REPORT

# 160-172 LORD SHEFFIELD CIRCUIT

NORTH PENRITH, NSW

## SOLAR REFLECTION SCREENING ANALYSIS

**RWDI PROJECT #2206353**
**3 NOVEMBER 2022**


**SUBMITTED TO**

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# INTRODUCTION

This Solar Reflection Screening Analysis is submitted to Penrith City Council on behalf of Urban Property Group (UPG) in support of a Development Application (DA) for a 9-storey residential and commercial mixed-use development at 160-170 Lord Sheffield Circuit, North Penrith (the site).

The proposed development, which is known as 'Mayfair on Penrith', seeks approval for the following scope of works:

- Construction of two residential towers above a joint commercial podium, with ground floor retail, containing:
    - 'East Tower':
      To consist of 8 levels above the podium (excl. rooftop), which will include:
        - 152 residential apartments.
        - Common circulation areas.
        - Rooftop open space, including 1x swimming pool, landscaped areas and other communal amenities.
    - 'West Tower':
      To consist of 8 levels above the podium (excl. rooftop), which will include:
        - 135 residential apartments.
        - Common circulation areas.
        - Rooftop open space, including 1x swimming pool, landscaped areas and other communal amenities.
    - 2-storey podium, including:
        - 15x retail units at ground level with a combined Gross Floor Area (GFA) of 1936 $m^2$.
        - Flexible commercial floorspace at level 1 with a GFA of 4280 $m^2$.
        - Rooftop landscaping
- Joint three level below ground basement parking for:
    - Car and Motorcycle Parking:
      A total of 412 car parking spaces, including:
        - 331 car parking spaces for residential occupants and residential visitors (incl. 29 accessible spaces).
        - 81 car parking spaces for commercial visitors and staff (incl. 3 accessible spaces).
        - 0 motorcycle spaces.
    - Building Services:
      Building services and plant rooms, the majority of which will be sited at Ground & Basement level 1.

This report provides the computer modelling results of reflected sunlight from the proposed Mayfair development located in North Penrith, NSW, as shown in Figure 1. The development will be surrounded by typical urban spaces such as busy roadways, other buildings, pedestrian walkway and railway.

# INTRODUCTION

RWDI was retained to investigate the impact that solar reflections emanating from the development will have on the surrounding urban terrain. This analysis was conducted in two parts. First a 'screening' simulation estimated peak reflection intensities and the frequency of occurrence of reflections which may cause glare for a broad area around the development. This was done in order to understand the potential for thermal and visual impacts to people and drivers due to the reflections.

The screening analysis intentionally assumed a very conservative direction in which the viewer is facing (horizontal, but directly towards the building).

Since reflections were predicted on sensitive spaces, the 'detailed' analysis phase was undertaken. This investigated the potential for glare at select locations in greater temporal detail and also included the effect of the direction viewers are likely to be facing.

Note that the results presented herein are based on an earlier iteration (as of August 17, 2022) of this design where the south facade of the West Tower had a different balcony profile and glazing position. RWDI does not expect the alteration to materially change the conclusions of this report.

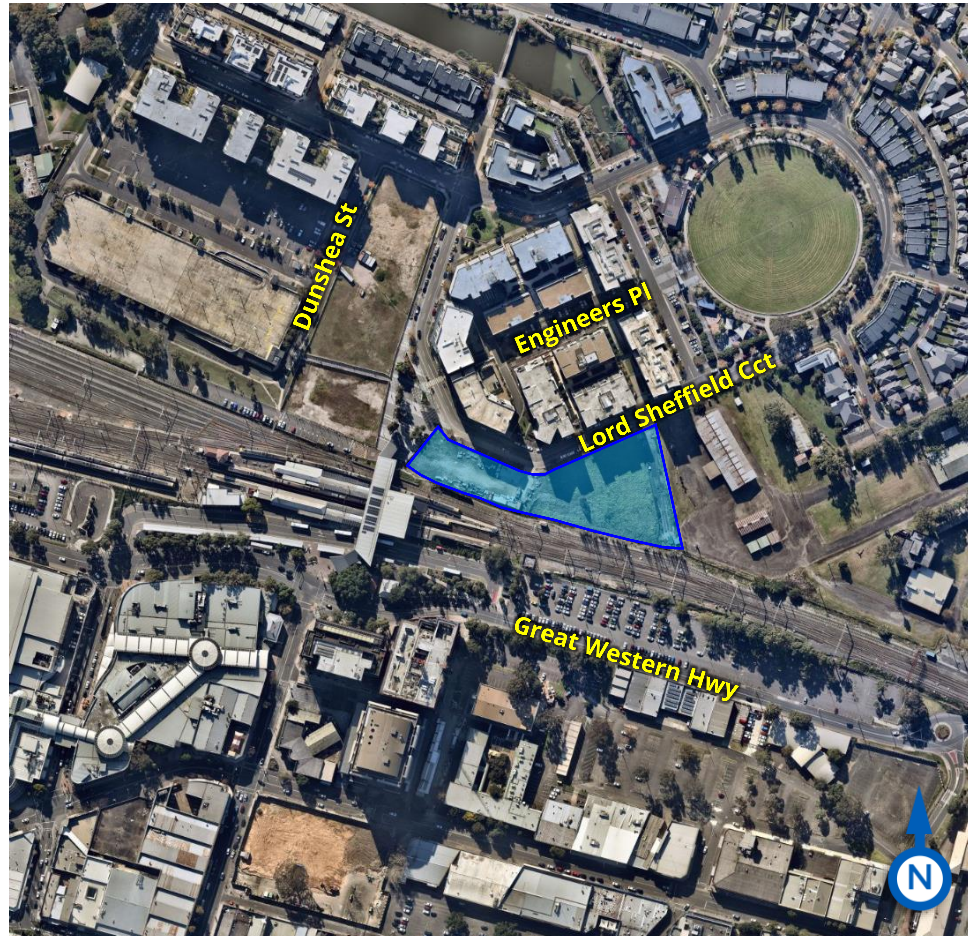


**Figure 1: Approximate Location of the Proposed Development (Blue Outline)**
**Map Credit: NearMap**

## Urban Reflections

While a common occurrence, solar reflections from buildings can lead to numerous visual and thermal issues.

**Visual glare** can:

- Impair the vision of motorists and others who cannot easily look away from the source;
- Cause nuisance to pedestrians or occupants of nearby buildings; and,
- Create undesirable patterns of light throughout the urban fabric.

**Heat gain** can:

- Affect human thermal comfort;
- Be a safety concern for people and materials, particularly if multiple reflections are focused in the same area; and
- Create increased cooling needs in conditioned spaces affected by the reflections.

The most significant safety concerns with solar reflections occur with concave facades (Figure 2) which act to focus the reflected light in a single area. The current design does not feature concave elements. As such, the focusing of energy is not expected from this development.

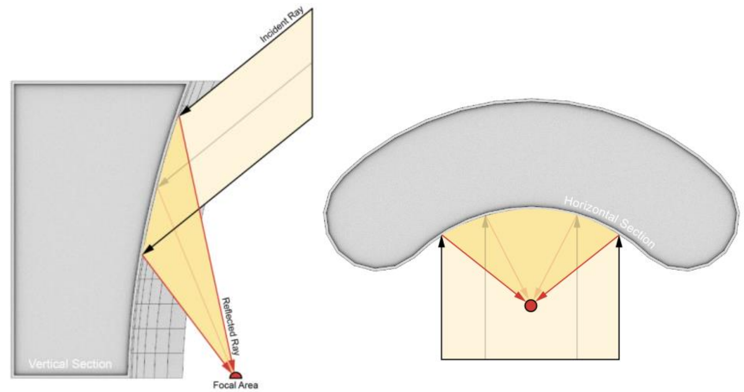


**Figure 2: Illustration of Reflection Focusing Due to a Concave Facade**

## Methodology

The analysis was conducted using RWDI's in-house proprietary *Eclipse* software, as per the steps outlined below:

- The assessment began with the development of a 3D model of the area of interest (as shown in Figure 3). This was then subdivided into many smaller triangular patches (see Figure 4).
- For each hour in a year, the expected solar position was determined, and "virtual rays" were drawn from the sun to each triangular patch of the 3D model.  Each ray that was considered to be "unobstructed" was reflected from the building surface and tracked through the surrounding area. The study domain included the entire urban realm within 300 m of the proposed buildings.
- The total reflected energy at that hour from all of the patches was computed and its potential for visual and thermal impacts was assessed.
- Finally, a statistical analysis was performed to assess the frequency, and intensity of the glare events occurring throughout the year within the study domain. The criteria used to assess the level of impact can be found in Appendix A of this report.

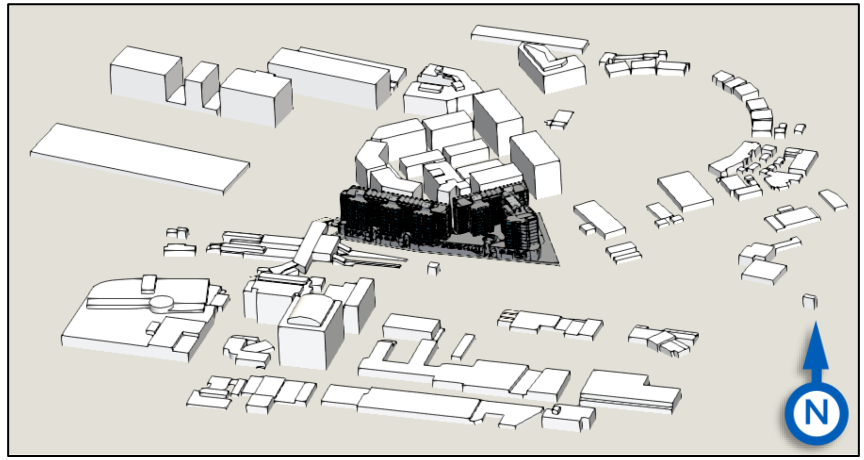


**Figure 3: 3D Computer Model of the Proposed Building and Surrounding Context**

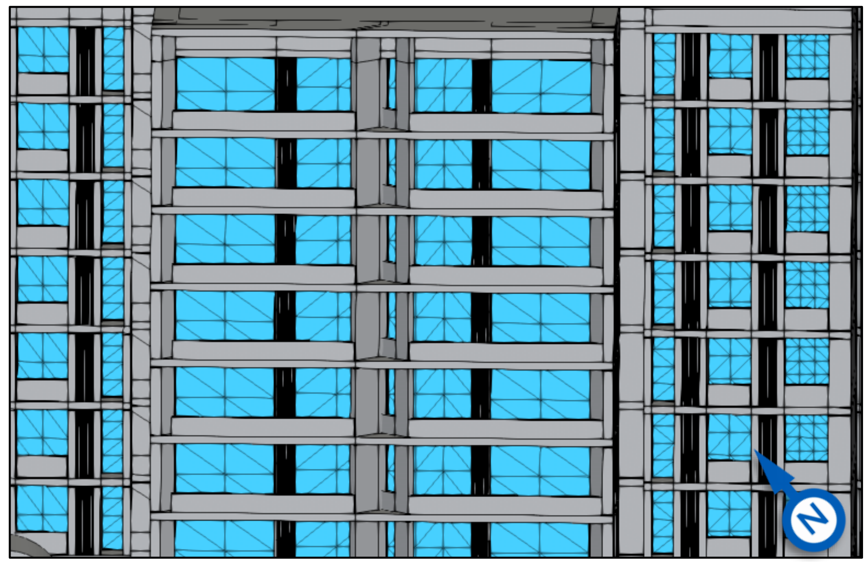


**Figure 4: Close-up View of the Model, Showing Surface Subdivisions**

## Methodology (cont'd)

- In the event that the potential for glare exists on roadways, the detailed analysis phase is triggered.
- This analysis works similarly to the screening simulation, except glare is tested at one-minute increments and a direction of view is prescribed.
- The detailed study also provides the locations on a building where the glare emanates from and the level of reflectivity reduction required to comply with local criteria.

## Assumptions and Limitations

### Meteorological Data

This analysis used 'clear sky' solar data computed at the location of Penrith Lakes weather station. This approach uses mathematical algorithms to derive solar intensity values for a given location, ignoring local effects such as cloud cover. This provides a 'worst case' scenario showing the full extent of when and where glare could ever occur.

### Radiation Model

RWDI's analysis is only applicable to the thermal and visual impacts of solar radiation (i.e. ultraviolet, visible and infrared wavelengths) on people and property in the vicinity of the development. It does not consider the impact of the building related to any other forms of radiation, such as cellular telephone signals, RADAR arrays, etc.

Potential reductions of solar reflections due to the presence of vegetation or other non-architectural obstructions were not included, nor are reflections from other buildings. Light that has reflected off several surfaces is assumed to have a negligible impact. As such, only a single reflection from the development was included in the analysis.

### Study Building and Surrounds Models

The analysis was conducted based on a 3D model of the proposed development provided by SJB Architecture to RWDI on August 17, 2022.

The surrounding model was based of data from publicly available data in the area. All data sources were cross checked against LiDAR data published by the NSW Department of Planning, Industry and Environment. This dataset was also used to generate the ground surface and has a stated vertical and horizontal accuracy of 0.3 m and 0.8 m respectively (both at a 95% confidence interval).

All glazing has been assumed to have a nominal 20% reflectivity for both visible light and solar energy. Glass balustrades have been assumed to have a visible reflectance and transmittance of 20% and 80% respectively. It is RWDI's understanding that all other materials on the facades have negligible specular reflectivity.

## Assumptions and Limitations (cont'd)

**Applicability of Results**

The results presented in this report are highly dependent on both the form and materiality of the facade. Should there be any changes to the design, it is recommended that RWDI be contacted and requested to review their potential effects on the findings of this report.

This analysis also assumes reasonable and responsible behaviour on the part of people in the vicinity of the development. A reasonable and responsible person would not purposely look towards a bright reflection, purposely prolong their exposure to reflected light or heat, or otherwise intentionally try to cause discomfort/harm to themselves or others and/or damage to property.

## Presentation of Results

This section presents the screening results pertaining to the solar impacts of the development on the surrounding urban area. The following plots are presented:

- **Peak Annual Reflected Irradiance:** Figure 5 displays the maximum intensity of solar energy reflected from the building at any point in the year. The plot identifies any areas where solar energy may be concentrated and create thermal risks. As a reference point, 800 $W/m^2$ is a typical maximum intensity of direct sunlight.

- **Percentage of Time Above the Veiling Luminance Threshold:** Figure 6 identifies the percentage of day-time hours where the veiling luminance was predicted to exceed the 500 $cd/m^2$ limit proposed by Hassall. *Note that as a conservative assumption, at each location it is assumed a viewer is facing horizontally in the direction of the building.*

Note that veiling luminance-based results present predictions for the age of 60 years old. This represents approximately the 80$^{th}$ percentile age of the residents of New South Wales.

The intention of the following plots is to illustrate the general characteristics of reflections from the development.

In order to attain a complete understanding of the impact that reflections may have on people, other factors must be considered, including where the viewer is looking, which is explored in the detailed study if needed.

## Peak Annual Reflected Irradiance

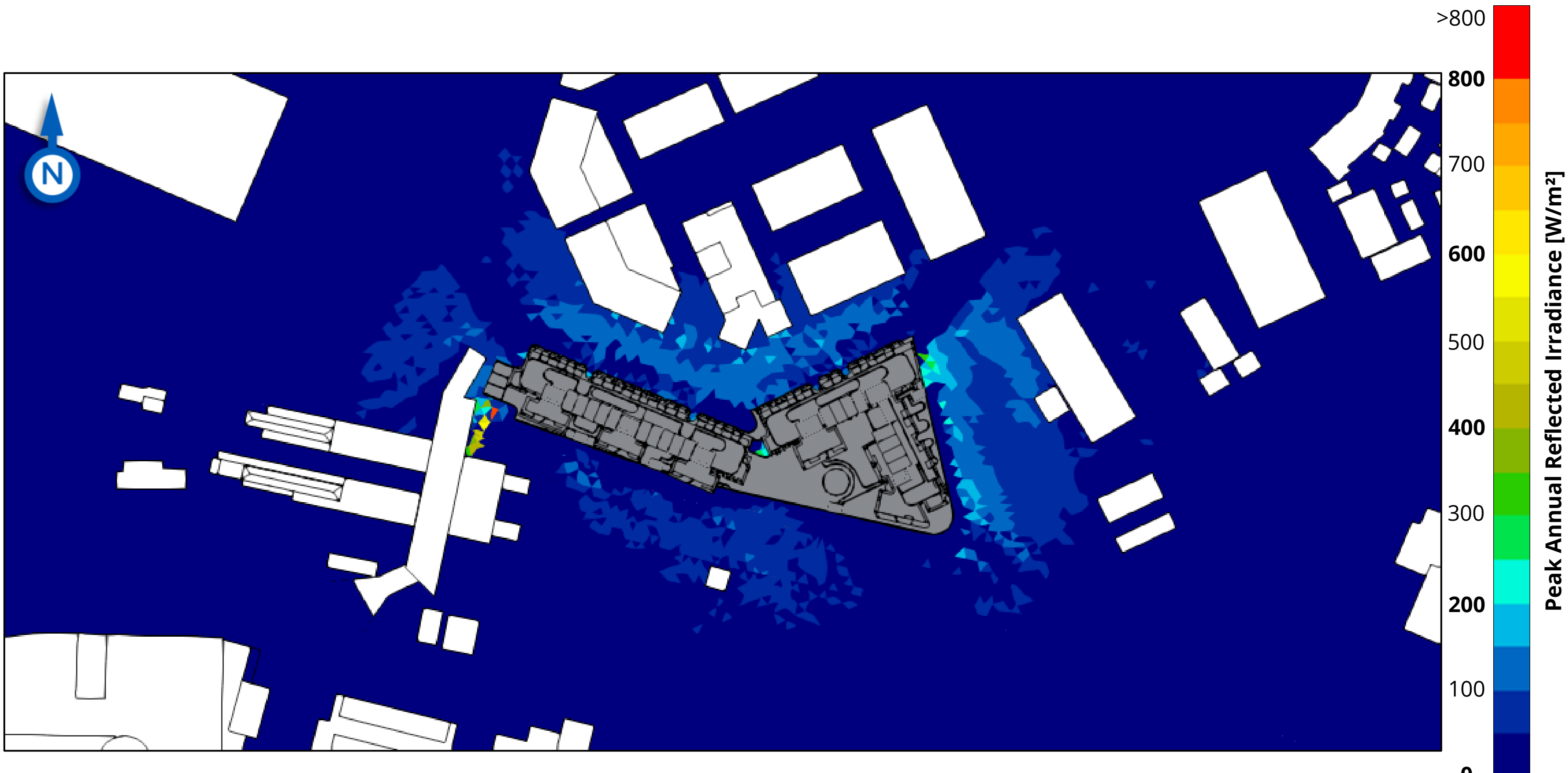


**Figure 5: Maximum Annual Intensity of Reflections at Ground Level (eye height)**

## Percentage of Time Above the Veiling Luminance Threshold

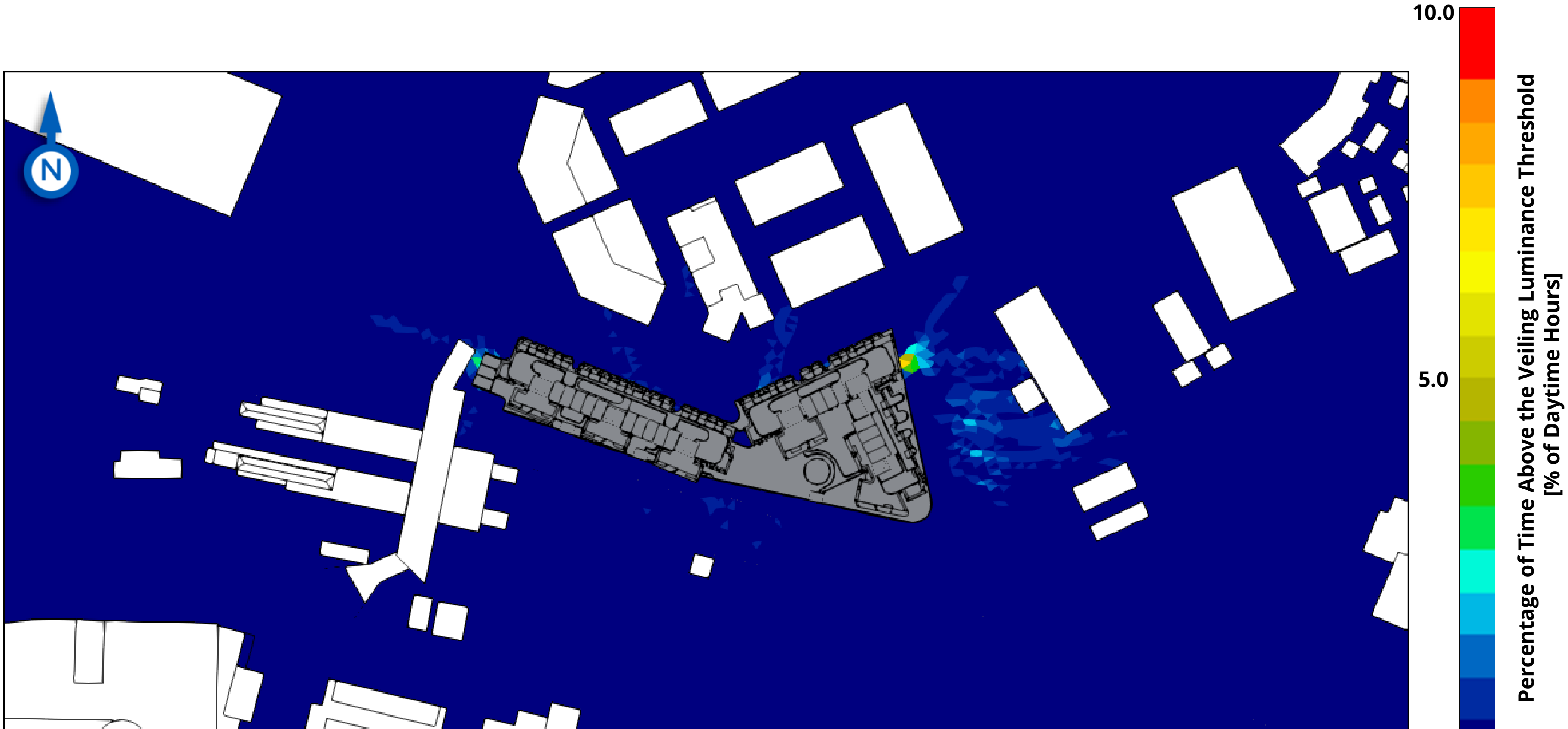


**Figure 6: Frequency (% of Daylit Hours) Where Veiling Luminance Above Threshold at Ground Level (eye height) for an 80th Percentile Resident (Age 60)**

Based on the findings of the Screening Analysis and the risk levels associated with reflections affecting specific areas, 10 representative points were selected for the Detailed Analysis. These points are described in Table 1 and illustrated in Figure 7.

The direction of view for the drivers is indicated by the arrows in Figure 7.

**Table 1: Receptor Descriptions**

| Receptor Number | Receptor Description |
|---|---|
| D1 | Westbound drivers on William Hart Cres |
| D2 | Westbound drivers on Lord Sheffield Cct |
| D3 | Southbound drivers on Aviators Way turning right onto Lord Sheffield Cct |
| D4 | Southbound drivers on the driveway behind Quest Penrith exiting onto Lord Sheffield Cct |
| D5 | Southbound drivers on Lord Sheffield Cct |
| D6-D7 | Eastbound train drivers on North Shore & Western Line |
| D8-D9 | Westbound train drivers on North Shore & Western Line |
| P10 | Pedestrian at the North Entrance of Penrith Station |

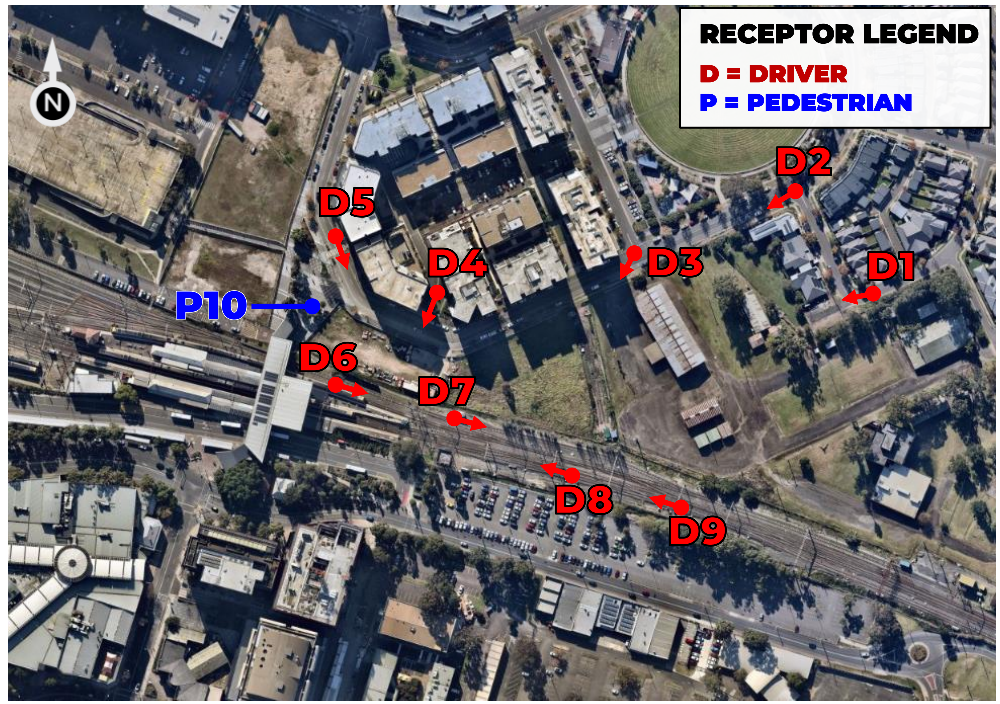


**Figure 7: Receptor Locations (Map Underlay Credit: NearMap)**

## Presentation of Results

Results are illustrated using "annual impact diagrams". These plots condense the minute-by-minute annual dataset into a single image. The vertical axis represents the time of the day and the horizontal axis indicates the day of the year. A sample of such a diagram is shown in Figure 8.

Please note that the referenced times are in local standard time. When Daylight Savings Time is observed, the time should be shifted by an hour.

The colours on this plot indicate when reflections falling on a specific point can occur and if the predicted veiling luminance of those reflections exceeds the disability glare threshold (500 cd/m²). Hatching (i.e., dark green areas) indicates when the sun would be within 30° of a drivers' direction of view.

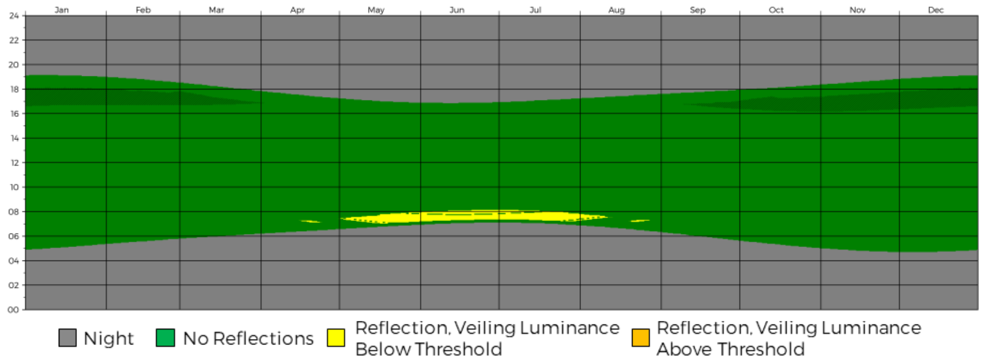


**Figure 8: Annual Reflection Impact Diagram for Receptor D1**

## Receptor D1

Receptor D1 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling west along William Hart Crescent.

The simulation results indicated that reflections may fall on this point from mid-April through late August between approximately 7:00 am AEST and 8:15 am AEST.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

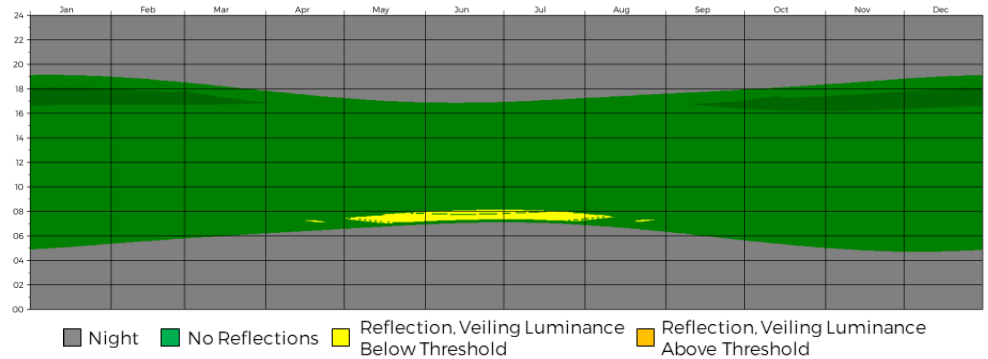


**Figure 9: Annual Reflection Impact Diagram for Receptor D1**

## Receptor D2

Receptor D2 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling west along Lord Sheffield Circuit approaching the Aviators Way intersection.

The simulation results indicated that reflections may possibly fall on this point during the morning hours between 5:30 am and 7:15 am AEST from mid-February to mid-April and again from late August through late October.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

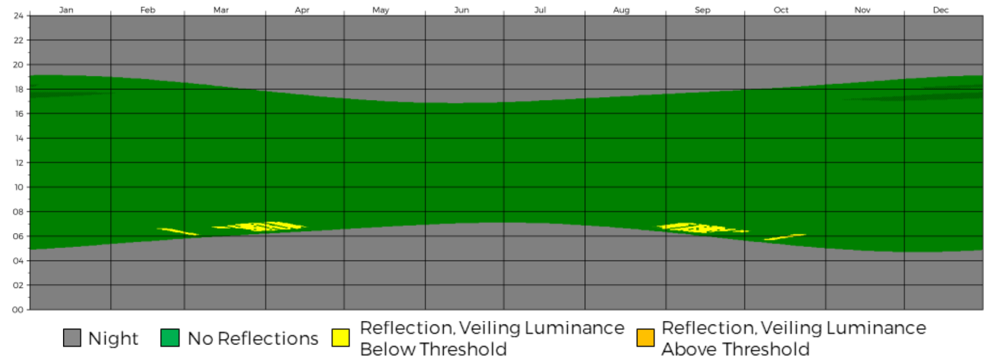


**Figure 10: Annual Reflection Impact Diagram for Receptor D2**

## Receptor D3

Receptor D3 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling south on Aviators Way, turning right onto Lord Sheffield Circuit.

The simulations predicted that reflections may fall on this point between 4:45 am and 7:30 pm AEST from late October to late February.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

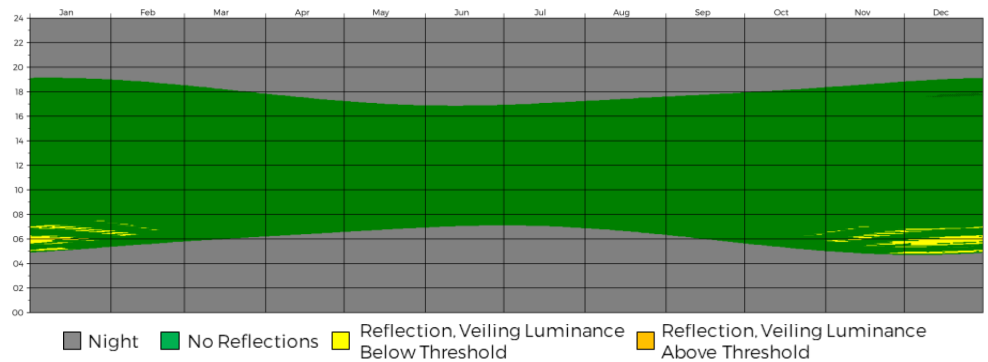


**Figure 11: Annual Reflection Impact Diagram for Receptor D3**

## Receptor D4

Receptor D4 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling south on the driveway behind Quest Penrith, exiting onto Lord Sheffield Circuit.

The simulation results indicated that intermittent reflections may fall on this point between 7:45 am and 12:00 pm AEST from April through mid-September.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

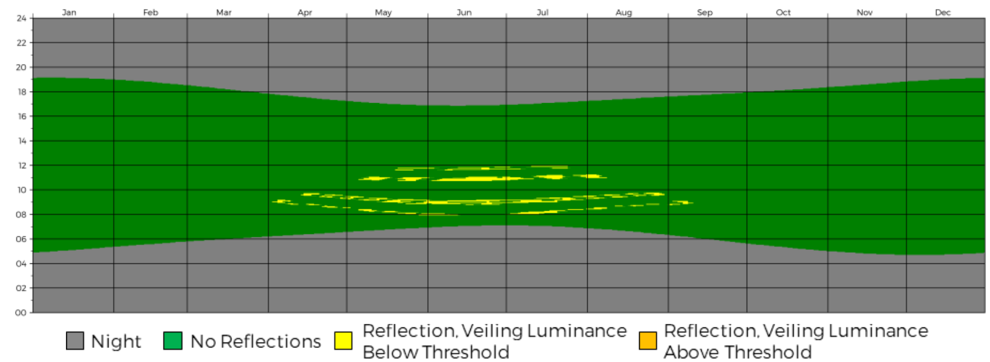


**Figure 12: Annual Reflection Impact Diagram for Receptor D4**

## Receptor D5

Receptor D5 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling south on Lord Sheffield Circuit, approaching the development.

The simulation results indicated that brief intermittent reflections may fall on this point between 6:30 am and 9:30 am AEST from mid-March through May, and again from mid-July through late September.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

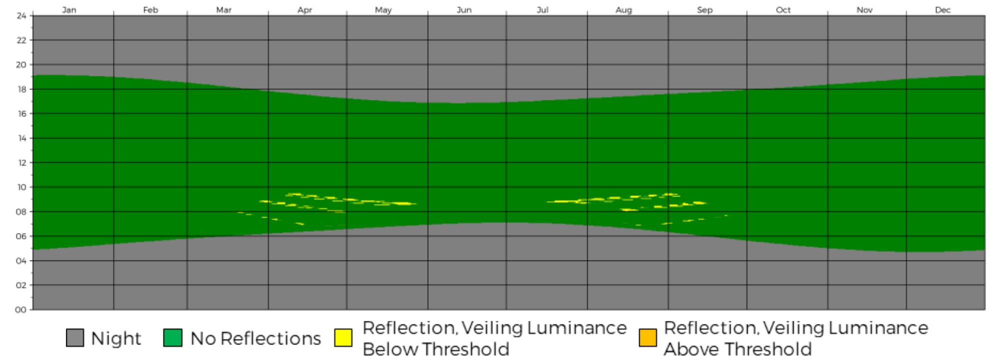


**Figure 13: Annual Reflection Impact Diagram for Receptor D5**

## Receptor D6

Receptor D6 was chosen to assess the visual impact associated with solar reflections affecting train drivers travelling east on the North Shore and Western Line, at the Penrith Station.

The simulation results indicated that very brief reflections are possible at this point between 5:00 am and 5:45 am AEST from late November through mid-January.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

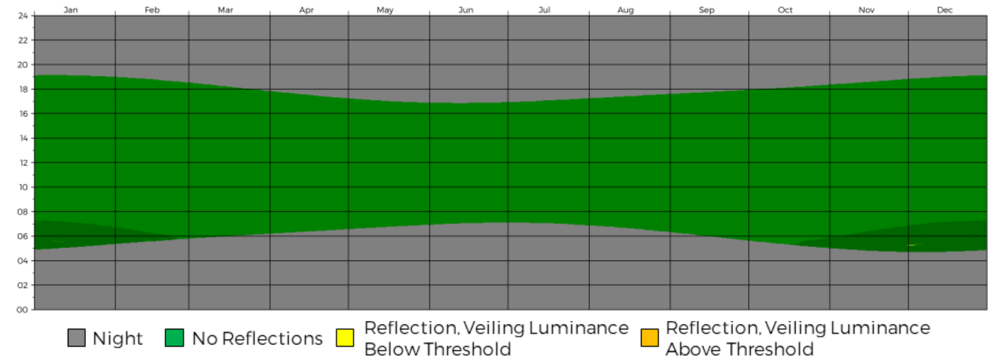


**Figure 14: Annual Reflection Impact Diagram for Receptor D6**

## Receptor D7

Receptor D7 was chosen to assess the visual impact associated with solar reflections affecting train drivers travelling east on the North Shore and Western Line, leaving the Penrith Station.

The simulations predicted that brief intermittent reflections are possible on this point between 3:00 pm and 4:15 pm AEST from late March through April, and again from mid-August to mid-September.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

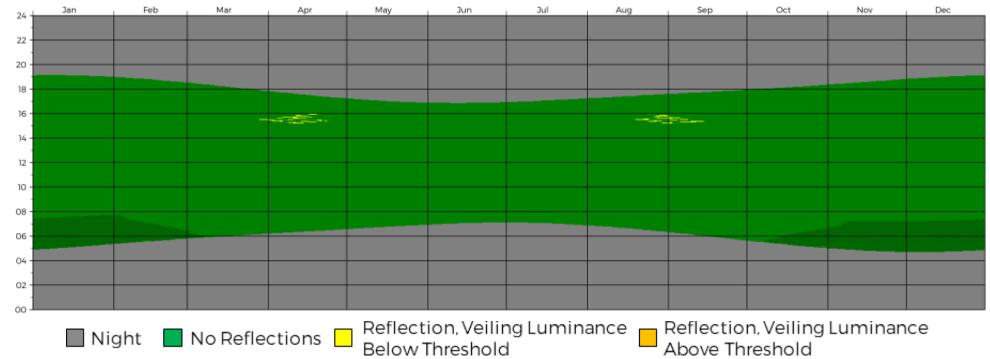


**Figure 15: Annual Reflection Impact Diagram for Receptor D7**

## Receptor D8

Receptor D8 was chosen to assess the visual impact associated with solar reflections affecting train drivers travelling west on the North Shore and Western Line, approaching the Penrith Station.

Very brief reflections were predicted at this location intermittently in late January, early to mid-March, late September to mid-October and in mid-November to late November between 6:00 am and 8:45 am AEST. Brief reflections were also predicted between approximately 4:30 pm and 6:45 pm AEST from late September through March.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

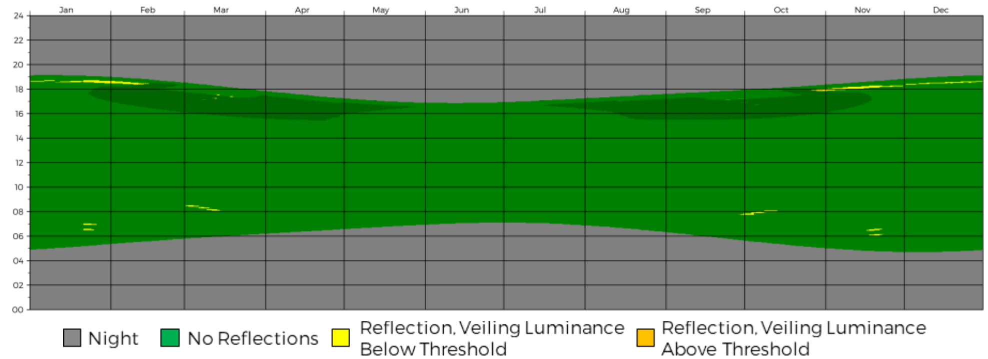


**Figure 16: Annual Reflection Impact Diagram for Receptor D8**

## Receptor D9

Receptor D9 was chosen to assess the visual impact associated with solar reflections affecting  train drivers travelling west on the North Shore and Western Line, approaching the development.

Brief reflections at this location were predicted between 5:00 am and 6:45 am AEST from November to early February. Very brief reflections were also predicted from late September to mid-March between 5:30 pm and 6:45 pm.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

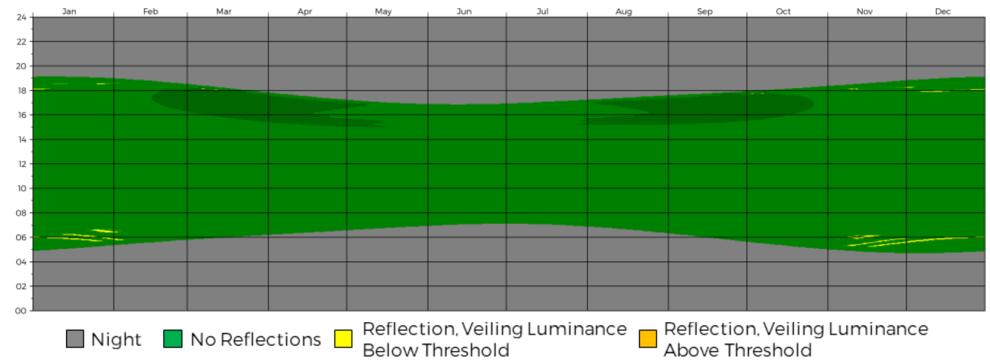


**Figure 17: Annual Reflection Impact Diagram for Receptor D9**

## Receptor P10

Receptor P10 was chosen to assess the visual impact associated with solar reflections affecting pedestrians near the north entrance of Penrith Station.

The simulation results indicated that reflections may fall on this point between 3:00 pm and 6:45 pm AEST from late January through late November.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m².

Note that due to the veiling luminance calculations dependence on view, this finding assumed reasonable behaviour on the part of the pedestrian. That is to say, the individual is facing horizontally and not purposely looking up towards the reflections from the proposed development.

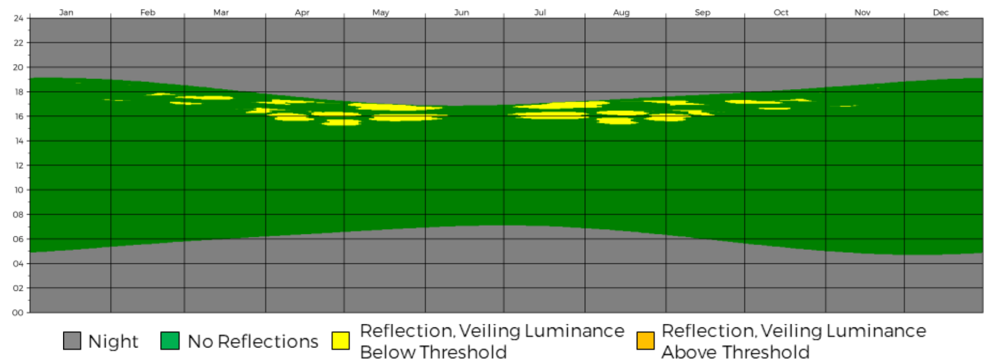


**Figure 18: Annual Reflection Impact Diagram for Receptor P10**

# OBSERVATIONS AND CONCLUSIONS

1. Like any contemporary building, the reflective surfaces of the proposed development are naturally causing solar reflections in the surrounding area.
2. The maximum intensities of the reflected solar energy at ground level were predicted to be low, with most reflections having a maximum intensity below 300 W/$m^2$ and no evidence of focusing. The area to the west of the proposed development, as well as a small localised area of the railway track, were predicted to have the potential for reflections above that level of intensity but not in excess of what can commonly occur in an urban environment. Note that this analysis assumed the glass had the same reflectivity for both visible light and thermal energy. Modern glazing units can be much more reflective to infrared so actual peak intensities may be higher than predicted. However, the simulations did not indicate any potential for solar focusing/convergence. This means that the thermal impacts of this project are unlikely to be significantly different than what commonly occurs in an urban area.
   Overall, RWDI does not anticipate significant heat gain issues on people or property, nor do we expect the reflections to create significant additional heat loads in adjacent buildings.
3. The screening analysis generally predicted a low potential for glare at the pedestrian realm, even with its highly conservative assumption that the viewer would always be looking horizontally towards the source of the reflection. The most frequent reflections are confined to the east of the proposed development. This was predicted to be possible in up to approximately 7.0% of the daytime hours annually. That said, this can only occur if the pedestrian purposely looked towards the source of the reflection.
4. The screening analysis also predicted the potential for reflections to fall on the existing railway track, though this was predicted to occur for no more than 0.9% of the daytime hours annually.
5. The detailed analysis, which accounted for more realistic view directions and operated at one-minute increments, predicted that all the driver receptors, including train drivers in the vicinity of the project site have the potential to be exposed to reflections emanating from the proposed development. However, none of these reflections exceed the veiling luminance threshold of 500 cd/$m^2$.

6. The pedestrian receptor near the north entrance of Penrith station (receptor P10) was also predicted to experience reflections emanating from the proposed development, mostly during the late afternoon hours. However, none of these reflections were predicted to exceed the veiling luminance threshold of 500 cd/m$^2$. It is also important to note that these reflections do not necessarily present a safety risk and would only be possible if people chose to look up at the project. Landscaping or other shading devices would be expected to be sufficient to control the visual impact of any reflections that do occur.
7. Given the safety risks associated with glare impacts to drivers and pedestrians, RWDI's analysis is intentionally conservative. It assumed clear skies for all daytime hours and ignored the effects of any landscaping, the use of sunglasses, as well as obstructions to reflected light due to the car body.
8. A "*Solar PV Options*" report dated 26 August 2022 was received by RWDI shortly before the publication of this report, which showed plans for PV panels to be installed on the rooftop. Given their location, tilt angle and the presence of an anti-reflective coating, RWDI does not anticipate the PV panels to have significant glare potential for the car and train drivers approaching the proposed development.
9. An updated design was received by RWDI on 1 November2022 which featured a change in the balcony profile as well as glazing position on the south facade of the West Tower. The setback of the glazing (of more than 2 m) will act to reduce the impacts compared to what was predicted in this report. Thus, RWDI does not expect this change to materially alter the conclusions presented in this report.

# GENERAL STATEMENT OF LIMITATIONS

This report entitled "160-172 *Lord Sheffield Circuit– Solar Reflection Screening Analysis*", dated 3 November, 2022, was prepared by RWDI Australia Pty Ltd ("RWDI") for Urban Property Group ("Client"). The findings and conclusions presented in this report have been prepared for the Client and are specific to the project described herein ("Project"). The conclusions and recommendations contained in this report are based on the information available to RWDI when this report was prepared.

Because the contents of this report may not reflect the final design of the Project or subsequent changes made after the date of this report, RWDI recommends that it be retained by Client during the final stages of the project to verify that the results and recommendations provided in this report have been correctly interpreted in the final design of the Project.

The conclusions and recommendations contained in this report have also been made for the specific purpose(s) set out herein. Should the Client or any other third party utilize the report and/or implement the conclusions and recommendations contained therein for any other purpose or project without the involvement of RWDI, the Client or such third party assumes any and all risk of any and all consequences arising from such use and RWDI accepts no responsibility for any liability, loss, or damage of any kind suffered by Client or any other third party arising therefrom.

Finally, it is imperative that the Client and/or any party relying on the conclusions and recommendations in this report carefully review the stated assumptions contained herein and to understand the different factors which may impact the conclusions and recommendations provided.

# APPENDIX A

## RWDI REFLECTION CRITERIA

## Visual Glare

RWDI has extensive experience in the analysis and assessment of the impacts of sunlight and solar energy reflected from buildings[1].

In the work described herein, we have adopted the typical Australian criteria put forth by Hassall[2], which defines glare as occurring when the veiling luminance of a reflection exceeds 500 cd/m².

Veiling luminance was computed using the CIE General Disability Glare Equation[3]. This equation is a more robust formulation of the classical Stiles-Holladay glare equation that accounts for the effects of age and eye colour when predicting veiling luminance. This formulation remains valid for light sources between 0.1° and 100° away from the direction of view.

RWDI conservatively assumed a light-blue eye colour (pigmentation factor of 1.2) and an observer age of 60 years old for this work. Based on the most recent Australian Census, this age represents approximately the 80$^{th}$ percentile age for the residents of New South Wales.

This means that in reality, veiling luminance would be lower than these predictions for 80% of the population.

It should be noted that the 500 cd/m² limit assumes an adaptation luminance corresponding to a dawn or dusk time frame and may be overly conservative during brighter parts of the day.

## Thermal Impact (Heat Gain) on People

The primary sources for exposure limits to thermal radiation come from fire protection literature. However, there is currently inconsistency between different bodies regarding what level of exposure can be reasonably tolerated by people.

The U.S. National Fire Protection Association (NFPA) defines 1,700 W/m² as an upper limit for a tenable egress environment[4]; i.e. an individual could escape through such an environment successfully, though they would not necessarily emerge unscathed. The British Standards Institution[5] sets their limit at 2,000 W/m², which "*...is tolerable for ~ 5 min[utes]...*". Other researchers[6] have found that higher irradiance levels (3,500 – 5,000 W/m²) can be tolerated in outdoor environments for several minutes without issue.

The only current quantitative guideline specific to reflections comes from the City of London's Planning Note on 'Solar Convergence'[7]. Produced in conjunction with the UK Building Research Establishment (BRE), this document indicates that no areas should receive 10,000 W/m² or more for any duration, exposures above 2,500 W/m² should be limited to less than 30 seconds; and that "*...areas with reflected irradiances above 1,500 W/m², and preferably those above 1000 W/m², should be minimized.*"

It should be noted that all these thresholds are guideline values only, and that in reality many factors (skin color, age, clothing choice, etc.) influence how a person reacts to thermal radiation.

Clearly, there are currently no definitive guidelines or criteria with respect to the issue of thresholds for exposure to thermal irradiance in an urban setting. We know this criterion should be lower than the thresholds set in the context of an individual escaping from a fire and greater than typical peak solar noon levels of 1,000 W/m² which people commonly experience.

**Therefore, RWDI's opinion at this time, is that reasonable criteria is to establish 2,500 W/m² as a ceiling exposure limit, which reflection intensity should not exceed for any length of time; and 1,500 W/m² as a short term (10 minutes or less) exposure limit.**

## Thermal Impact (Heat Gain) on Property

The impact of solar irradiance on different materials is primarily based on the temperature gains to the material which can cause softening, deformation, melting, or in extreme cases, combustion. These temperature gains are difficult to predict as they are highly dependent on the convective heat transfer from air movement around the object and long-wave radiative heat transfer to the surroundings.

Generally, irradiance levels at or above 10,000 W/m² for more than 10 minutes are required to ignite common building and automotive materials in the presence of a pilot flame. That value increases to 25,000 W/m² when no pilot flame is present[8,9,10]. However, some materials like plastics and even some asphalts may begin to soften and deform at lower temperatures. For example, some plastics can deform at a temperature of 140°F (60°C), or lower if force is applied. The applied force typically comes from the thermal expansion of the material, the force of gravity acting on the material or an external mechanical force (i.e. someone or something pushing or pulling on it).

Aside from the risk of damage to the material itself, a hot surface poses a safety risk to any person who may come into contact with it. This is particularly important in an urban context as the individual may not expect the object to be heated. NASA[11] defines an upper limit of 111°F (44°C) for surfaces that require extended contact time with bare skin. Surface temperatures below this limit can be handled for any length of time without causing pain.

That said, surfaces within the urban realm are routinely exposed to reflections from windows, metal panels and bodies of water without causing material damage or excessive heating.

Therefore, as this time, RWDI takes a conservative approach and **uses a value of 1,000 W/m², consistent with a single (i.e. non-focused) reflection of the sun's peak intensity, as a baseline threshold for reflected irradiance on stationary objects.**

However, this is simply a starting point. As noted, depending on the environmental conditions and material properties of the object/assembly other values may be used instead.

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