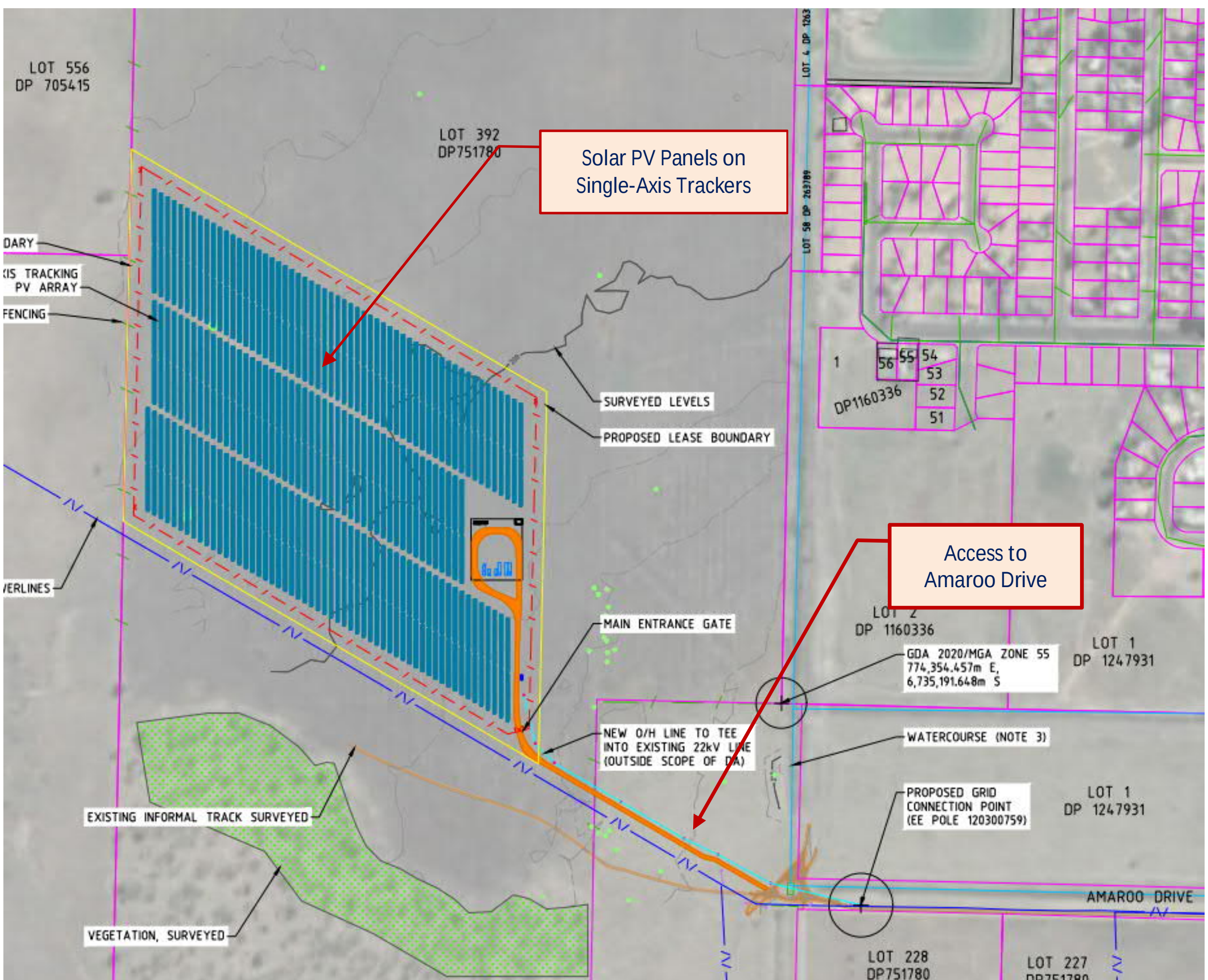
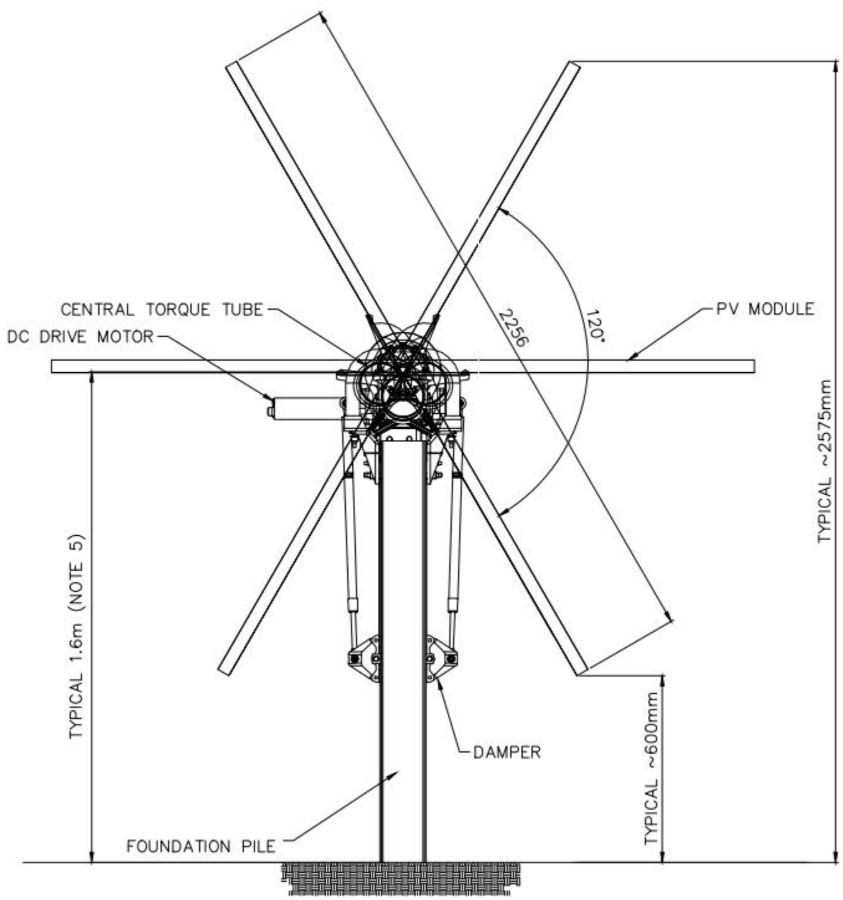


Fig.2 (cont'd)

(b) Single-Axis Tracker Profile (±60° **Tilt)**



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.

Aviation-Related Glint & Glare (Aircraft, Helicopters, Airport Control Towers)

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

Motorist Traffic Disability Glare on the surrounding 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 altitude angle less than 25° (altitude angles greater than this would be intersected and obstructed by a typical windscreen roof-line).

Train Driver Disability Glare on the surrounding 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 Machinery Operator Glare (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, typically associated with mining operations and draglines (whose Operators are in an elevated position).

Residential Nuisance Glare on surrounding receivers

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, although it is noted that none is currently planned for the Project.

3.2 Nearest Receiver Locations

Receivers of interest relevant to the Project are shown in:

Figure 3 Nearest aerodrome;

Figure 4 Surrounding road network;

Figure 5 Surrounding rail network; and

Figure 6 Nearest representative residential receivers.

Figure 3 Nearest Aerodrome to Project Site

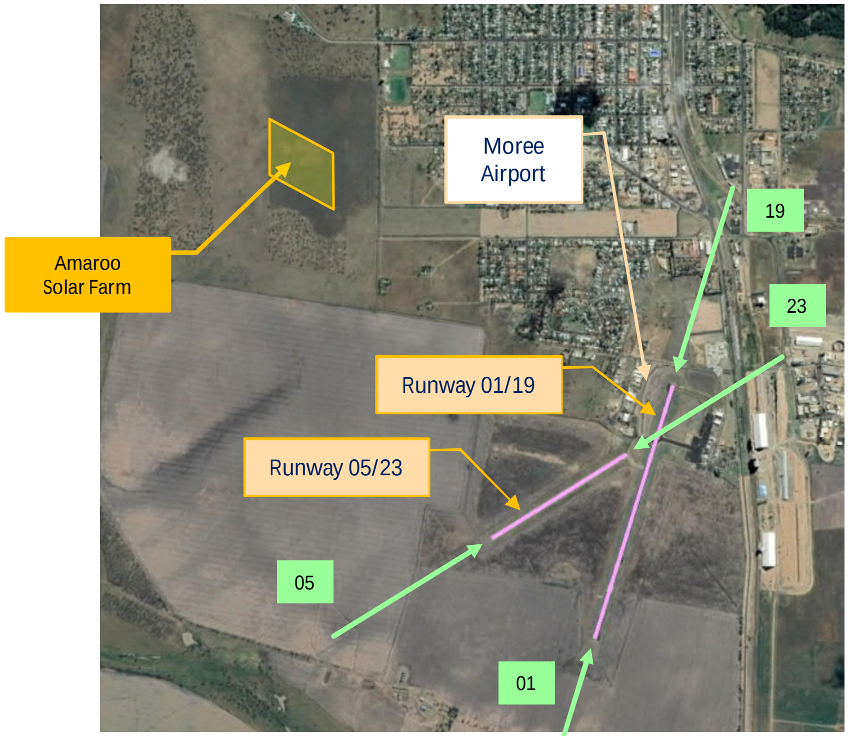


Figure 4 Surrounding Road Network (with potential line of sight to Amaroo SF reflections)

Figure 5 Surrounding Rail Network and NSW Rail Map

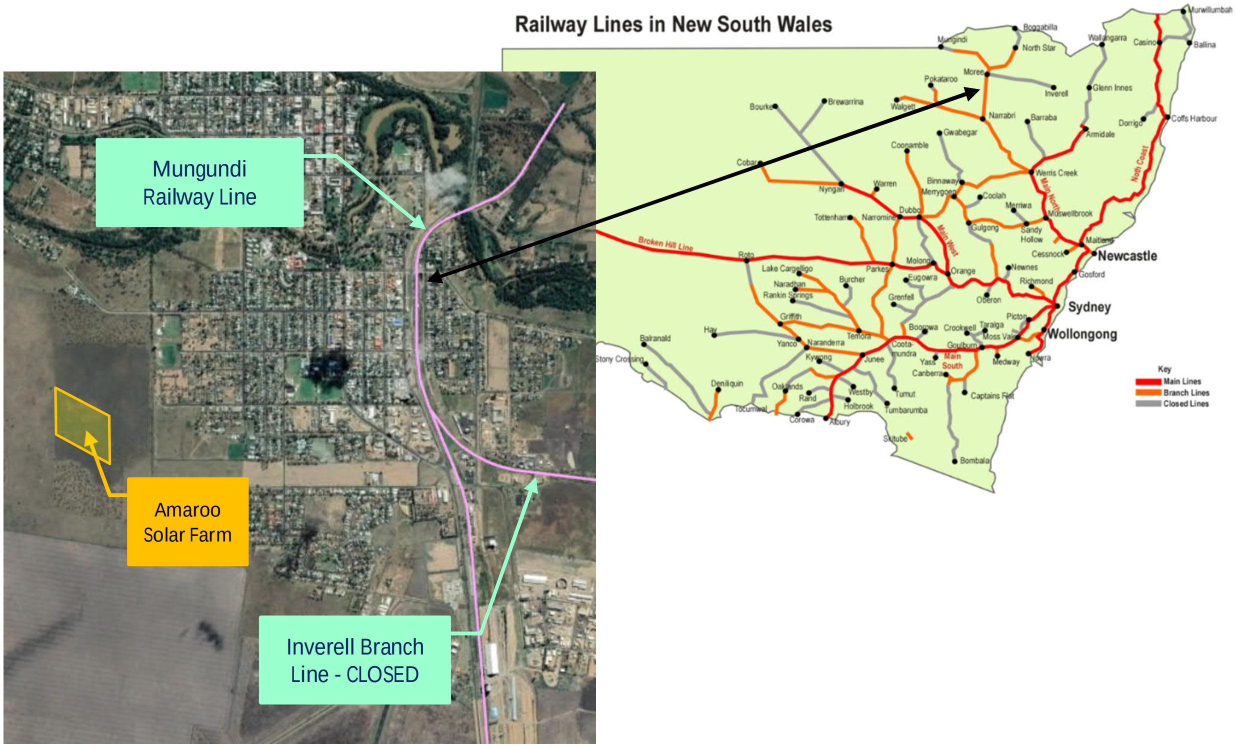
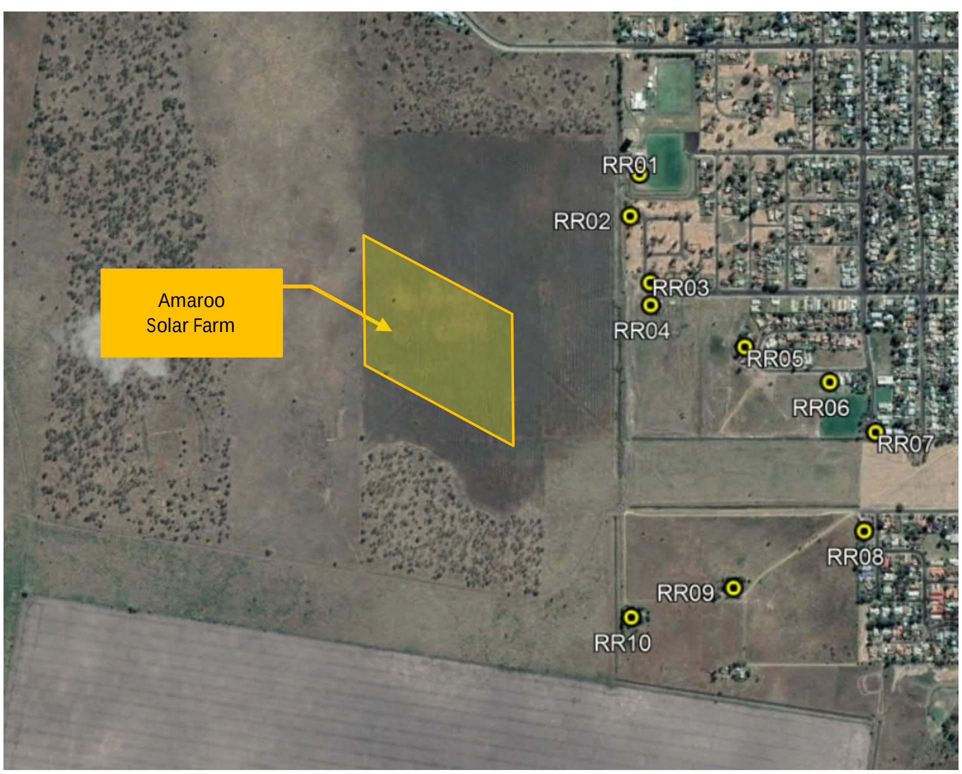


Figure 6 Nearest Representative Residential Receivers (“RR”)



4 GLARE ACCEPTABILITY CRITERIA

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

- PV modules mounted on single axis trackers.

In relation to night-time illumination glare impact, the Project may, in the future, include the following elements of interest:

- 24/7 lighting for access roads to enable site maintenance, fire and other emergency events, and 24/7 lighting for the on-site Operations & Maintenance building and power conversion unit which provide connection to the local distribution network.

Night-time illumination is not presently incorporated in the current Project design.

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, in particular those located either within or around airport precincts.

US FAA

In relation to the potential impact of solar PV systems on aviation activity, guidance is available from the US FAA which 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. The Technical Guidance Policy was updated in 2018.

- 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.
- FAA, "Technical Guidance for Evaluating Selected Solar Technologies on Airports", Federal Aviation Administration, Washington, D.C., Version 1.1, April 2018.

In support of the above, the FAA contracted Sandia Labs to develop their Solar Glare Hazard Analysis Tool (SGHAT) software as the standard tool 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.

SGHAT is described in the following references:

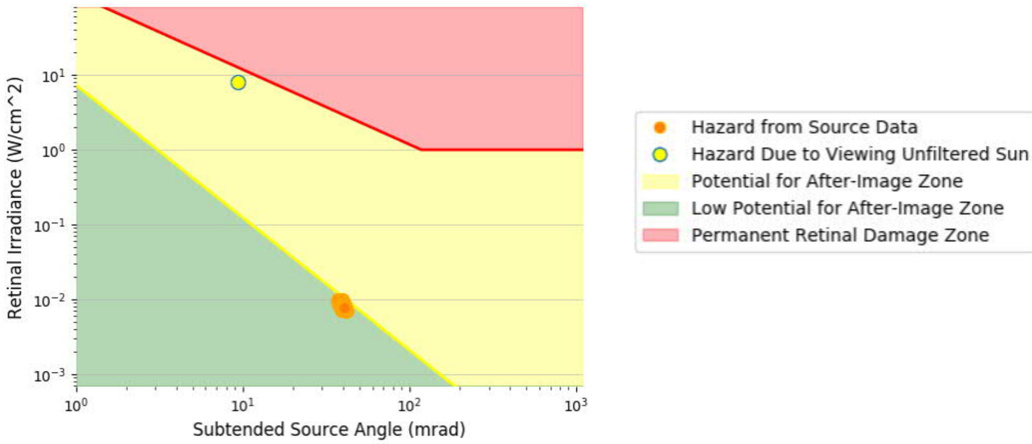
- Ho, C.K., Ghanbari, C.M. and Diver, R.B., "Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation", J. Solar Engineering, August 2011, Vol.133, 031021-1 to 031021-9.
- Ho, C.K. & Sims, C., "Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v2.0", Sandia National Laboratories, Albuquerque, NM. August 2013.

A sample Solar Glare Ocular Hazard Plot is shown in Figure 7. The analysis contained in this plot is derived from solar simulations that extend over the ENTIRE CALENDAR YEAR in 1-MINUTE intervals, sunrise to sunset.

The SGHAT criteria state that a proposed solar facility should satisfy the following:

- Airport Traffic Control Tower (ATCT) cab: NO Glare ("Green" or "Yellow" Zone)
- Final approach paths for landing aircraft: NO "Yellow" Zone Glare

Figure 7 Example Solar Glare Ocular Hazard Plot (SGHAT Software Output)



In Figure 7, the following is noted:

- SGHAT ocular impact is a function of both the "retinal irradiance" (ie the light seen by the eye) and "subtended source angle" (ie how wide an arc of view the light appears to be arriving from).
- SGHAT ocular impact falls into three categories:
  . GREEN: low potential to cause "after-image"
  . YELLOW: potential to cause temporary "after-image"
  . RED: potential to cause retinal burn (permanent eye damage)
- "After Image" is the term applied to a common retinal phenomenon that most people have experienced at some point or other, such as the effect that occurs when a photo with flash is taken in front of a person who then sees spots in front of their eyes for a few seconds. A more extreme example of "after-image" occurs when staring at the sun. "After-image" (also known as "photo bleaching") occurs because of the de-activation of the cells at the back of the eye's retina when subjected to a very bright light.
- The SGHAT plot provides an indication of the relative intensity of both the incoming reflection and the sources of light itself (ie the sun).

  . The occurrence of glare is shown in the plot as a series of orange circles, one circle for each minute that a reflection is visible.

  . A reference point is also shown in each SGHAT plot, the green circle, representing the hazard level of viewing the sun without filtering, ie staring at the sun.
- In Figure 7, it can be seen that the reflection visible by the receiver is roughly 1,000 times less intense than the light from the sun.

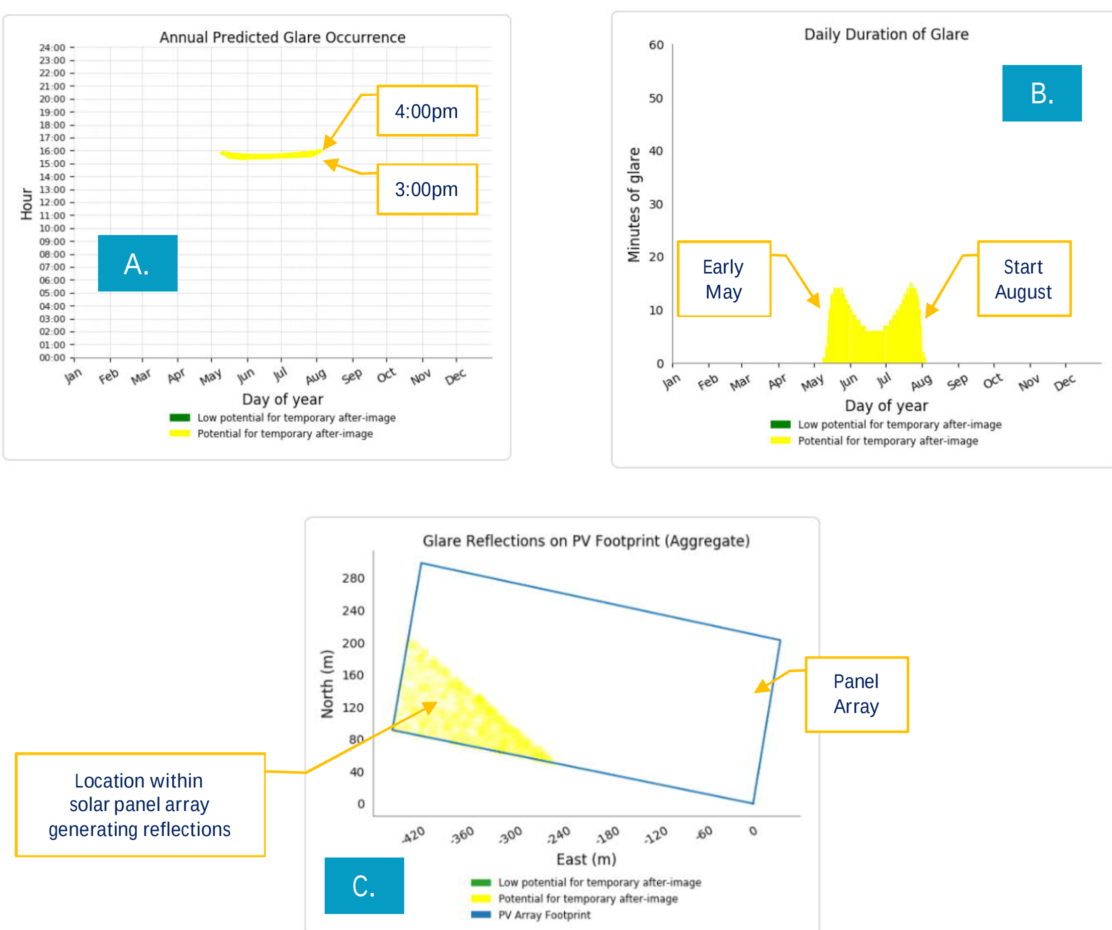
- Finally, in relation to PV Solar facilities, it is important to note that the third SGHAT Ocular Plot "RED" category is not possible, since PV modules DO NOT FOCUS reflected sunlight.

Additional Information Available with the SGHAT Analysis Tool

In addition to the above "assessment" output, the SGHAT software package also produces information which reveals the extent of visibility of reflections at any chosen receiver position, regardless of whether the reflections constitute a glare condition or not – an example is shown in Figure 8.

- Figure 8-A: shows the am/pm time periods when reflections occur at a specific position throughout the year, in this case typically between around 3:30pm and 4:00pm.
- Figure 8-B: shows the months during the year and the minutes per day when reflections occur at a specific position, in this case from early-May to the start of August.
- As noted above, this information is made possible because the SGHAT analysis covers the entire solar annual cycle in 1-minute intervals to ascertain any potential impacts on surrounding receivers.
- Finally, Figure 8-C shows WHERE within the solar farm panel array the reflection rays of interest are emanating from, in this case from panels near the southwest corner.

Figure 8 Example Solar Glare Output Plots (SGHAT Software Output)



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

The criteria commonly used by Australian Local Government Authorities to assess the acceptability or otherwise of potential adverse reflections from glazed façade systems onto surrounding roadways and pedestrian crossings utilise the so-called Threshold Increment (TI) Value of the reflection condition.

TI Value Definition

AS/NZS 4282:2019 defines TI as:

> "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. Note: Higher values of TI correspond to greater disability glare."

The TI Value is calculated as the ratio of "veiling" luminance (eg from a reflection) to the overall average background ("adaptation") luminance, with the necessary constant and exponent parameters provided in AS 1158.2:2005.

The formula for calculating the TI Value is … $TI = 65\ L_v / L_{tb}^{0.8}$, where:

- L_v = veiling luminance from a source of interest (eg reflection) – Cd/m^2
- L_{tb} = so-called "adaptation" luminance (total background) – Cd/m^2

TI Value Acceptability Criteria

The acceptability criteria adopted by Australian Local Government Authorities to assess the acceptability or otherwise of potential adverse reflections from glazed façade systems onto surrounding roadways and pedestrian crossings utilise the so-called TI Value of the reflection condition (refer above for definition and calculation equations).

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

For the present study, Pedestrian Discomfort Glare is relevant to the potential for residential nuisance glare from surrounding receivers.

It should be noted that while Pedestrian Discomfort Glare can occur over a wide range of solar altitude angles, in most such instances, a pedestrian has the ability to adjust their line of sight to a more horizontal view away from the glare source, thereby rendering TI values essentially negligible.

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 residential nuisance glare specific to solar PV.

Existing guidance that exists in relation to solar panels from state governments typically covers installation audits and compliance checks. Additional guidance in relation to compliance with Australia Standards is provided by:

Clean Energy Council
Website: https://www.cleanenergycouncil.org.au/industry/products/modules

Accordingly, to assist in addressing residential nuisance glare, reference has been made of the concepts used for glare acceptability criteria outlined in the preceding sections.

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 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 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 4282-2019.

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 1 for comparison.

Table 1 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 2. 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 2 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 just outside the Moree township "urbanised" area and has the potential to impact on surrounding residential properties – refer Figure 6. These properties are however located within township environs proper, and would therefore be classed as being in a residential area with "Light Surrounds" - refer Table 2.

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

For the Project, it is possible that internal access roads and any equipment buildings in particular, will be operational 24/7, 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 2 lux during curfew hours

It is noted that night-time lighting is not currently incorporated into the Project.

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. Biodiversity associated with the Project is discussed in the Flora and Fauna Assessment Report prepared for the Project. As far as is known, no adverse eco-lighting issues are apparent.

5 GLARE IMPACT ASSESSMENT - ASSUMPTIONS

The following potential glare conditions have been considered:

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

5.1 Assumptions – Solar Panel Geometry

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

- The solar panel array trackers are “single-axis” capable of rotating solar panels to a maximum of ±60°.
- The trackers are oriented north-south and spaced 6.4 m apart.
- Individual panels (2.26 m x 1.13 m) reach a maximum height above ground of 2.58 m at their full 60° tilt angle.

5.2 Project Site Solar Angles – Annual Variations

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

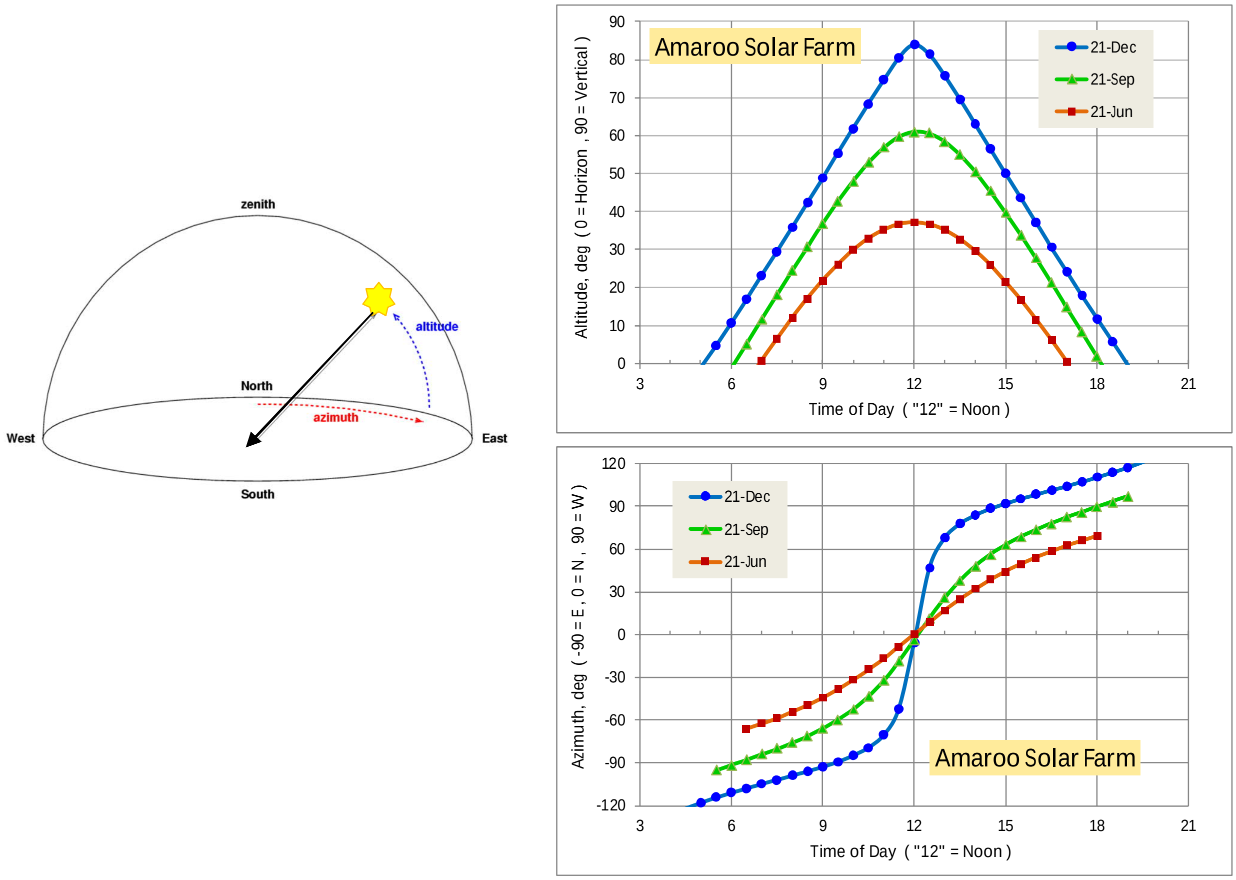
Any solar glare analysis must take into account the complete cycle of annual reflection variations noted above.

The potential range of incoming solar angles at the Project site relevant to daytime glare is shown in Figure 9 with relevant critical angles summarised in Table 3.

Table 3 Key Annual Solar Angle Characteristics for Project Site

Day of Year	Sunrise	Sunset	Azimuth Range (sunrise-sunset)	Max Altitude
Summer Solstice	5:06 am	6:59 pm	117.2° E of North to 117.2° W of North	83.9°
Equinox	6:06 am	6:09 pm	90.7° E of North to 90.7° W of North	61.0°
Winter Solstice	6:56 am	5:02 pm	62.8° E of North to 62.8° W of North	37.1°

Figure 9 Project Site Incoming Solar Angle Variations

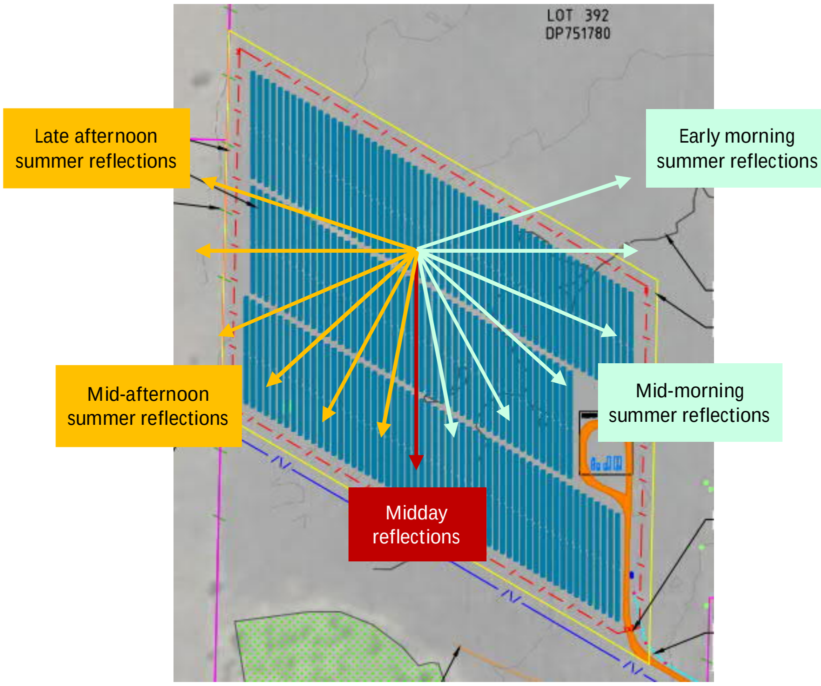


5.3 Project Solar Reflections

The project will use single-axis tracking panels (with the axis of rotation oriented north-south) as described in Section 2.2. In "plan" view, reflections from the Project's panels will be directed as shown in Figure 10 for a representative area of panels, with the direction of reflected rays shown for typical mid-summer days.

As a result of the tracking motion of the solar panels throughout the day, reflections will generally be directed upwards and hence not visible by ground-based receivers at roughly the same elevation as the facility. Where such reflections can be observed by surrounding elevated receivers they would typically be seen as "low incidence" reflections with corresponding low reflectivity. This is the inevitable outcome of the objective of maximising the solar gain of each panel (where the reflectivity would ideally be minimal) and justifying the additional cost of using a tracking system for the panels which follows the sun, rather than a fixed panel system.

Figure 10 Potential Solar PV Panel Reflection Angles from the Project (typical mid-summer)



5.4 Solar Panel Reflectivity Characteristics

Solar PV panels are designed to capture (absorb) the maximum possible amount of light within the layers below the front (external) surface. Consequently, solar PV panels are designed to <u>minimise reflections</u> 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, solar panel orientation), 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 PV Solar Panels (Solar Glass; Solar Glass with AR Coating)

Representative reflectivity curves are shown in Figure 11.

Figure 11 Typical Reflectivity Curves as a Function of Incidence Angle

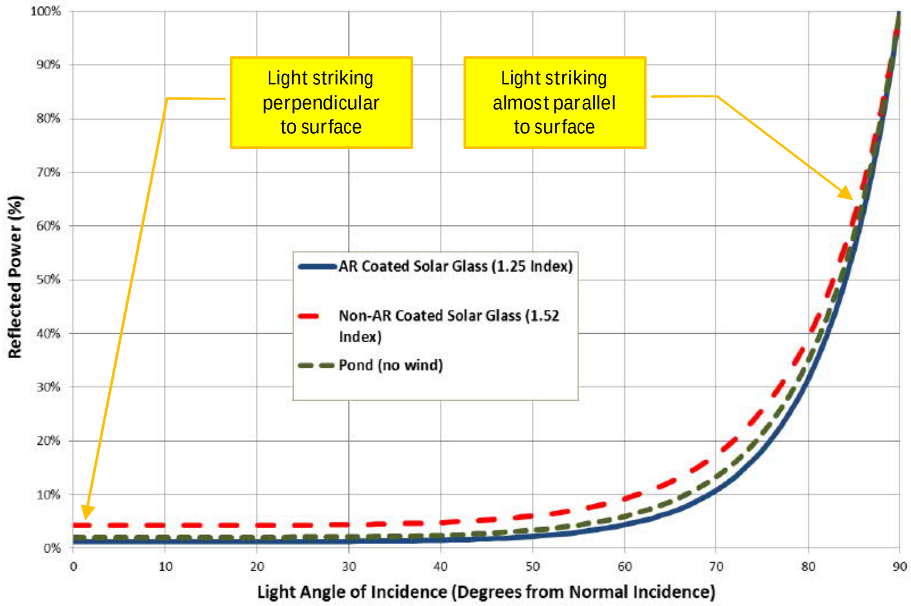


Figure 11 shows that:

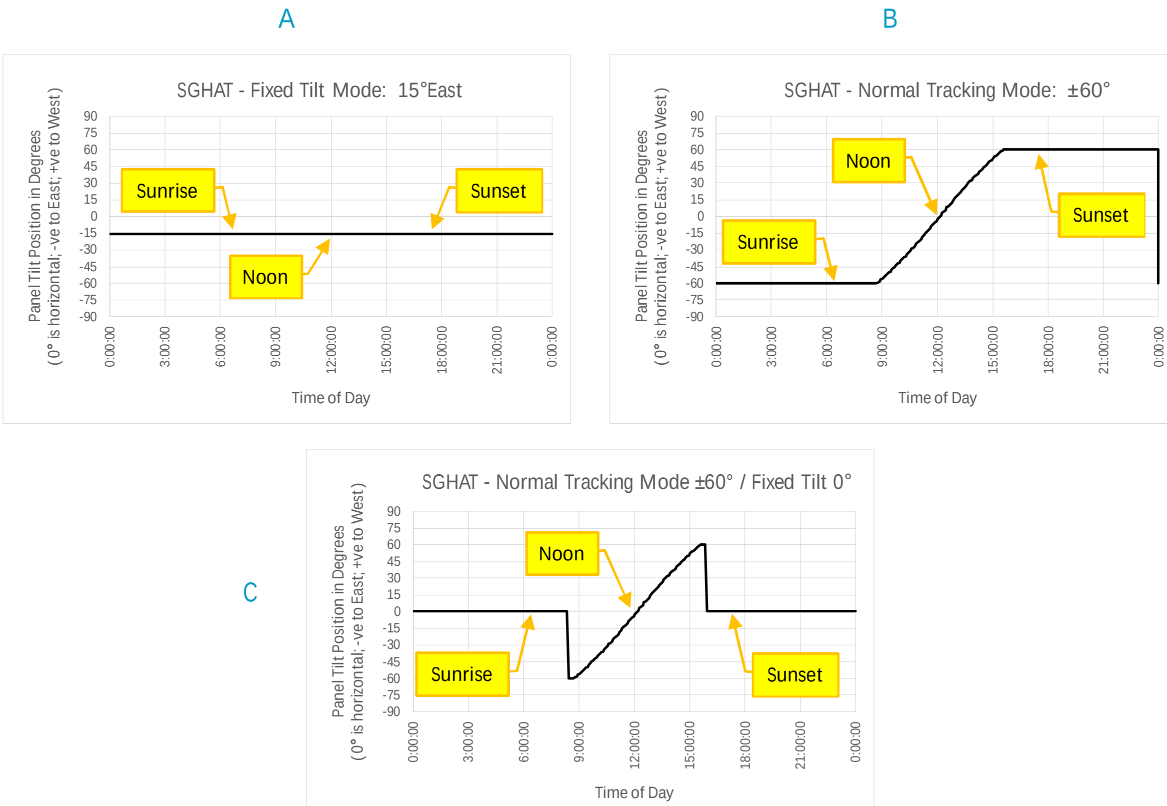
- When an oncoming solar ray strikes the surface of a solar PV panel close to perpendicular to the panel surface (i.e. low "incident" angle), the reflectivity percentage is minimal (less than 5% for all solar panel surface types).
- It is only when an incoming solar ray strikes the panel at a large "incidence" 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, for very high incidence angle, it would almost always be the case that the observer (motorist, train driver, pedestrian, etc) 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 intensity of the incoming solar ray itself would dominate the field of vision perceived by the observer.

5.5 Modelling Real-World Tracking Axis Operational Modes

The SGHAT software tool is capable of modelling solar farm panel positions in one of three modes – as shown in Figure 12.

- Fixed Tilt Mode: in this mode, all panels are assumed to remain at a user-defined fixed angle all day long, eg horizontal, 15°East, 10°West, etc – refer Figure 12-A.
- Normal Tracking Mode: in this mode, panels move between maximum tilt angles once the sun is above the relevant altitude angle (eg an altitude angle of 30° for ±60° single-axis trackers). They remain at the maximum tilt angles at all other times, switching over during the night – refer Figure 12-B.
- Normal Tracking Mode / Fixed Tilt Stowed: in this mode, panels move during the day in "normal tracking": mode, but can then move (instantaneously) to any user-defined fixed tilt angle at all other times – refer Figure 12-C where the panels move to a horizontal position (ie 0°) outside of "normal tracking" hours.

Figure 12 SGHAT Panel Mode Simulation Options



"Backtracking" Mode

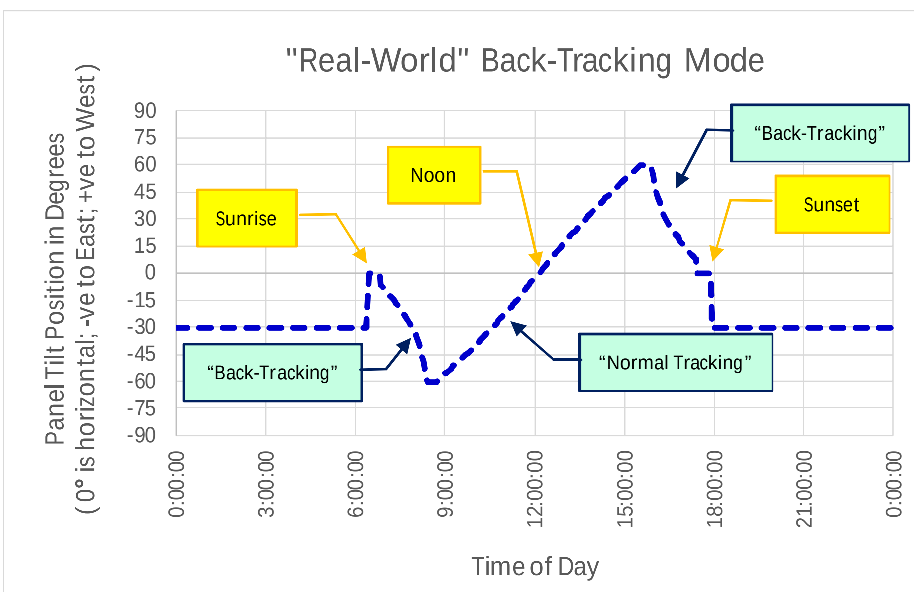
Most recently, sophisticated "back-tracking" operational modes have been developed, typically by the manufacturers of the tracking systems on which the solar panels are mounted.

- Algorithms are developed (usually fine-tuned during the commissioning stage of a solar facility) aimed at minimising inter-row shading in the early morning and late afternoon. These algorithms are based on the location of a solar facility (ie its latitude), topography, panel row spacing, etc.
- They typically involve constantly re-positioning panels in the early morning and late afternoon starting and ending in a more horizontal position, that "just" avoids inter-row shading.
- During these early morning and late afternoon periods, panel motion is referred to as being in "back-tracking" mode.
- During the remaining hours in the middle of the day, solar panels follow the simplified "normal tracking" mode, ie moving between their maximum (±60°) tilt positions.
- There is typically a transition period between the two tracking modes (say ~15 minutes), calculated according to the local site tracking system algorithms.

A real-world example of a "back-tracking" mode is shown in Figure 13.

- The sun reaches an altitude angle of 30° in the morning at around 8:30am and again in the afternoon at around 3:45pm. During these hours (ie between around 8:30am and 3:45pm), the panels operate in "normal tracking" mode, ie from -60° facing East to +60° facing West.
- From sunrise till 8:30am and from 3:45pm to sunset, the panels operate in "back-tracking" mode, starting at sunrise and ending at sunset in a horizontal position.
- Overnight, the panels are "stowed" in a fixed (in this case, -30°) position to minimise wind loading and ensure any moisture (dew or rain) does not pool on the panel overnight and cause increased soiling.

Figure 13 Example 24-Hour "Back-Tracking" Operational Mode (around equinox)



SGHAT has not evolved yet to deal with sophisticated “back-tracking” operational modes of the type shown in Figure 13. They can only simulate solar farm panel positions in the three simplified modes shown in Figure 12.

It will be appreciated therefore that care must be taken when comparing the glare predictions of simplified SGHAT-type simulation modes, such as those shown in Figure 12, with possible real-world reflectivity behaviour of operational panel modes as shown in Figure 13.

6 GLARE IMPACT ASSESSMENT - RESULTS

6.1 Aviation Sector Reflective Glare

Moree Airport (ICAO: YMOR, IATA: MRZ) is located to the southeast of the Project site, with the nearest southern boundary of the site approximately 2.3 km from the northern thresholds of its two runways. The aerodrome is serviced by scheduled aircraft (QantasLink), general aviation, agricultural support aircraft and helicopters.

- The aerodrome's 1,613 m asphalt Runway 01/19 is oriented roughly north-south.
- The aerodrome's 977 m gravel Runway 05/23 is oriented roughly northeast-southwest.
- The aerodrome does not have a control tower (and as far as is known to SLR, none is planned).

Figure 3 shows (landing) flight paths of interest:

- Aircraft using Runway 01 and Runway 05 (approaching from the south and southwest respectively) would have a line of sight towards the Project; however, reflections would emanate from the north with high-altitude (midday) angles – glare would be expected to be minimal or non-existent.
- Aircraft using Runway 19 and Runway 23 (approaching from the north and northeast respectively) would also have a line of sight towards the Project; in this instance, reflections would emanate from the west at relatively low-altitude (later afternoon) angles – accordingly, there would be potential for glare.
- Helicopter flight paths can be highly variable and landing approach paths in the direct line of sight of the Project are possible, although there is greater flexibility in adjusting helicopter flight paths if required.

On the basis of the above, 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 <u>landing scenarios</u> (worst-case with the pilot looking downwards).

The flights paths assessed for the Project are shown in Figure 3.

SGHAT Modelling Assumptions:

- All runway approaches shown in Figure 3 were examined.
- Landing flight paths are aligned with their respective runways.
- All aircraft landing flight paths are 2 miles in length, on a 3° glide angle (standard SGHAT protocol).
- The SGHAT analysis examines ALL possible solar angles throughout the year – in 1-minute intervals.
- The reflectivity of the PV panels was assumed to be the same as that shown in the standard solar glass shown in Figure 11.
- SGHAT simulations are run with two "height above threshold" values: 5m and 15m, to determine the worst-case result.

In terms of the relative heights above sea level (ASL) of flight paths and the solar farm:

- Ground elevations (ASL) of Amaroo Solar Farm range from 209 m to 211 m.
- Ground elevations below the various flight paths are in the range 210 m to 213 m.

From the above, it can be seen that the terrain in the vicinity of the Project is reasonably flat, with all surrounding receivers (residences, vehicles) at similar elevations compared to the solar farm.

A number of panel scenarios were assessed:

- "Normal Tracking": panels tilt ±60° about a north-south horizontal axis – this would be the normal operational mode for the solar farm;
- "Tracking + Stowed": panels tilt ±60° about a north-south horizontal axis and then rest for the remainder of the time at a fixed angle of 0°
- "Fixed Tilt": panels remain fixed at angles of 0° (horizontal) and ±15° – this is a scenario theoretically possible under a situation involving: shutdown, maintenance, pre-commissioning, etc

SGHAT Results – "NORMAL TRACKING ±60°"

The SGHAT Ocular Plots results for this scenario for all flight paths shown in Figure 3 are presented in Table 4, which shows the total number of minutes in a year that solar panel reflections would be potentially visible within any relevant SGHAT "zone" (refer Figure 7).

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 flight landing paths.

For all runways, the SGHAT analysis yields NO "Yellow" or even "Green" Zone results, hence no glare.

Table 4 SGHAT Analysis Results (No of Minutes Reflections are in SGHAT Zones)

Flight Landing Path (refer Fig.3)	SGHAT Results for "NORMAL TRACKING" ±60° Scenario		
	"Green" Zone	"Yellow" Zone	"Red" Zone
Runway 01	0	0	0
Runway 19	0	0	0
Runway 05	0	0	0
Runway 23	0	0	0

SGHAT Results – FIXED TILT Scenarios (20°, 10° West, 0° and 10°, 20° East)

The SGHAT Ocular Plots results for these scenarios for all flight paths shown in Figure 3 are presented in Table 5, which shows the total number of minutes in a year that solar panel reflections would be potentially visible within any relevant SGHAT "zone" (refer Figure 7).

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 flight paths.

For all runways, the SGHAT analysis yields NO "Yellow" Zone results, hence no glare.

Table 5 SGHAT Analysis Results (No of Minutes Reflections are in SGHAT Zones)

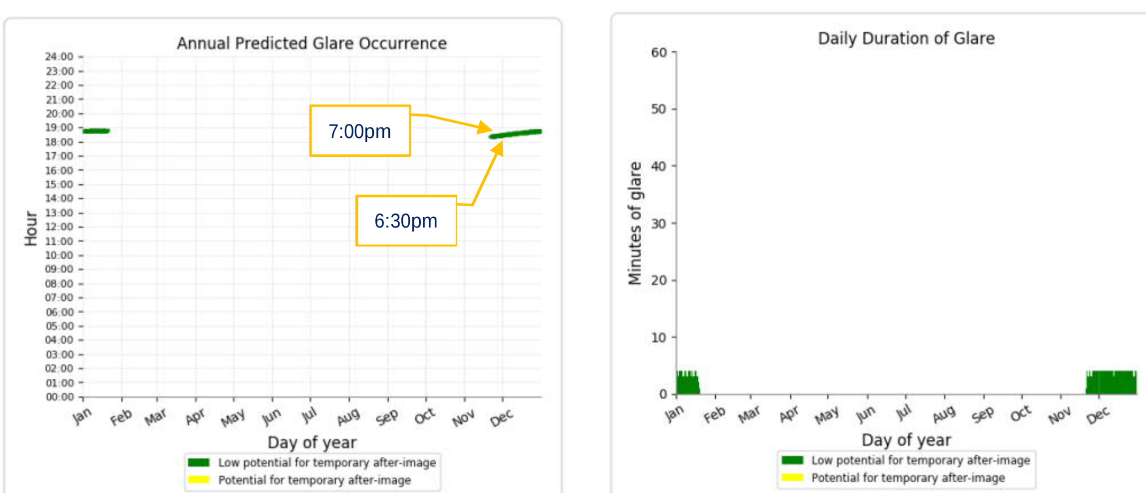
Flight Landing Path (Fig.3)	SGHAT Results for "FIXED TILT" Scenarios									
	30° West		15° West		0° (Horizontal)		15° East		30° East	
	Green Zone	Yellow Zone	Green Zone	Yellow Zone	Green Zone	Yellow Zone	Green Zone	Yellow Zone	Green Zone	Yellow Zone
Runway 01	0	0	0	0	0	0	0	0	0	0
Runway 19	0	0	0	0	226	0	0	0	0	0
Runway 05	0	0	0	0	0	0	0	0	0	0
Runway 23	0	0	0	0	225	0	214	0	257	0

Representative Results - 0° FIXED Tilt (ie FLAT) / Runway 19

Figure 14 shows representative reflection conditions occurring at different times of the year for Moree Airport Runway 19:

- Reflections are visible approximately one month either side of the summer solstice (ie mid-summer) in the late afternoon (low altitude solar rays); during this period, reflections are visible for periods ranging up to 4 minutes each day.

Figure 14 Selected SGHAT Results: FIXED TILT 0° (FLAT) Mode (Runway 19)



SGHAT Results – TRACKING + FIXED TILT 0° Scenario

The SGHAT Ocular Plot results for this scenario for all flight paths shown in Figure 3 are presented in Table 6, which shows the total number of minutes in a year that solar panel reflections would be potentially visible within any relevant SGHAT "zone" (refer Figure 7).

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 flight paths.

It can be seen that the SGHAT results for this scenario are identical to the results for the Fixed Tilt 0° (FLAT) scenario, indicating that visible reflections occur at the time that panels are in their flat, horizontal position (after the ±60° tracking period had finished).

As per the above scenarios, the SGHAT analysis yields NO "Yellow" Zone results, hence no glare.

Table 6 SGHAT Analysis Results (No of Minutes that Reflections are in SGHAT Zones)

Flight Landing Path (ref Fig.3)	SGHAT Results for "±60° TRACKING + 0° FIXED TILT" Scenario		
	"Green" Zone	"Yellow" Zone	"Red" Zone
Runway 01	0	0	0
Runway 19	226	0	0
Runway 05	0	0	0
Runway 23	225	0	0

Summary of SGHAT Results:

On the basis of the "±60° Normal Tracking" mode scenarios and all "Fixed Tilt" scenarios: 20°, 10° West, 0° (horizontal) and 10°, 20° East:

- Solar panel reflections (glint and glare) are acceptable according to the FAA-SGHAT protocol as there are NO "Yellow" Zone or "Red" Zone results for all aircraft flight landing paths.

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

The "major" and "minor" thoroughfares in the immediate vicinity of the Project are shown in Figure 4, including:

- Newell Highway – northbound and southbound "major"
  Gwydir Highway – eastbound "major"
- Amaroo Drive – westbound "minor"
  Boland Drive - westbound "minor"
  Jones Avenue– westbound "minor"
  Adelaide Street – westbound "minor"

The relevant TI criteria for the above roads would be:

- For (Motorist) Traffic Disability Glare, the TI Value should remain below 20 for “minor” roads and below 10 for “major” roads; and
- For Pedestrian Discomfort Glare, the TI Value should remain below 2 at pedestrian crossings and below 3 for other locations.

Important factors influencing the potential for traffic disability glare include:

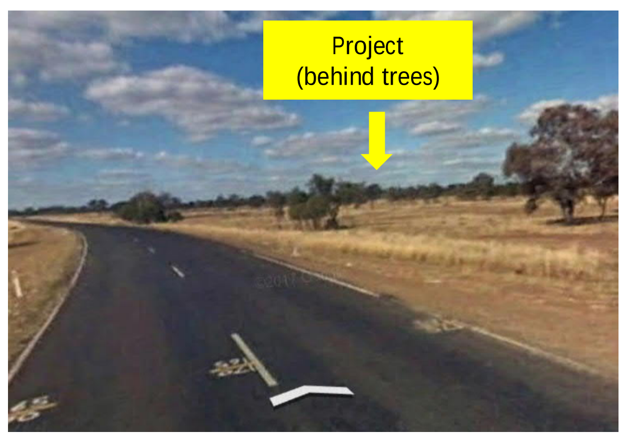
- Any difference in elevation between the motorist and the solar panel array;
- The potential for solar reflections of concern to be obstructed by intervening terrain and topography as well as dense vegetation;
- The difference between the line of sight of a driver (i.e. in the direction of the road) and the line of sight relative to incoming reflections. Significant TI values can only occur when this difference is small. In some cases, eg when traffic is moving away from the line of incoming reflections, such reflections become essentially invisible to the motorist – this would apply for example to traffic on the Gwydir Highway westwards out of Moree.

Figure 15 shows representative road glare scenarios examined for the Project site. The difference between the line of sight of a driver and the Project (and hence potential reflections) varies from modest, as in the case of Jones Avenue, to reasonable (i.e. not small) as in the case of the Gwydir Highway. In fact, for the Gwydir Highway, there are dense trees surrounding the Mehi River between the site and the highway (which can be seen in Figure 15) indicating that the line of sight for the Gwydir Highway is nil.

Figure 15 View of the Project from Surrounding Roads

Looking west from Jones Avenue

Looking east from the Gwydir Highway



SLR has undertaken TI Value calculations for the roadways discussed above. Calculation locations were varied along the relevant carriageways, focussing on positions where the line of sight of drivers was close to the angle of potential incoming solar reflected rays.

Table 7 shows the results for the standard "±60° Normal Tracking" mode.

Table 7 TI Value Results – Results for NORMAL TRACKING

Carriageway (class)	Direction	TI Value	Occurrence	
			Time of Year / Hour	Duration/Day
Newell Highway (major)	northbound southbound	nil nil	all-year-round all-year round	na na
Gwydir Highway (major)	eastbound	nil	all-year-round	na
Amaroo Drive (minor)	westbound	nil	all-year-round	na
Boland Drive (minor)	westbound	nil	all-year-round	na
Jones Avenue (minor)	westbound	nil	all-year-round	na
Adelaide Street (minor)	westbound	nil	all-year-round	na

The TI calculation results shown in Table 7 for "normal" tracking mode indicate the following:

- TI Values registered for ALL carriageways will be zero at all times of the year.

The reasons for this result are:

- Essentially the same elevation for motorists and the solar array panels; and
- The single axis trackers which support the panels – these cause outgoing reflections for all incoming solar angles to be redirected upwards away from the ground.

Table 8 shows combined results for three FIXED TILT scenarios, 10° West, 0° (flat) and 10° East.

The TI calculation results shown in Table 8 for the fixed tilt modes indicate the following:

- Reflections will NOT be visible from any surrounding carriageways for the 0° (flat) and 10° West Fixed Tilt angle scenarios.
- Reflections will be visible for the 10° East fixed tilt scenario but only for Jones Avenue westbound traffic. For this case, reflections will reach a TI Value at the limit for minor roads. However, the reflections will be visible for no longer than 1 minute per day all year round at around the time of sunset. At this time, these reflections will be visible from approximately the SAME angle as incoming solar rays. This would not constitute a "glare" condition.
- While the Jones Avenue westbound traffic condition would not "formally" be considered a glare condition, it is noted that leaving all solar panels either flat (0° tilt) or at a fixed tilt angle of 10° West would eliminate all visible reflections at all surrounding carriageways.

Table 8 TI Value Results –Results for FIXED TILT 0° (Panels Flat) Scenario

Carriageway (class)	Direction	TILT	TI Value	Occurrence	
				Time of Year / Hour	Duration/Day
Newell Highway (major)	northbound	10° West 0° (flat) 10° East	nil nil nil	all-year round	na
Newell Highway (major)	southbound	10° West 0° (flat) 10° East	nil nil nil	all-year round	na
Gwydir Highway (major)	eastbound	10° West 0° (flat) 10° East	nil nil nil	all-year-round	na
Amaroo Drive (minor)	westbound	10° West 0° (flat) 10° East	nil nil nil	all-year-round	na
Boland Drive (minor)	westbound	10° West 0° (flat) 10° East	nil nil nil	all-year-round	Na
Jones Avenue (minor)	westbound	10° West 0° (flat) 10° East	nil nil TI ~ 10	all-year-round all-year-round Jan to Dec, ~sunset	na na 1 min / day
Adelaide Street (minor)	westbound	10° West 0° (flat) 10° East	nil nil nil	all-year-round	na

6.3 Rail Operator Reflective Glare

Figure 5 shows the Mungundi Railway Line running through Moree is a general north-south direction. At its closes approach point, the line is over 2 km to the east of the site.

SLR has undertaken TI Value calculations for sections of the Mungundi Railway Line focussing on positions where the line of sight of train drivers was closest to the angle of potential incoming solar reflected rays.

- For ALL scenarios investigated - "±60° Normal Tracking", "Fixed Tilt" modes, etc, the TI Values for Disability Glare were NIL.

6.4 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 the kind of machinery where the relevant operators have the potential to experience reflective glare from the Project, eg elevated cabins in draglines, etc.

6.5 Residential "Nuisance" Glare

The nearest residential receivers to the Project are identified in Figure 6.

- They surround the site at varying distances from the nearest respective site boundary.
- Their ground elevations are similar to the Project, with only selected receivers minimally higher.
- Importantly, all "nearest" residential receivers are located to the EAST of the Project.
- There are also receivers to the north of the Project, but these receivers cannot be impacted by reflections from the Project as such reflections would have to originate from incoming solar rays from the south, a condition which does not exist – refer Figures 9 and 10.

There are no formal TI Value (or alternative) criteria governing reflective glare from solar facilities regarding residential receivers.

Accordingly, SLR has carried out TI Value calculations for the receivers discussed above, to gain an understanding of the potential for nuisance glare conditions from the project. The results are shown in Table 9.

Note that, in the ensuing computations, no advantage was taken of the vegetation present in the area. Examples of this vegetation are shown in Figure 16.

Figure 16 Vegetation Examples Surrounding the Project Site

Residences Located Southeast of the Site

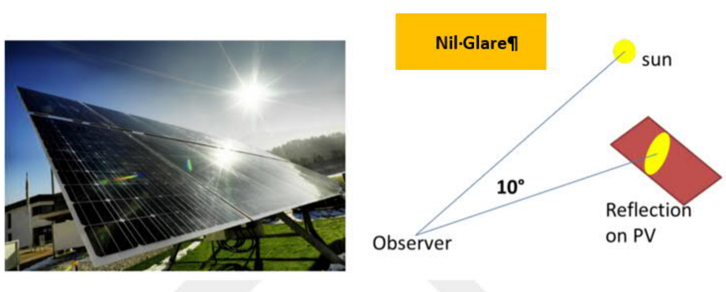
Table 9 TI Value Results – Residential Receivers

Scenario	Receivers (refer Figure 6)	TI Value	Occurrence	
			Time of Year / Hour	Duration/Day
±60° Normal Tracking	RR1 to RR10	nil	all-year-round	na
Fixed Tilt 10° WEST	RR1 to RR10	nil	all-year-round	na
Fixed Tilt 0° (flat)	RR1-2, RR5-8 RR3, RR4	Up to TI ~ 3 up to TI ~ 6	6 months / late afternoon 12 months / late afternoon	2-4 min /day 5-10 min /day
Fixed Tilt 10° EAST	RR1-2, RR5-9 RR3, RR4	Up to TI ~ 3 up to TI ~ 6	6 months / late afternoon 12 months / late afternoon	2-4 min /day 5-10 min /day

The results indicate the following:

- For the standard operational "±60° Normal Tracking" mode and the Fixed Tilt 10 West scenario, TI Values were NIL at all receivers.
- For the FIXED TILT 10° East and FIXED TILT 0° (flat) scenarios, reflections will be potentially visible for a number of receivers to the east of the site, for periods ranging from 6 to 12 months of the year and up to 10 minutes per day. The associated TI Values are potentially highest at Receivers RR3 and RR4, the closest receivers due east of the Project.
- Note that these reflections all occur late in the afternoon, where visible reflections would be roughly in the same line of sight as the incoming solar rays themselves – this would not constitute a glare condition – as is shown in Figure 17, although as previously noted there are no actual criteria governing the acceptability or otherwise of such glare conditions.
- Note also that the above computations did not take into account the blockage provided by vegetation, trees, etc (refer Figure 16).

Figure 17 Nil Glare Condition for Residential Nuisance Glare



If it is intended to avoid all potential residential glare issues (e.g. if the mere visibility of reflections was to cause an issue within the surrounding community) the following options are recommended:

- Avoid fixed tilt scenarios for either 0° Tilt (flat) or EASTwards Tilt all-year-round. If it is necessary to leave panels in a close to horizontal position (e.g. during construction, for maintenance, etc) leave panels with a slight tilt WESTwards (minimum 10° west).

6.6 Night-Time Illumination Glare

Although presently not fully defined, it is assumed that an area within the Amaroo Solar Farm Project site will be set aside for an Operation and Maintenance buildings, power conversion unit, fire access routes and egress, etc, and that some of these may need to be operational 24/7.

Although night-time illumination is not presently planned for the Project, it may be required in the future for some of the above relevant areas and, as such, is addressed in principle in this assessment.

The only potential for any future night-time illumination glare would be associated with the nearest thoroughfares and residential and other sensitive receivers to the Project. Consideration has also been given to the potential for adverse eco-lighting impacts on nocturnal fauna habitats in close proximity to the Project site, especially within any close-by native vegetation areas. On the basis of the Flora and Fauna Assessment Report carried out for the Project, there are no such habitats close to the Project site.

The recommendations set out below are therefore made in the event that future 24/7 lighting is incorporated into the Project, to achieve the best lighting performance (taking into account safety considerations) while having a minimal impact on the surrounding properties, carriageways and nocturnal fauna.

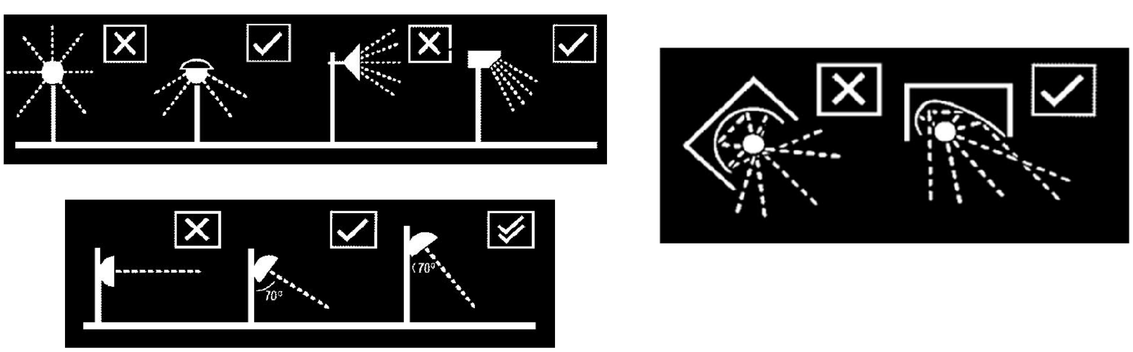
In terms of any future potential night-time lighting, the adopted goal of limiting night-time light spill to no more than 2 lux falling on the nearby residential facades during curfew hours will be easily achieved given the distances to the nearest residential and other receivers.

Accordingly, the potential for any future 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 18.
- 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 18 Luminaire Design Features that Minimise Light Spill



7 CONCLUSION

SLR Consulting Australia Pty Ltd (SLR) has been engaged to carry out a Reflective Glare assessment of the proposed Amaroo Solar Farm (the “Project”) under development by Providence Asset Group. The proposed (up to) 5 MWac facility will comprise 13,524 solar PV panels within a 15 ha project site area. The 540W panels, measuring approximately 2.26 m by 1.13 m, will be installed on single-axis trackers oriented north-south with a spacing of 6.4 m. The Project is located on the outskirts of the township of Moree and in relatively close proximity to Moree Airport.

The following potential glare conditions have been considered:

- Daytime solar panel Reflective glare (and glint) and Night-time Illumination glare.

Aviation-Related Potential Glare

Quantitative analysis using the FAA-SGHAT software tool has shown that there will be nil glare from the Project at Moree Airport with the solar array in normal tracking mode, i.e. panels tilting ±60°.

If the facility’s panels are left horizontal (i.e. flat), reflections in the SGHAT “Green” zone, which is an acceptable outcome for aviation glare, are likely to be perceived on Runways 19 and 23. Leaving the solar array with a fixed westwards tilt angle of at least 10° eliminates all reflections completely.

Motorist, Rail Traffic and Residential Glare

There will also be nil glare from the Project in relation to road traffic, rail traffic and surrounding residential receivers under the standard operational ±60° tilt angle scenario.

There is potential for reflection visibility to nearby residential receivers if solar panels are left in a fixed tilt horizontal or with a slight eastwards tilt (eg for maintenance, during construction, under back-tracking mode, etc). This is predicted for several residential receivers located east of the site, although it is noted that this is a conservative estimate, as the predictions did not take into account the benefit of landscaping, trees, etc, in the vicinity of these residences. Again, leaving the solar array with a fixed westwards tilt angle of at least 10° eliminates all of these potential reflections completely.

Night-Time Illumination Glare

Night-time lighting is not currently incorporated into the Project. If 24/7 lighting is required in the future for operational purposes, there should be negligible impact, assuming the lighting design is in accordance with AS 4282-1997 Control of the Obtrusive Effect of Outdoor Lighting. This would also address any potential adverse eco-lighting issues in relation to nocturnal fauna within and surrounding the site, although, as far as is known, no biodiversity issues have been identified in relation to the Project. Any future lighting design should also be checked against CASA’s NASF Guidelines (E & F).

ASIA PACIFIC OFFICES

BRISBANE
Level 2, 15 Astor Terrace
Spring Hill QLD 4000
Australia
T: +61 7 3858 4800
F: +61 7 3858 4801

CANBERRA
GPO 410
Canberra ACT 2600
Australia
T: +61 2 6287 0800
F: +61 2 9427 8200

DARWIN
5 Foelsche Street
Darwin NT 0800
Australia
T: +61 8 8998 0100
F: +61 2 9427 8200

GOLD COAST
Ground Floor, 194 Varsity Parade
Varsity Lakes QLD 4227
Australia
M: +61 438 763 516

MACKAY
21 River Street
Mackay QLD 4740
Australia
T: +61 7 3181 3300

MELBOURNE
Suite 2, 2 Domville Avenue
Hawthorn VIC 3122
Australia
T: +61 3 9249 9400
F: +61 3 9249 9499

NEWCASTLE
10 Kings Road
New Lambton NSW 2305
Australia
T: +61 2 4037 3200
F: +61 2 4037 3201

PERTH
Ground Floor, 503 Murray Street
Perth WA 6000
Australia
T: +61 8 9422 5900
F: +61 8 9422 5901

ROCKHAMPTON
rockhampton@slrconsulting.com
M: +61 407 810 417

SYDNEY
2 Lincoln Street
Lane Cove NSW 2066
Australia
T: +61 2 9427 8100
F: +61 2 9427 8200

TAMWORTH
PO Box 11034
Toowoomba NSW 2340
Australia
M: +61 408 474 248
F: +61 2 9427 8200

TOWNSVILLE
Level 1, 514 Sturt Street
Townsville QLD 4810
Australia
T: +61 7 4722 8000
F: +61 7 4722 8001

AUCKLAND
68 Beach Road
Auckland 1010
New Zealand
T: +64 27 441 7849

NELSON
5 Duncan Street
Port Nelson 7010
New Zealand
T: +64 274 898 628

NEW PLYMOUTH
Level 2, 10 Devon Street East
New Plymouth 4310
New Zealand
T: +64 0800 757 695