BOGGABRI SOLAR FARM

Visual Analysis, Landscape Concept and Reflectivity Statement

Prepared for:

Providence Asset Group

704/99 Bathurst Street, SYDNEY NSW 2000

SLR Ref: 631.00000-20399 Version No: -v0.2 December 2020

PROJECT NAME

Location	Lot 151 DP1048145 211 Vine Lane, Boggabri NSW 2382
Project Number	631.00000.20399
Client	Providence Asset Group

PREPARED BY

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Reference	Date	Prepared	Checked	Authorised
620.00000.20399-v0.1	10 December 2020	Dallas Ellis	Dean Butcher	Dean Butcher
620.00000.20399-v0.2	16 December 2020	Dallas Ellis	Dean Butcher	Dean Butcher

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1. INTRODUCTION

1.1 Background

This Visual Analysis and Landscape Concept has been prepared for the proposed Solar Farm near Boggabri, NSW.

This visual analysis assessment has been prepared to provide an effective and objective assessment of the anticipated high level impacts of the project on the surrounding visual environment.

SLR has worked closely with other members of the project team in determining and rating visual impacts of the proposed solar farm project works on its immediate surrounds as well as suggesting mitigation measures to further reduce any impacts that may occur.

There are 3 parts to this report.

- Visual Analysis
- Reflectivity Analysis and
- Landscape Concept

1.2 Site Location

The land on which the Solar Farm is located (the subject site) for the proposed Solar Farm (the project) is situated approximately 2.4km north east of the township of Boggabri, NSW.

The site is located at 211 Vine Lane, Boggabri NSW 2382. The proposed development will consist of solar panels mounted on single-axis trackers connected to a power conversion station with an access and hardstand area from Vine Lane. The development will be confined to Lot 151 DP755475 (**Figure 1**).

Figure 1. Locality Plan

2. BASELINE VISUAL ENVIRONMENT

2.1 Subject Site and Surrounding Context

The subject site is located on the western side of Vine Lane, Boggabri and is a typically open grassed rural site, similar to those rural properties surrounding it. The site falls generally from northwest to southeast from approximately AHD 267m to AHD 254m.

2.1.2 Roads and Access

The subject site is accessed by one road, Vine Lane which is unsealed and is aligned to the east of the subject site and parallel to the railway line adjacent to the site. The Kamilaroi Highway (B51) is located approximately 1km to the east of the subject site. It is a sealed classified state highway and joins Boggabri to the south. There are a number of other local and unsealed roads to the east and south of the subject site.

2.1.3 Vegetation

The subject site is largely cleared of vegetation (trees and shrubs), except for scattered trees on the northern side of the proposed Solar Farm lease area and trees along the existing creek line to the south of the proposed Solar Farm. There are also a number of established medium sized trees along Vine Lane adjacent to the proposed Solar Farm.

2.1.4 Structures

There are no structures on the subject site. The existing residential dwelling on the western side of the proposed Solar Farm is single storey and has a number of smaller, residential scale ancillary structures around it.

2.1.5 Infrastructure

Apart from Vine Lane, the only other relevant infrastructure in the vicinity of the subject site is the Rail Line to the east and power poles and lines also to the east adjoining Vine Lane.

3. LANDSCAPE CHARACTER ANALYSIS

3.1 Regional Context

The landscape character of the region surrounding the site is typically flat, open rural lands used for a mix of pastoral and agricultural uses. Whilst the vegetation is sparse on the agricultural lands, it is typically concentrated on the elevated local hills surrounding the site on the north, east and western sides. Although not as prominent as the vegetated hills in the region, vegetation along the Namoi River and local tributaries and creek lines also contributes to the local rural character.

3.2 Baseline Visual Character of Subject Site and Surrounds

The subject site is typical of the rural landscape character of the region in that it is open, generally flat and grassed (minimal tree coverage). As the size of the site is small in the context of its surrounds, it utilises the 'borrowed landscape' of the adjoining rolling hills to define its visual context and define local views. The vegetation on the hills provides the local visual context a more vegetated feel when viewing the site from the south and east. When viewed from the north the site appears more exposed without the benefit of the hills that terminate local views.

4. PROPOSAL

4.1 Project Description

A full description of the proposal is provided within the main Statement of Environmental Effects and site plans, but a brief description is as follows. Section 4.1.1 identifies key elements of the proposal that are of particular relevance to an assessment of impacts on the visual analysis

4.1.1 Indicative project Layout

The solar electricity generating facility will consist of the following elements:

- Solar array area of approximately 8.8 hectares within a total fenced area of approximately 12 hectares
- Solar array mounted on trackers (153 sets)

- Rectangular photovoltaic module
- Trackers area horizontal single-axis type
- Solar array up to 2.6m high with +/-60° rotation angle
- Trackers orientated north - south

- Associated infrastructure

- Power Conversion Station (PCS)
- Site access from Vine Lane via a 4m wide road
- Security fencing
- Car park area
- Off-load and hardstand area

- Onsite stormwater detention basin

During construction, temporary facilities located within the site may include:

- Construction office

4.1.2 Solar panel dimensions and arrangement

The proposed solar array module dimensions are approximately 1.1 m wide x 2.3m high. They are mounted on a tracking system that will maximise the electricity production. The tracking system rotates about a north-south axis to follow the sun with the aim of orienting each panel to be as close to perpendicular as possible to the incoming sun.

The tracking systems will be arranged in rows running in a north-south direction as indicated in **Figure 2** The enclosure for the solar panel arrays and associated equipment will cover approximately 12Ha.

The diagram in **Figure 2.1** illustrates the dimensions and rotation of the panels. The panels only rotate from east to west and are not tilted toward the north.

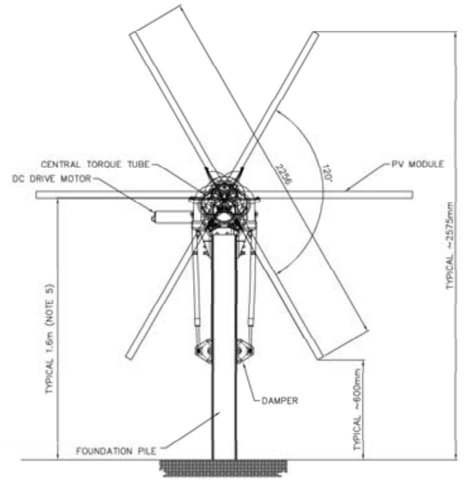


Figure 2.1 Solar panel / tracking system

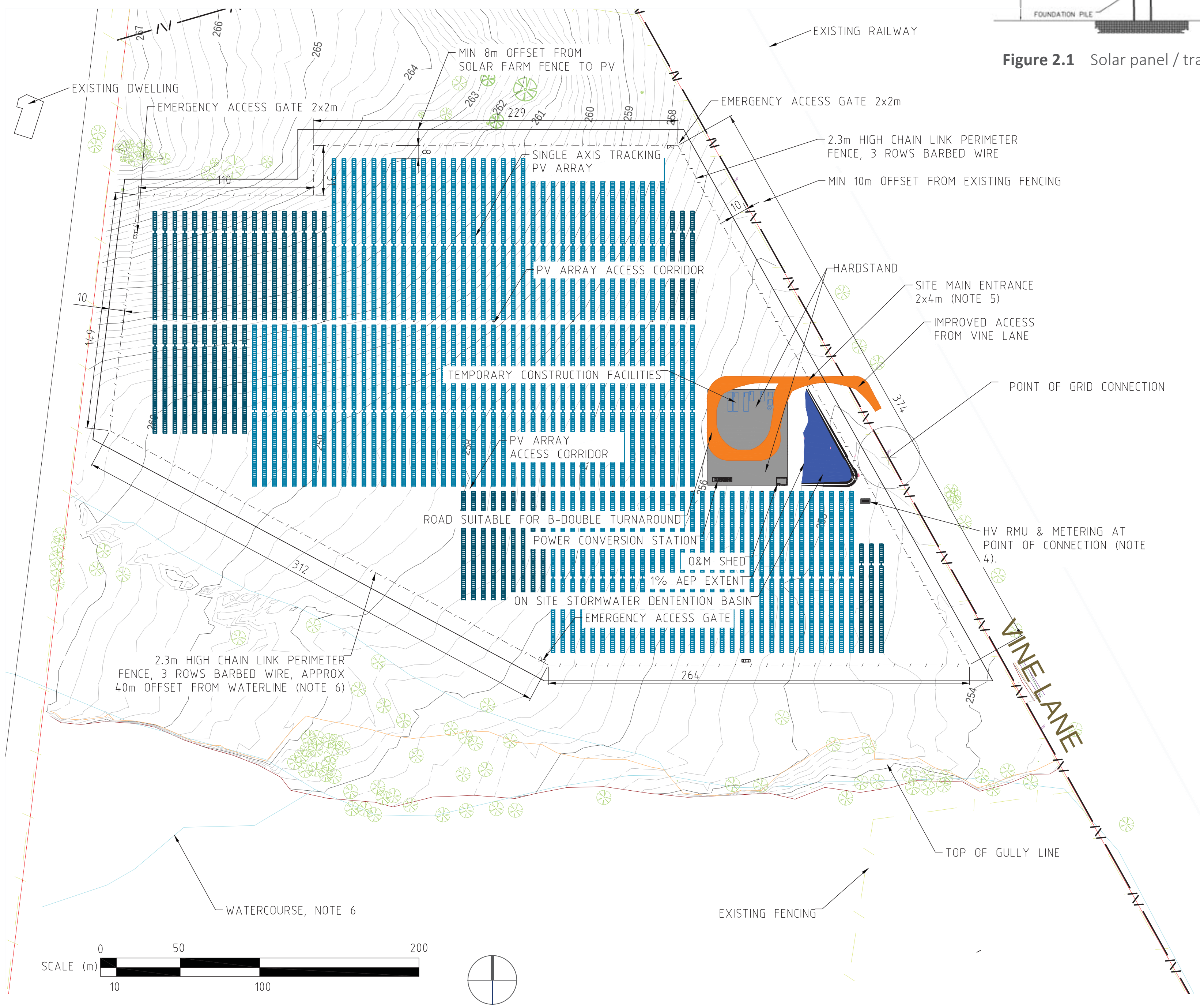


Figure 2. Concept layout of the project

5. VISUAL IMPACT ASSESSMENT

5.1 Process

The Visual Impact Analysis generally applies the assessment techniques set out in the 'Guidelines for Landscape and Visual Impact Assessment, Third Edition' (2013) prepared by The Landscape Institute and the Institute for Environmental Management and Assessment (UK).

The analysis includes the following:

- Review of the proposal (scale, bulk, height, technical specifications and landscape);
- Analysis of the subject site (visual exposure, visual qualities and landscape values);
- Identification of potential impacts on key receptors including the rating of magnitude for each receptor group;
- Rating of impact significance for each receptor group.
- The significance is evaluated as a product of the sensitivity or value of the receptor, and the magnitude of impacts on the receptor; and
- Potential mitigation measures to meet the necessary planning requirements and any community expectations.
- The report included a desktop analysis and a visual site investigation in November 2020. The desktop review included the review of aerial photography, site topography and vegetation cover.

Photo-montages were also prepared to inform the analysis.

5.2 Assessment of Visual Impacts for Key Receptors

Photographic imagery was taken of the site to assist in the assessment of visual impacts. Photos were taken with a Canon EOS 6D Mark II digital single-lens reflex (DLSR) camera with a 50 mm lens.

Three photomontage images were prepared to assist in the Visual Analysis process; all from public receptor points.

The receptors used in the photomontage were selected to investigate a range of visual solutions and illustrating views from areas of perceived sensitivity. During the site investigation, local areas around the site were observed to determine the potential visibility of the proposed Solar Farm.

For the purposes of this Visual Analysis a Photomontage image was produced from each of the three viewpoints chosen. The approximate extent of the proposed Solar Farm has been identified to give a general impression of the location on site and the approximate height.

The Photo montage Images are represented in Section 5.8 and show the following overlays of information.

- Existing visual baseline (existing landform);
- Overlay of the final solar farm proposed development

5.3 Receptor Sensitivity

The receptor sensitivity is derived from a combination of factors including:

- Receptors interest in the visual environment (high, medium or low interest in their everyday visual environment and the duration of the effect);
- Receptors viewing opportunity (prolonged, regular viewing opportunities); and
- Number of viewers and their distance/ angle of view from the source of the effect, extent of screening/ filtering of view.

Whilst the assessment of visual values and effects is largely measured on a qualitative basis, assessment against scale enables a more objective evaluation and comparison of sensitivity of receptors and magnitude of effects. The Receptor Sensitivity Rating is described as being High, Medium, Low or Negligible as described in **Table 1.**

5.4 Magnitude of Landscape Change

The Magnitude of Change to the landscape character depends on the nature, scale, intensity, extent and duration of the impacts/ change due to proposal. The magnitude of change also depends on the loss, change or addition of any feature to the existing landscape and is based on the character type that is most likely to be impacted by the project prior to the addition of any mitigation measures.

The Magnitude of Change is described as being High, Medium, Low or Negligible as described in **Table 2**.

Descriptions of Magnitude and Sensitivity are illustrative only and there is no defined boundary between levels of impacts.

Table 1. Receptor Sensitivity Rating

Receptor Sensitivity	Description
High	• Visitors to heritage sites, regionally important locations, scenic routes, lookouts within 2.5km with quality views, important views of the site and surrounding areas where landscape is the specific focus. • High numbers of visitors • Views to landscape that are rare and or unique and are possibly vulnerable to change • Views from residences within 1km of the site or are representative of high quality views
Medium	• Travellers/visitors along roads or rail routes that are not scenic routes but offer quality views within 2.5km of the site • Medium numbers of visitors/ residents (rural communities or townships) • Views that are representative of local character or sense of place but are not rare or unique • Views from residences beyond immediate vicinity (1km-5km) of the site or are representative of moderate quality views • Recreational users/ viewers beyond 2.5km from the site with moderate interest in their surrounds
Low	• Travellers/visitors along roads or rail routes that are not scenic routes but offer reasonable views within 4km of the site • People at place of work where setting or views not important to quality of working environment • Recreational users not dependent on views or scenic quality of landscape • View experience takes in broad context with which site is visible but not an important element. • Small numbers of visitors with passing interest in their surroundings (those travelling along mid-level roads) • Viewers whose interest is not specifically focused on landscape or scenic qualities (commuters, workers)
Negligible	• Very occasional or low level of users with passing interest in their surrounds (those travelling along minor roads or views from the air) • Travellers/visitors along unsealed roads offering views greater than 4km of the site

5.5 Impact of Significance on Landscape Character

The Impact Significance is evaluated according to 2 key criteria as noted above and is reflected in **Table 3.**
The rating is a means of comparing impacts on different receptors. Professional judgement and experience have been applied in order to identify the level of significance for each character type which has been assessed on its own merits.

- The sensitivity of the receptor or existing landscape; and
- The magnitude of the change or impact that is likely to occur.

The process of assessment and the use of the ratings tables reflect typical outcomes for visual impacts.

- Impacts on receptors that are particularly sensitive to change in views and visual amenity are more likely to be significant.
- Impacts that constitute a substantial change to the visual environment are likely to be more significant than the impacts that do not cause substantial change.

5.6 Summary of Potential Landscape Character Impacts

The following sheets summarise the assessment of impacts on each of the identified visual receptor groups.

Three representative viewpoints were identified where the site could be seen preferably from public locations. Due to the distances from the site, presence of topographic and vegetated features, surrounding structures and the limited views from publicly accessible areas, the choice of viable views was limited. The following sheets describe and rate the sensitivity of each viewpoint, the nature and magnitude of impacts likely to occur and the resultant significance of impacts for each receptor.

Typically views to the site from local roads and other public locations in the area were very limited. Photos from each receptor are provided and photomontages prepared to show how the proposed Solar Farm will be perceived from that particular viewpoint. Mitigation measures have been included where appropriate.

Table 2. Magnitude of Change

Magnitude of Change	Description
High	Dominant Change • Major change in view at close distances, affecting substantial part of the view continuously visible for a long duration or obstructing a substantial part or important elements of the view • Overwhelming loss or additional features in the view such as the nature of view or character of landscape fundamentally changed • Views to key landscape features affected • Visual amenity of local residents or road users substantially diminished • Substantial change to the landscape due to loss of and or change to elements, features or characteristics of the landscape creating an overall worsening of landscape quality
Medium	Considerable Change • Clearly perceptible changes in views at intermediate distances resulting in either distinct new element in a significant part of the view or a more widely ranging, less concentrated change across a wider area • Significant loss or addition of features in the view, such that nature of view or character of landscape is altered • Noticeable contrast of any new features in the view such that the nature of the view or landscape character is changed • Noticeable contrast of any new features or changes compared to existing landscape • Views to key landscapes partially obstructed but views remain intact
Low	Noticeable Change • Minor memorable change to the landscape or views • Temporary or reversible impact • Landscape dominant element and built form/ development well integrated within it • Little permanent change or no fundamental change to local landscape character
Negligible	Barely Perceptible Change • No memorable or rarely perceptible change to landscape character or key views

Table 3. Effect Significance Rating

Receptor Sensitivity	Magnitude of Change in Landscape			
	High (Dominant Change)	Medium (Considerable Change)	Low (Noticeable Change)	Negligible (Barely Perceptible Change)
High	High	Moderate-High	Moderate	Minor-Moderate
Medium	Moderate-High	High	Minor-Moderate	Minor
Low	Moderate	Minor-Moderate	Minor	Minor-Negligible
Negligible	Minor-Moderate	Minor	Minor-Negligible	Negligible

5.6.1 Selected Viewports

Figure 3. Selected Visual Receptors and Direction of View

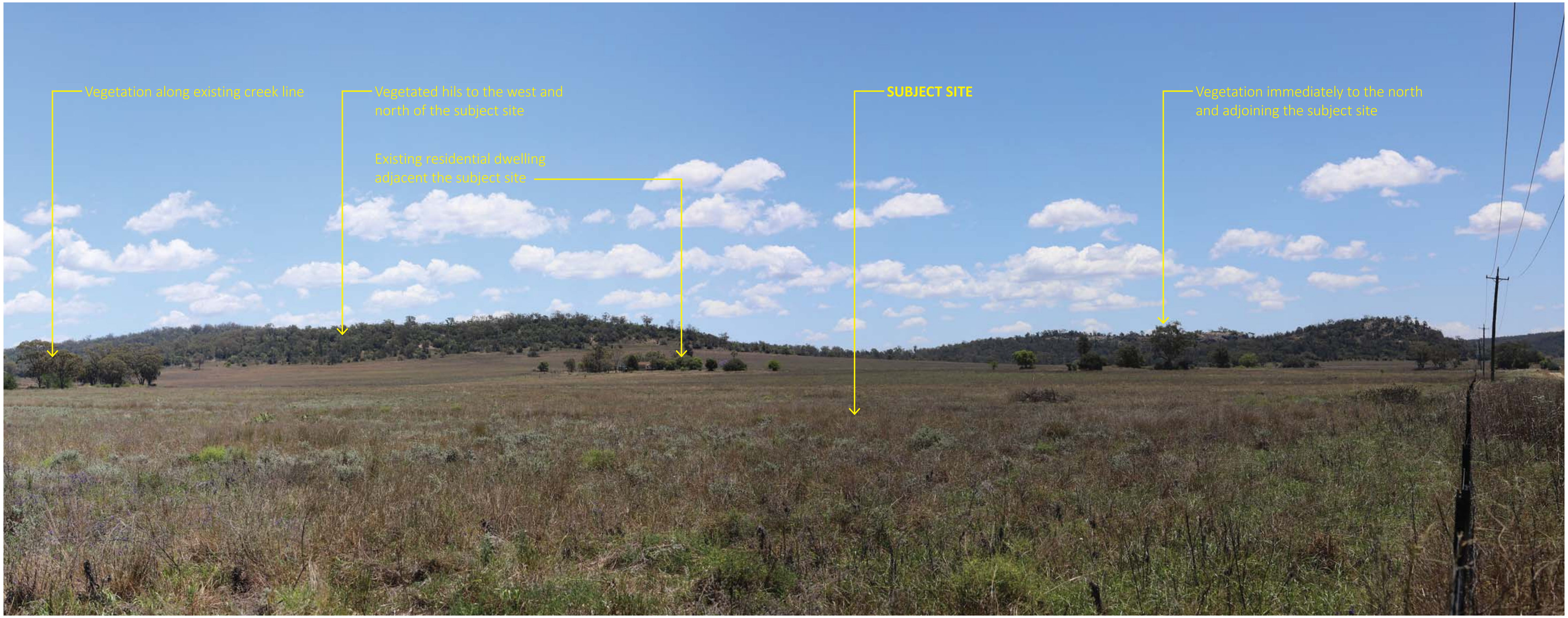
5.6.2 Viewpoint 1 - Existing

Receptor - VP1	Kamilaroi Highway, Boggabri
Coordinate Location	30°40'39.756" S 150°2'26.232" E
View Description	View from the Kamilaroi Highway looking west toward the solar farm site.
Distance from Site	approx. 1km
Comments • Open rural (pastoral) landscape, with minimal canopy vegetation in the foreground is a dominant landscape character type in the region • Vegetated hills to the north and west of the subject site from this viewpoint are clearly visible and terminate views.	

5.6.3 Viewpoint 1 - Proposed

Receptor - VP1	Summary of Impact Assessment
Receptor Sensitivity	Medium
View Magnitude of Landscape Change	Low
Impact Significance	Minor - Moderate
Mitigation Measures	• Possible shrub planting (native species to 3m) outside of security fence and within the lease boundary on the eastern side only that screens (or primarily screens) views from the viewpoint.

5.6.4 Viewpoint 2 - Existing



Receptor - VP2	Vine Lane, Boggabri
Coordinate Location	30°40'35.226" S 150°1'46.584" E
View Description	View towards the site from Vine Lane.
Distance from Site	approx. 50m

Comments

- Open rural (pastoral) landscape, with minimal canopy vegetation in the foreground is a dominant landscape character type in the region
- The site slopes up gently from Vine Lane towards the vegetated hills

5.6.5 Viewpoint 2 - Proposed

Receptor - VP2 Summary of Impact Assessment	
Receptor Sensitivity	Negligible
View Magnitude of Landscape Change	Medium
Impact Significance	Minor
Mitigation Measures	• Possible shrub planting (native species to 3m) outside of security fence and within the lease boundary on the eastern side only that screens (or primarily screens) views from the viewpoint.

5.6.4 Viewpoint 3 - Existing

Receptor - VP3	Vine Lane, Boggabri
Coordinate Location	30°40'18.21" S 150°1'37.488" E
View Description	View from Vine Lane, looking south into the solar farm site
Distance from Site	Approx. 180m
Comments • Views south terminated by local topographic features and creek line vegetation	

5.6.5 Viewpoint 3 - Proposed

Receptor - VP3	Summary of Impact Assessment
Receptor Sensitivity	Negligible
View Magnitude of Landscape Change	Minor
Impact Significance	Minor - Negligible
Mitigation Measures	• Possible shrub planting (native species to 3m) outside of security fence and within the lease boundary on the eastern side only that screens (or primarily screens) views from the viewpoint.

5.6.4 Viewpoint 4 - Existing

Receptor - VP4	Caloola Road, Boggabri
Coordinate Location	30°41’46” S 150°1’38” E (Approx)
View Description	View from Caloola Road, looking north into the solar farm site past rural landscapes
Distance from Site	Approx. 2200m

Comments

- Views south terminated by topographic features (hills in the background). Generally open views with scattered vegetation.

5.6.5 Viewpoint 4 - Proposed

Receptor - VP4	Summary of Impact Assessment
Receptor Sensitivity	Low
View Magnitude of Landscape Change	Low
Impact Significance	Minor
Mitigation Measures	• No mitigation measures required for this viewpoint.

6. SUMMARY OF ASSESSMENT

6.1 Summary of Assessment

The visual environment for the subject site and surrounding area is characterised by open, flat rural land.

Whilst, the subject site itself has been cleared of tree vegetation, heavy stands of existing tree vegetation located on the elevated hills to the north, east and west of the site contribute to the natural rural character of the area.

Although the subject site is located within a relatively short distance from Boggabri, views of the existing site from public viewpoints are very limited due to the presence of obstructions such as topographic features, vegetation and built elements. The only views from public viewpoints as described within the report were from the Kamilaroi Highway, Caloola Road and Vine Lane.

The nature of the array as outlined above including its height have meant that the relative visual impacts of the Solar Farm are generally low, especially given the distance from most notable public vantage points.

The relative distance of the receptors from the site as viewed from the Kamilaroi Highway as well as the speed being travelled would, mean that views would be relatively distant and of short duration. Because of the scale of the solar farm in relation to the overall landscape surrounding the site the degree of change could be considered relatively low.

The views form Vine Lane whilst representing a moderate change to the landscape could be considered to have a low impact significance primarily based on the low number of public visitations along the road and the resulting lower level of significance of the views.

Based on the appraisal and findings of this Visual Analysis it can be considered that the proposed Boggabri Solar Farm Project would have a 'minor' visual impact rating on the existing landscape character of the site and its local context.

Table 4. Summary of Visual Impact Ratings for each Receptor

Magnitude of Change in Landscape			
VP1	Low	Low	Minor
VP2	Negligible	Medium	Minor
VP3	Negligible	Minor	Minor

6.2 Mitigation Measures

As described in the summary for each of the 4 viewpoints, the height and nature of the proposed solar farm and the distance from public vantage points with a moderate level of users would therefore dictate that mitigation measures would only be required on the eastern side of the development.

Given the relatively low height of the Solar Farm, the informal planting of native shrubs to compliment the existing rural landscape character along the Vine Lane (eastern) side of the lease area, outside of the fence line would assist in minimising any visual impacts of the development on the surrounding rural landscapes. The planting of trees directly adjoining the solar farm would not be encouraged due to the potential for shadows to be cast over the array during certain times of the day.

Whilst this planting will help screen the Solar Farm as viewed from the Kamilaroi Highway, its benefits will be of lesser value to those viewpoints along Vine Lane.

7. REFLECTIVE GLARE

7.1 Glare Conditions Assessed

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" Reflective Glare and Pedestrian "Discomfort"
- Reflective Glare;
- Rail Operator Reflective Glare;
- Industrial critical machinery operators (heavy vehicles, etc.) Reflective Glare; and
- Residential "Nuisance" Glare
- Night-time Illumination glare if any 24/7 security lighting is incorporated into the Project in the future; none is currently planned.

7.2 Key Project Characteristics Relevant to Glare

The proposed solar array would consist of 153 trackers oriented in a north-south direction, each supporting either 52 or 84 x 540W solar panels (11,648 panels in total);

- The trackers are "single-axis" capable of rotating solar panels to a maximum of ±60° - **refer Figure 4**;
- Individual panels (2.3 m x 1.1 m) reach a maximum height above ground of 2.57 m at their full 60° tilt angle; and
- The trackers are oriented north-south and spaced 6.25m apart.

7.3 Receivers and Associated Impacts

The issues of concern assessed in this study in relation to daytime reflective glare and night-time illumination glare are detailed below – **refer Figure 5** for receivers of interest.

7.3.1 Aviation-Related Glint & Glare

Potential impacts on pilots during landing and air traffic control tower operations (if relevant).

7.3.2 Traffic Disability & Pedestrian Discomfort Glare

Potential impacts on motorist disability glare and pedestrian discomfort (relevant to pedestrian crossings).

7.3.3 Train Driver Disability Glare

Potential impacts on train operator's activities, eg reflections obscuring railway signals.

7.3.4 Industrial Critical Machinery Operators

Potential impacts on operators of critical industrial machinery, eg mining draglines.

7.3.5 Residential Nuisance Glare

Potential impacts on surrounding residences in relation to "nuisance" glare and light spill from night-time illumination (if relevant)

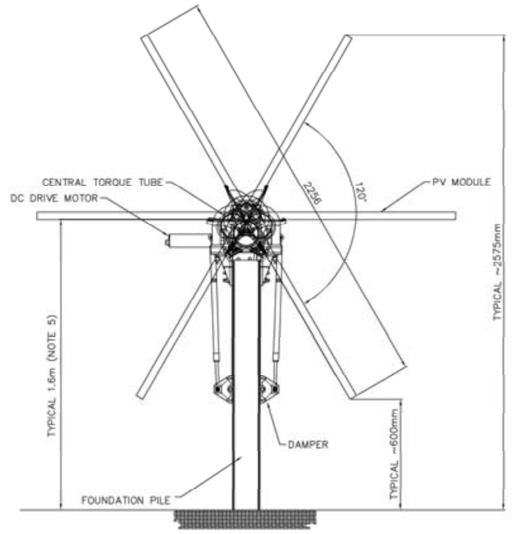


Figure 4 Boggabri Solar Farm Single-Axis Trackers

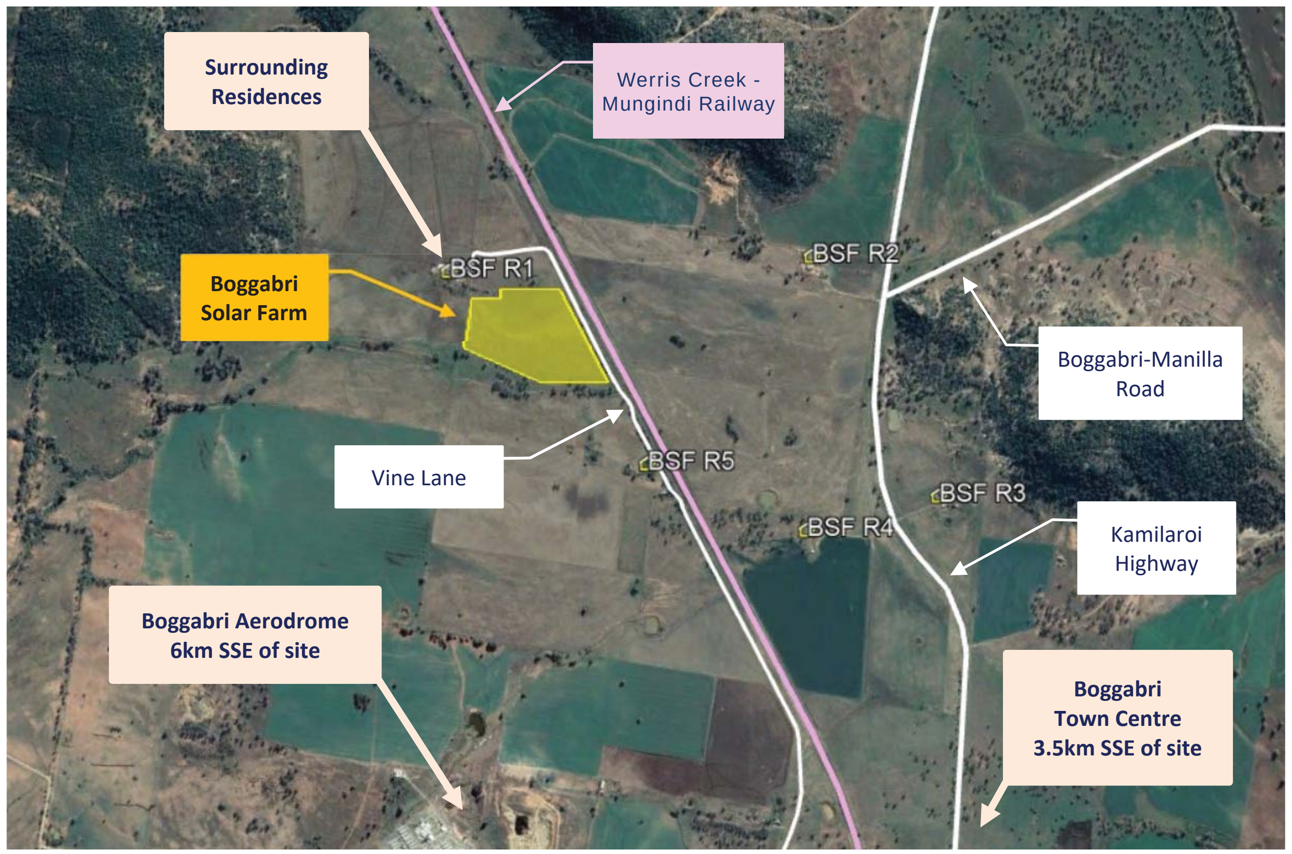


Figure 5 Surrounding Receivers of Interest

7.4 Glare Criteria

7.4.1 Aviation-Related Glint & Glare

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.

- 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. SGHAT utilises the Solar Glare Ocular Hazard Plot to determine and assess the potential for glare.

A sample SGHAT Ocular Hazard Plot is shown in **Figure 6.** 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
- Final approach paths for landing aircraft: Glare to NOT exceed "Low Potential for After-Image"

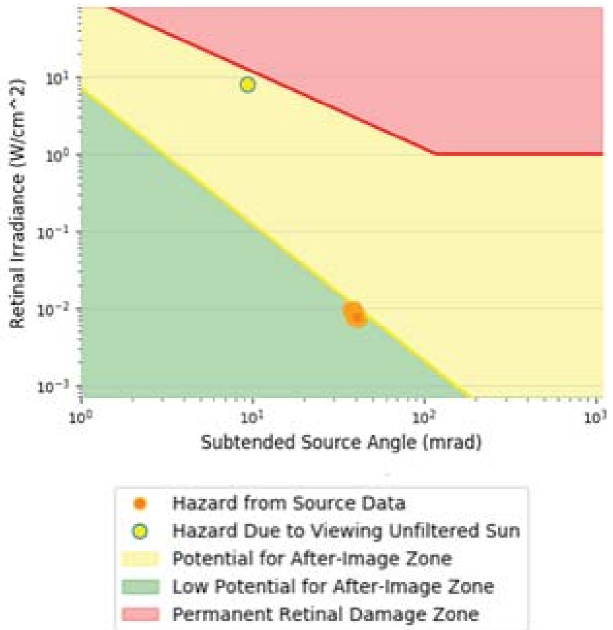


Figure 6 Example SGHAT Plot

In **Figure 6**, 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).
  - 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.
- 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" can occur for example 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.
- The SGHAT plot also provides an indication of the relative intensity of the sources of light itself (ie the sun) – refer the **green** circle in the plot.
- Finally, in relation to PV Solar facilities, it is important to note that a "RED" category outcome is **not possible**, since PV modules DO NOT FOCUS reflected sunlight.

7.4.2 Motorist Disability & 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, defined in AS/NZS 4282:2019 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 Lv / Ltb0.8, where:

- Lv = veiling luminance from a source of interest (eg reflection) – Cd/m2
- Ltb = so-called "adaptation" luminance (total background) – Cd/m2

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

7.4.2 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.

7.4.3 Residential "Nuisance" Glare

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 from state governments that exists in relation to solar panels typically covers installation audits and compliance checks.

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

7.4.4 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 (eg dragline operations). Instead, the concepts used for the TI Value acceptability criteria can assist when dealing with this issue.

7.4.5 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.

The Project is located outside the Boggabri township area and has the potential to impact on surrounding residential properties – refer **Figure 5**.
As these properties are not located within township environs proper, they would therefore be classed as being in a residential area with "Dark Surrounds" - refer AS 4282-2019.

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

If at some point of time in the future such lighting is incorporated into the facility, the following criterion will apply:

- Light spill from the Project onto the facades of any surrounding residential dwellings should be kept below 1 lux during relevant 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. 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.

7.5 Glare Impact Assumptions

7.5.1 Project Site Solar Angles

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 the summer and winter solstices.

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 7** with relevant critical angles summarised in **Table 5**.

Table 5 Key Annual Solar Angle Characteristics

Day of Year	Summer Solstice	Equinox	Winter Solstice
Sunrise	5:02 am	6:05 am	6:58 am
Sunset	7:02 pm	6:08 pm	4.59 pm
Daily Azimuth Range	±118° E/W	±91° E/W	±63° E/W
Max Altitude	82.7°	59.9°	35.9°

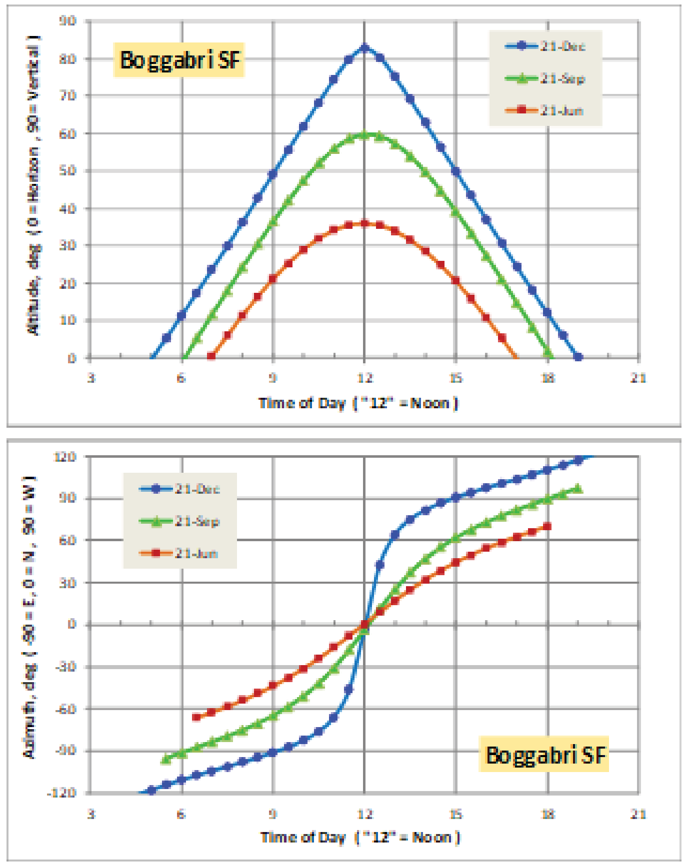


Figure 7 Project Site Solar Angle Variations

7.5.6 Project Site Panel Reflection Angles

The project will use single-axis tracking panels with a north-south axis of rotation). In "plan" view, reflections from the Project's panels will be directed as shown in **Figure 8** 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.

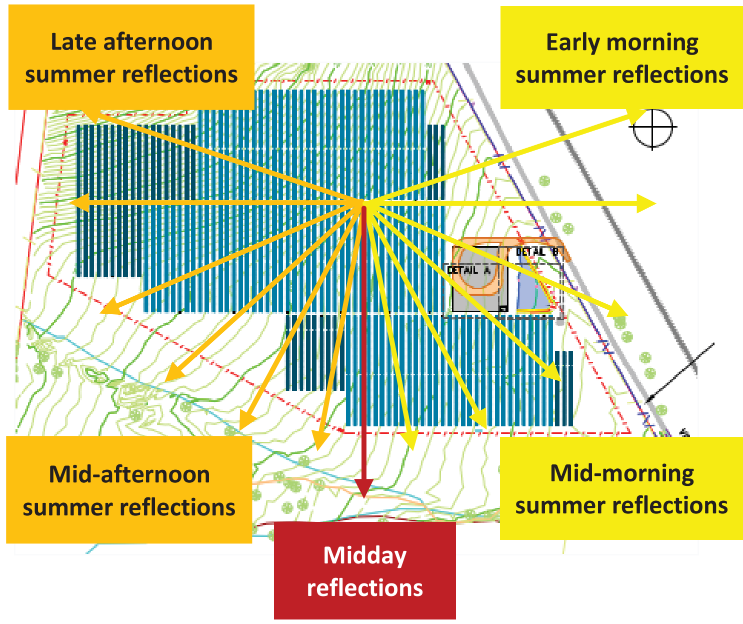


Figure 8 Potential Summer Reflection Angles

7.5.7 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. Consequently, solar PV panels minimise reflections which 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 panel surface and associated degree of diffuse (non-directional) versus specular (directional or mirror-like) reflection. Typical values of the refractive index "n" range from n = 2.0 (fresh, flaky snow) to n = 1.3 (standard solar glass).

Figure 9 shows the reflectivity off typical solar panel surfaces and the still surface of a lake as a function of incidence angle.

The reflectivity of the PV panels assumed in this study is the same as that shown for the standard solar glass 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, 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.

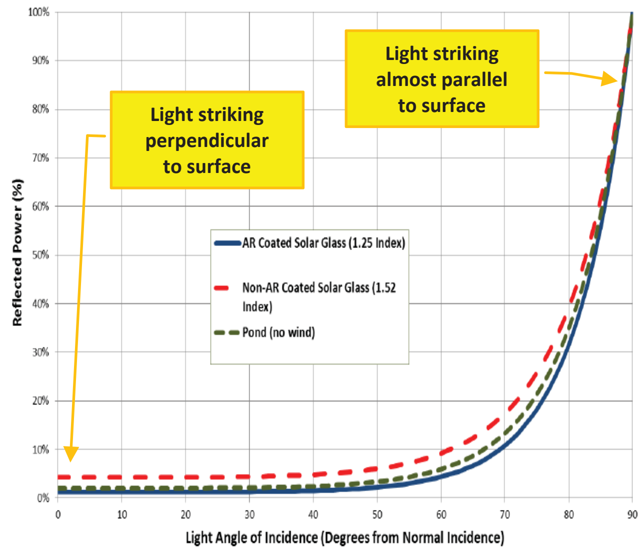


Figure 9 Typical Refectivity v Incidence Angle

7.5.8 Operational Tracking Axis Configurations

Current single-axis tracking systems, as would be used for this project, are capable of operating in a number of different panel position modes. Possible options are shown in **Figure 10.**

- **"A": 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;
- **"B": 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;
- **"C": Normal Tracking Mode / Fixed Tilt Stowed:** in this mode, panels move during the day in "normal tracking": mode, but then move (instantaneously) to any user-defined fixed tilt angle at all other times, eg 0° (horizontal);
- **"D": "Real-World Back-Tracking":** in this mode, panels move during the day in "normal tracking": mode, but then gradually move to a horizontal position, thereby minimising shading of one panel array from adjacent arrays – the example shown is from an operating solar farm.

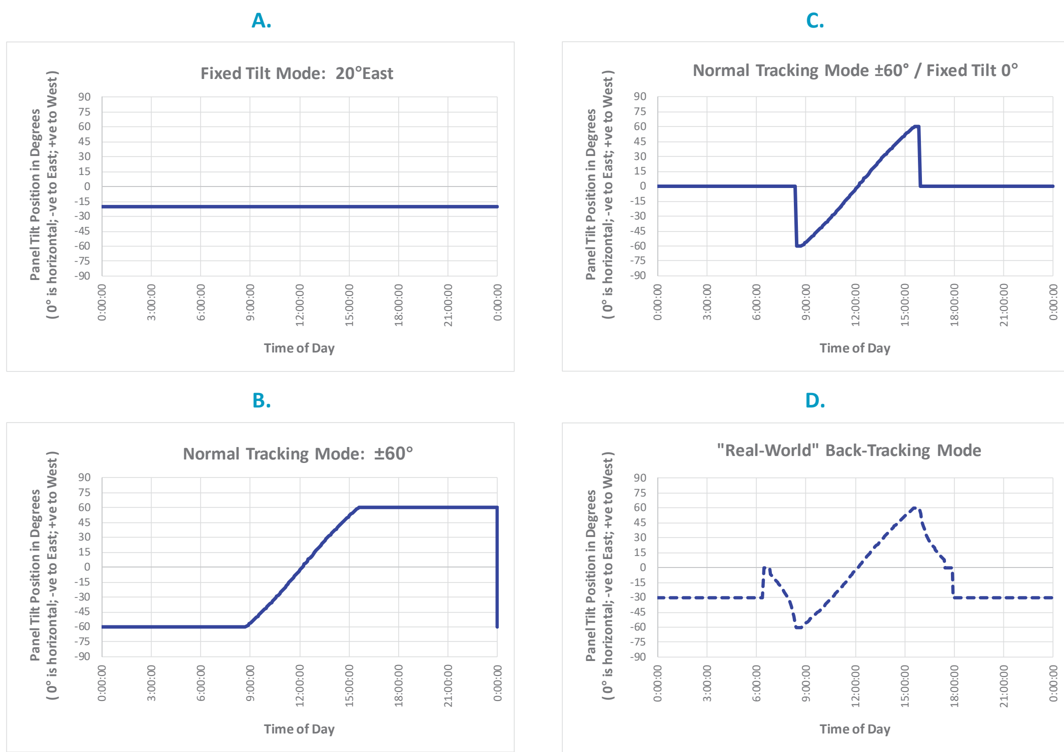


Figure 10 Single-Axis Tracking Mode Options

7.6 Glare Impact Assessment

7.6.1 Aviation Glint & Glare

As can be seen in **Figure 5** , the nearest airfield to the Project site is Boggabri Aerodrome (6km south-southeast of the site). Gunnedah Airport is 38km southeast of the site and Narrabri Airport is 44km north-northwest of the site.

Due to the distances involved (refer above) and the possible angles of reflections from the Project's solar PV panels (refer **Figure 12**) in relation to the pilot line of sight on landing approach in the case of Boggabri Aerodrome, potential glare conditions for aircraft on any possible approach paths for all the nearest airports are deemed non-existent.

Helicopter flight paths can be highly variable and landing approach paths often vary in relation to an airfield's standard runway glide paths. However, again, due to the distances involved, potential glare conditions for any possible helicopter landing approach paths are deemed non-existent.

Accordingly, a quantitative analysis (eg using Sandia Labs SGHAT) is not deemed necessary to assess the potential for adverse and unacceptable glare (and glint) conditions.

7.6.2 Aerial Spraying / Crop Dusting

Given the surrounding agricultural land usage in the vicinity of the Project site, it is possible that aerial spraying might take place within several kilometres of the Project. There are no "standard" aircraft flight paths associated with such aviation activity.

SLR has previously undertaken quantitative analyses using the SGHAT software tool of such activities, for the following scenario:

- Assume potential flight paths whereby an aircraft is flying horizontally towards a Project site from any direction and at an elevation of 200 ft (60 m) above local ground level;
- Assume that the aircraft can get as close as 1 km to the nearest part of the Project's solar array; and
- Assume that solar panels track the sun during the day, tilting from 60 east to 60 west, about a horizontal axis oriented north-south.

When run for a full year of potential incoming solar angles at latitudes similar to the Project site (hence similar incoming solar angles), the resulting SGHAT Ocular Plots showed that the potential for aviation glare was negligible. This was primarily due to the low incidence angle of reflected rays (regardless of the time of the year) arising from the tilting action of the tracking systems.

7.6.3 Motorist Disability & Pedestrian Discomfort Glare

The "major" and "minor" thoroughfares in the immediate vicinity of the Project (refer **Figure 5**) are:

MAJOR (TI Values should be less than 10)

- Kamilaroi Highway – southbound, northbound
- Boggabri-Manilla Road - westbound

MINOR (TI Values should be less than 20)

- Vine Lane - northbound

Important factors influencing the potential for traffic disability glare include:

- Any difference in elevation between the motorist and the solar panel array;
- Obstructions by intervening terrain, vegetation and topography; and
- 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 non-visible to the motorist, eg east moving traffic on Boggabri-Manilla Road.

TI calculations have been made for the roadways surrounding the Project site. The results, shown in **Table 6,** indicate the following:

- TI Values registered for all carriageways were zero at all times of the year for the "±60° Normal Tracking" mode, where reflections are directed upwards for all incoming solar angles, all year round.
- Low TI Values are possible if the panels are left in a FIXED TILT eastwards mode at a low angle to the horizontal – this applies to west moving traffic on Boggabri-Manilla Road and traffic moving northwards along Vine Lane.

In the FIXED TILT mode cases examined the relevant Motorist Traffic Disability Glare criteria and Pedestrian Discomfort Glare criteria are satisfied. The primary reason for this result is the difference in elevation for motorists and the solar array panels: for example, a motorist facing west on Boggabri-Manilla Road at the intersection with Kamilaroi Highway would be over 15 m lower than the elevation of the solar array.

- The primary reason for this result is the difference in elevation for motorists and the solar array panels: for example, a motorist facing west on Boggabri-Manilla Road at the intersection with Kamilaroi Highway would be over 15 m lower than the elevation of the solar array.

Table 6 Roadway TI Value Calculation Results

Roadway	TI Values	Comment
Kamilaroi Highway	**nil**	All year round
Boggabri-Manilla Road	**nil**	All year round
Vine Lane	Max 3	If panels left tilted slightly eastwards (near horizontal)

7.6.4 Train Driver Disability Glare

Figure 5 shows the Mungindi Rail Line running just to the east of the eastern perimeter of the Project site.

SLR has undertaken TI Value calculations for the section of the line approaching from the south focussing on positions where the line of sight of train drivers was closest to the angle of potential incoming solar reflected rays (note that no reflection angles are possible when viewed from the north).

- For the standard operational "±60° Normal Tracking" mode, the TI Values for Disability Glare were NIL, as reflections are directed upwards for all incoming solar angles, all year round.
- For any scenarios involving panels being left in a FIXED TILT eastwards mode, reflections may be visible on the Mungindi Rail Line for late afternoon periods after the equinox months of the year. These reflections would be visible for periods less than a minute. The associated TI Values are modest and below the limiting criteria of TI=20 as a result of the difference in line of sight of the train driver and the incoming solar rays and associated reflections (which would roughly be from due west).

7.6.5 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.

7.6.6 Residential Nuisance Glare

The nearest residential receivers to the Project are identified in **Figure 5.**

- They surround the site at varying distances from the nearest respective site boundary.
- Their ground elevations are mostly LOWER than the Project's solar array, with the exception of BSF R1 (refer **Figure 5**) which is at the same elevation.

There are no formal criteria governing residential reflective nuisance glare from solar facilities.

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 7**.

Table 7 Residential TI Value Calculations Results

Receivers	TI Values	Comment
BSF R1	Up to ~3	If panels left tilted slightly westwards (near horizontal)
BSF R2-R5	**nil**	All year round

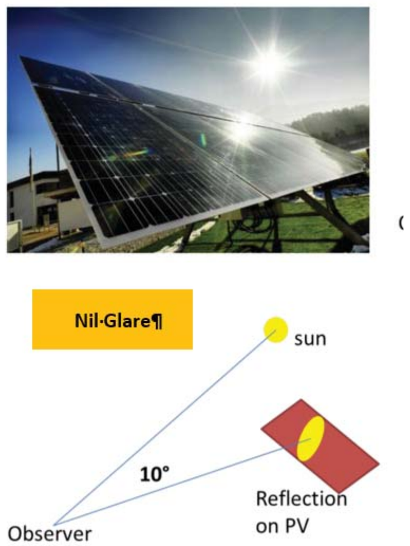


Figure 11 Nil Glare Condition for Residential Nuiscance Glare

The results indicate the following:

- For the standard operational "±60° Normal Tracking" mode, the TI Values were NIL at all receivers;
- For FIXED TILT eastwards and FIXED TILT 0° modes, reflections will not be visible for receivers to the east of the site due to the elevated position of the Project solar array relative to these receivers;
- For a FIXED TILT westwards mode (low angle, ie near horizontal), reflections will be potentially visible to BSF R1 for up to 4 months of the year and up to 5 minutes per day. Because these reflections occur early in the morning, visible reflections would be in the same line of sight as the solar rays themselves – this would not constitute a glare condition – as is shown in **Figure 11**.
- In the preceding analysis, no account was taken of the potential "shielding" benefit to residence BSF-R1 from the trees lying between the property and the Project site.

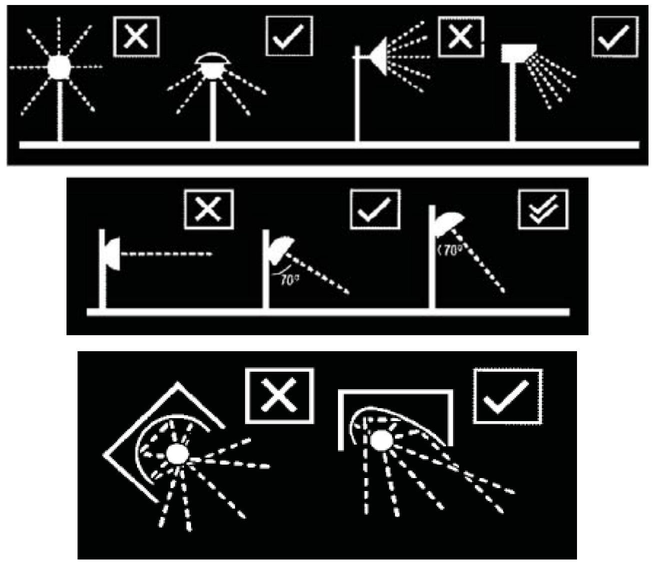


Figure 12 Luminance Design Features that Minimise Light Spill

7.6.7 Night-Time Illumination Glare

Although presently not fully defined, it is assumed that an area within the Boggabri Solar Farm Project site will be set aside for an Operation and Maintenance building, 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 1 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 12**.
- 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.

7.7 Glare Assessment Conclusion

7.7.1 Aviation-Related Potential Glare

There will be nil impact from the Project in relation to aviation-related glare.

7.7.2 Motorist “Traffic Disability” Glare

Primarily due to the selection of the single-axis tracking system for the mounting of the ground-based array panels, there will be nil glare from the Project in relation to traffic disability glare.

7.7.3 Rail Traffic “Disability” Glare

Similarly, there will be nil glare from the Project in relation to rail traffic disability glare.

7.7.4 Residential Nuisance Glare

Reflections from the proposed facility may be visible at one surrounding residence, although the TI Values calculated for this occurrence are minimal. To avoid the potential for visible reflections, it is recommended that if panels need to be left at a near horizontal position, they should be left with a slightly eastwards fixed tilt angle of at least 10°.

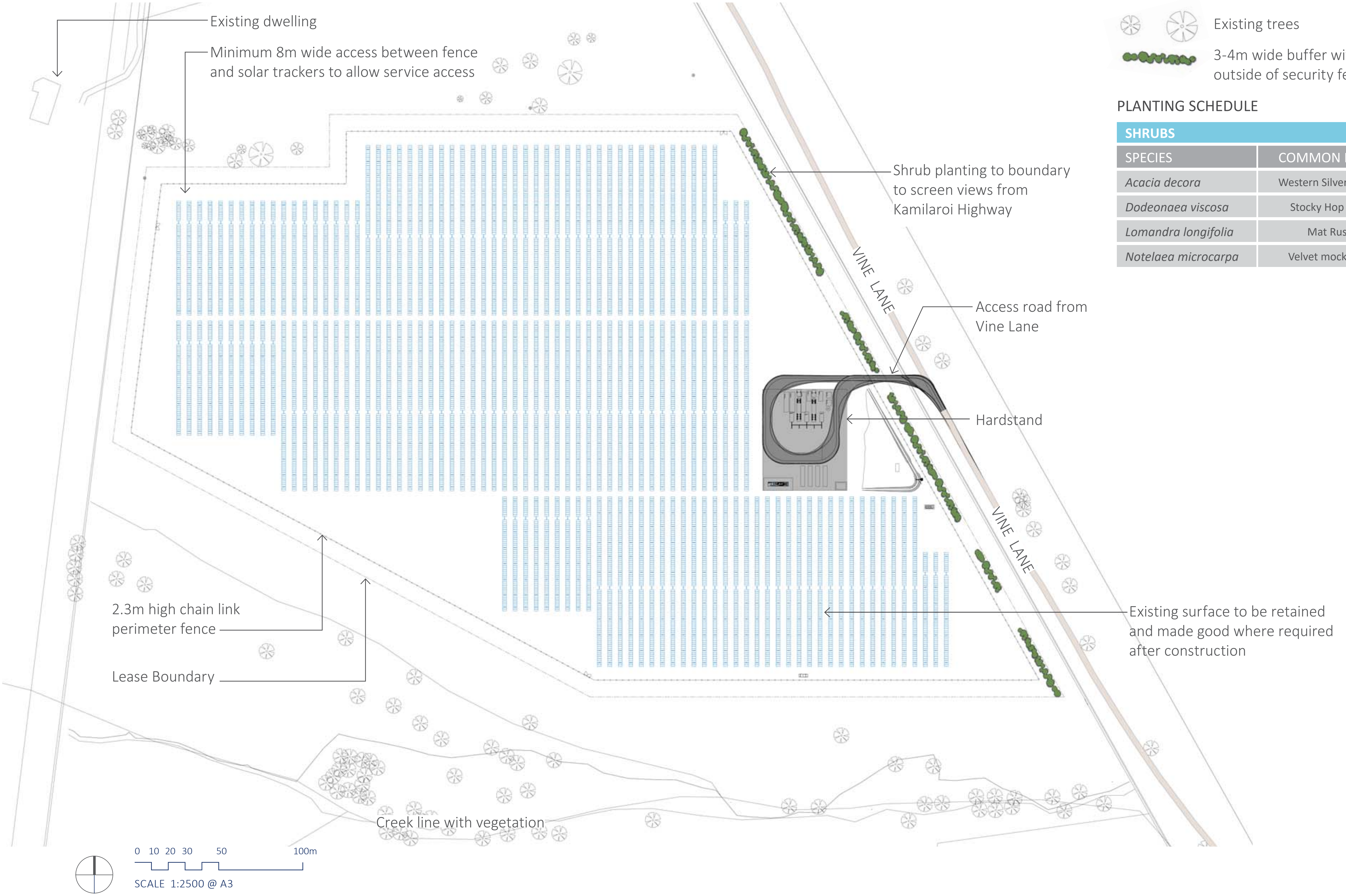
7.7.5 Night-Time Illumination Glare

Although presently not incorporated into the Project, consideration has been given to the future potential for night-time lighting related to equipment and/or buildings, fire access routes and egress, etc.

Recommendations have been made to ensure that the potential for any future possible night-time illumination glare will be non-existent.

8. LANDSCAPE CONCEPT

8.1 LANDSCAPE PLAN



PLANTING SCHEDULE

SHRUBS			
SPECIES	COMMON NAME	APPROX. HEIGHT	POT SIZE
Acacia decora	Western Silver Wattle	Up to4m	150mm
Dodeonaea viscosa	Stocky Hop Bush	Up to 4m	150mm
Lomandra longifolia	Mat Rush	1m	50mm
Notelaea microcarpa	Velvet mock olive	Up to 2m	50mm

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