FINAL REPORT

MIDTOWN MACQUARIE PARK STAGE 2

MACQUARIE PARK, NSW

SOLAR REFLECTION SCREENING ANALYSIS

RWDI PROJECT #2104325
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SUBMITTED TO

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INTRODUCTION

This report provides the computer modelling results of reflected sunlight from the proposed Midtown Macquarie Park (Stage 2) development located in the heart of Macquarie Park in northwest Sydney, as shown in Figure 1. It is RWDI's understanding that the development will be surrounded by typical urban spaces such as roadways and other buildings.

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 property 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.

As reflections were predicted on roadways, the second 'detailed' phase of analysis was undertaken. This investigated the potential for glare at select locations in greater temporal detail and also included the effect of the direction in which the viewer is likely to be facing.

Note that the results presented herein are based on an earlier iteration (as of May 17, 2021) of this design where building C4 had a slightly higher building mass. RWDI does not expect the alteration to materially change the conclusions of this report.

Figure 1: Approximate Location of the Proposed Development (Map Credit: Google Earth)

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.

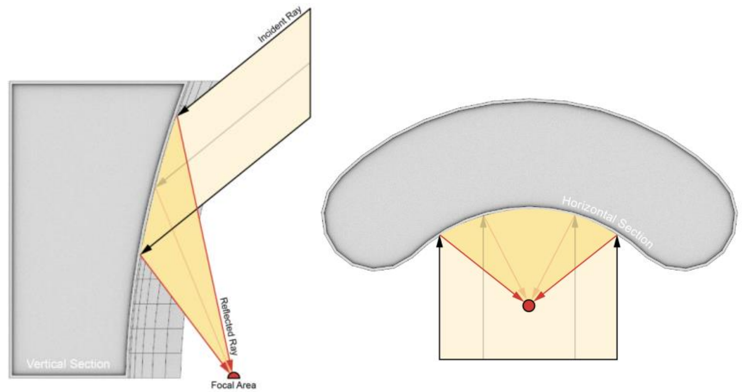

Figure 2: Illustration of Reflection Focusing Due to a Concave Facade

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 400 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 nearby airspace. The criteria used to assess the level of impact can be found in Appendix A of this report.

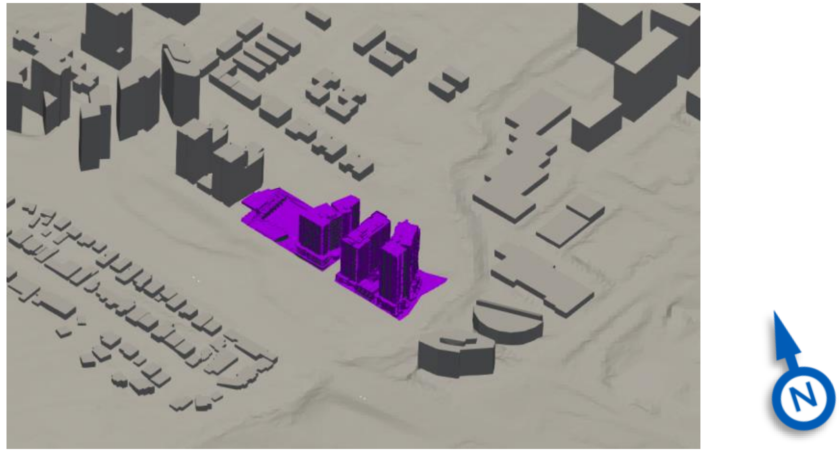

Figure 3: 3D Computer Model of the Proposed Building and Surrounding Context

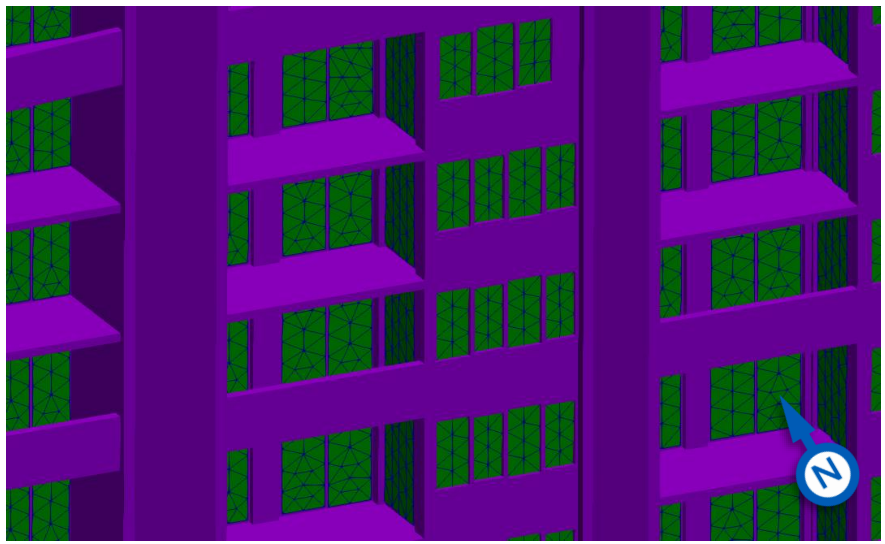

Figure 4: Close-up View of the Model, Showing Surface Subdivisions

Methodology (cont'd)

- In the event that the potential for glare on roadways is predicted, 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 explicitly 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 Sydney Airport. 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 Frasers Property Australia to RWDI up to May 17, 2021. The present analysis includes both Stages 1 and 2 (i.e. Lots A1, C1, C2, C3 and C4); all future stages of the development have been excluded in this analysis.

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

Assumptions and Limitations (cont'd)

Facade Material Reflectance

All glazing has been assumed to have a nominal 20% reflectivity for both visible light and solar energy. This reflectivity increases with increasing angle of incidence. Glass railings were noted in the model for building C3. This is assumed to be clear glass with a visible reflectance and transmittance of 20% and 80% respectively. All other materials on the facades are assumed to have negligible specular reflectivity.

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.*

The veiling luminance-based results present predictions for a 60 year old viewer. This represents approximately the 80th percentile age of the residents of New South Wales which means that veiling luminance will be lower than these predictions for 80% of the population.

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 phase of study as required.

Peak Annual Reflected Irradiance

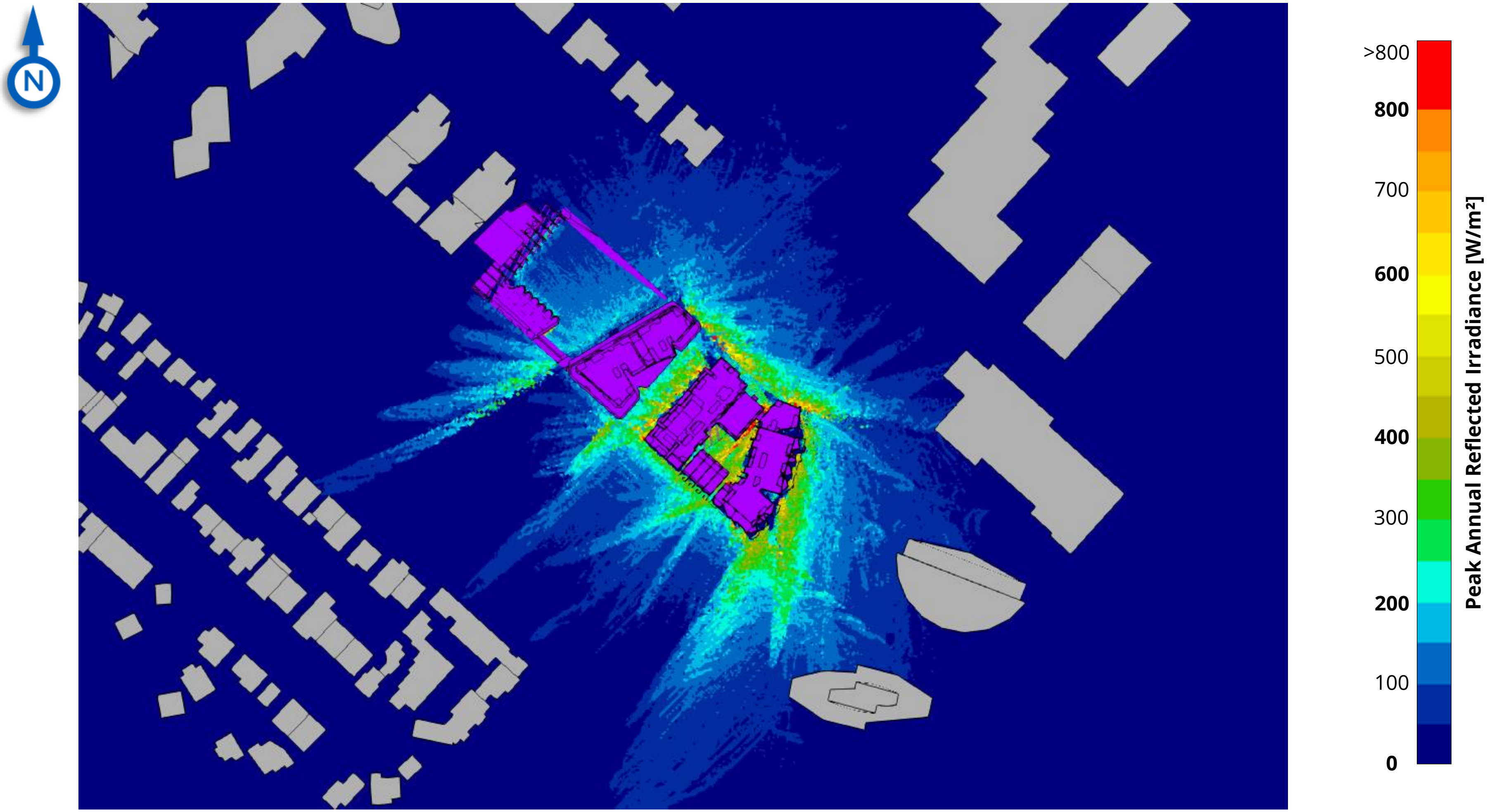

Figure 5: Maximum Annual Intensity of Reflections at Ground Level (eye height)

Percentage of Time Above the Veiling Luminance Threshold

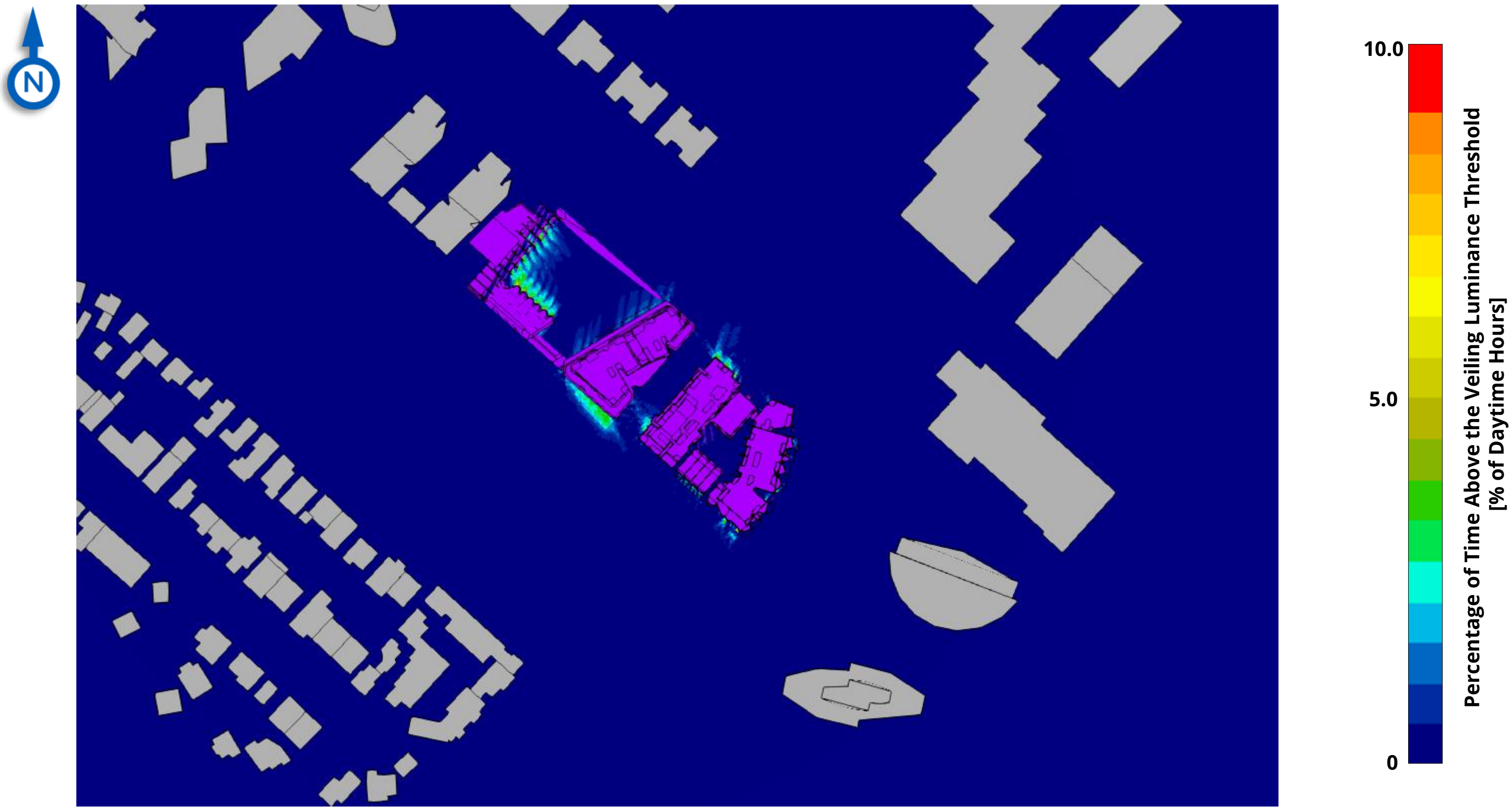

Figure 6: Frequency (% of Daylit Hours) Where Veiling Luminance Above Threshold at Ground Level (eye height) for an 80th Percentile NSW Resident (Age 60)

DETAILED ANALYSIS RESULTS

Based on the findings of the Screening Analysis and the risk levels associated with reflections effecting specific areas, 2 representative points were selected for the Detailed Analysis. These points are described in Table 1 and illustrated in Figure 7.

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

Table 1: Receptor Descriptions

Receptor Number	Receptor Description
D1 – D2	Northbound drivers on Epping Road

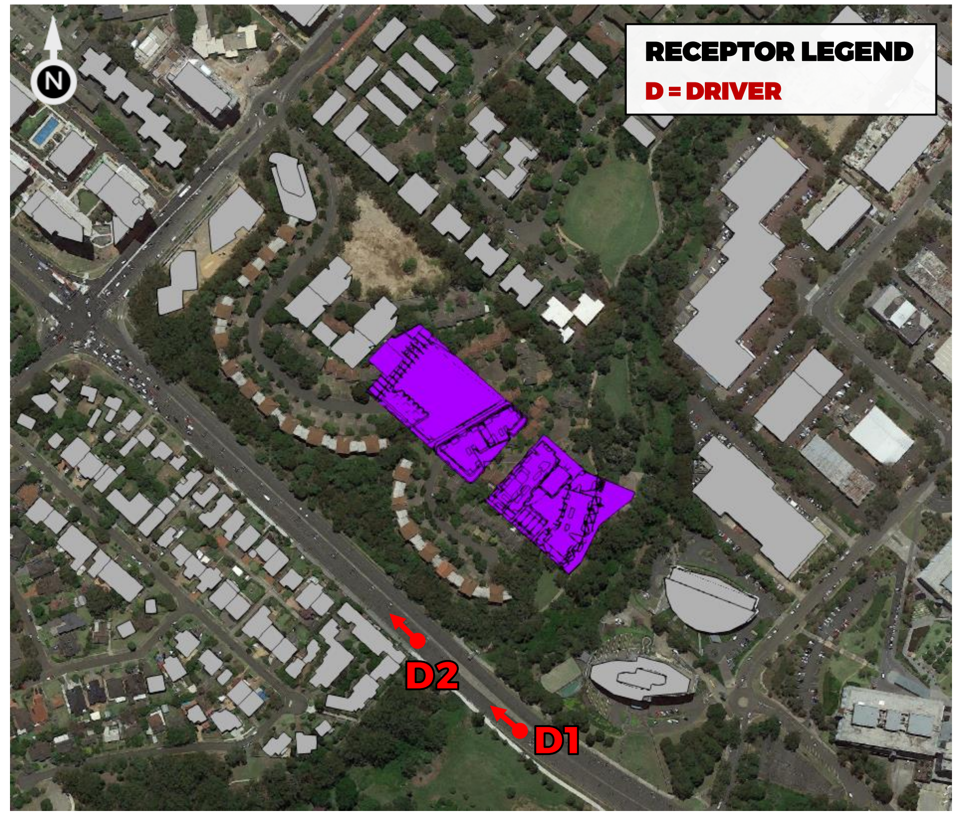

Figure 7: Receptor Locations (Map Underlay Credit: Google Maps)

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 when appropriate.

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

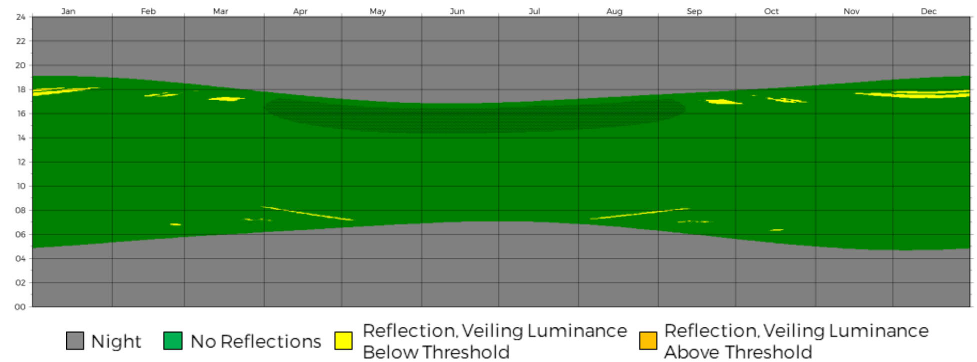

Figure 8: Annual Reflection Impact Diagram for Driver Receptor D1

Receptor D1

Receptor D1 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling north along Epping Road.

The simulation predicted that reflections can intermittently fall on this point during the afternoon hours between 4:45 pm and 6:45 pm AEST from mid-September to March. Very brief reflections were also predicted to fall on this point during the morning hours between 6:00 am and 8:15 am AEST from February to early May and again from August to October.

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

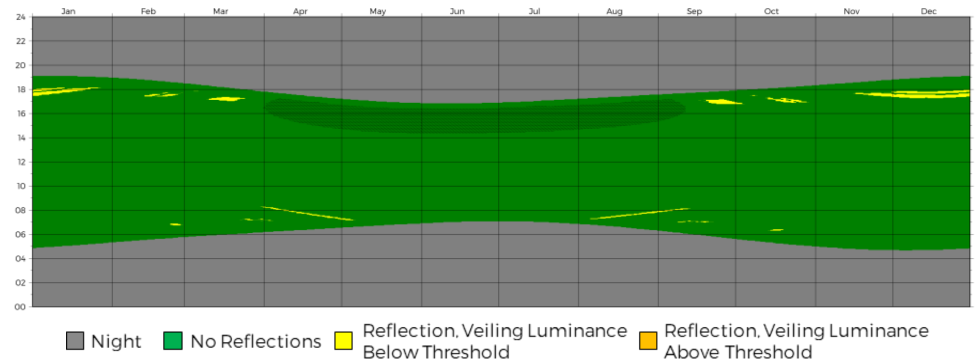

Figure 9: Annual Reflection Impact Diagram for Driver Receptor D1

Receptor D2

Receptor D2 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling north along Epping Road.

The simulation indicated that reflections can primarily fall on this point during the afternoon hours between 4:45 pm and 7:00 pm AEST from late September to mid-November and again from mid-January to mid-March. Very brief reflections were also predicted to fall on this point during the morning hours between 6:00 am and 8:45 am AEST from March to October.

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

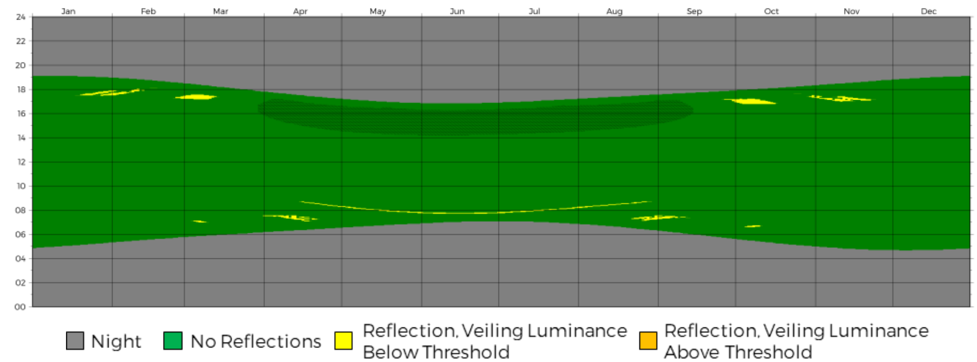

Figure 10: Annual Reflection Impact Diagram for Driver Receptor D2

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 the majority of reflections having a maximum intensity below 120 W/m^2.

3. The maximum intensities of the reflected solar energy at ground level within the project site itself were predicted to be higher, but not in excess of what is commonly seen in an urban area, with maximum intensities below 600 W/m^2. This indicates that no concentration of reflections is occurring. Thus, 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.

4. The screening analysis predicted a low potential for glare, even with its highly conservative assumption that the viewer would always be looking horizontally towards the source of the reflection. The areas most frequently exposed to reflections are predicted to be confined to the ground-level area in front of the Ivanhoe Community Centre on the Village Green and the south-western aspect of Building C3. However, the predicted frequencies were not predicted to exceed 6% of daytime hours. Further, since these are pedestrian areas, RWDI would not consider this a safety risk.

5. Only a small area of the southbound lanes of Epping Road were predicted to have the potential to experience reflections. Given the angle of the predicted reflections they are not expected to fall in the field of view of a southbound driver and thus pose little risk of glare.

6. The detailed analysis, which accounted for more realistic view directions and operated at one-minute increments, was conducted for northbound drivers as a due-diligence. This analysis predicted that while northbound drivers do have the potential to be exposed to reflections from the proposed development, no reflections were predicted to exceed the veiling luminance threshold of 500 cd/m^2.

7. Given the safety risks associated with glare impacts to drivers, RWDI's analysis was 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. The dense trees around the perimeter of the site in particular are expected to provide additional protection to drivers.

8. Overall RWDI's analysis indicated no significant potential for veiling glare on drivers and typical levels of reflected energy elsewhere.

9. Although these results are based on an earlier design iteration (up to 17 May 2021), the subsequent reduction of building massing is not expected to materially alter these conclusions.

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 80th 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 colour, 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.

References

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