Sovereign Wynyard Centre Pty Limited

One Carrington Street

Reflectivity Study

REP

Issue 2 | 24 March 2014

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 229159-07

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Contents

Executive Summary

This reflectivity study assesses the impact of solar reflections on pedestrians and road traffic participants in the area surrounding the proposed building at One Carrington Street in terms of reduced visibility of visual tasks, to address the qualitative requirements of the Central Sydney DCP 2012 Provision 3.2.7. As per this provision, the report focuses on the impact to traffic participants. This assessment is performed following the methodology of David N.H. Hassall of the University of New South Wales[1].

The proposed building has been found to perform well in terms of solar reflectivity, and reflections have not been found to cause unacceptable glare according to the Hassall methodology, as long as glazing reflectivity is kept within the following limits:

- **All glazed facades: 20%**

This result is obtained in spite of worst case assumptions about the extent of reflective facade cladding, and not taking into account obscuring effects from smaller façade elements and surrounding vegetation.

Pedestrians are easily able to adjust their view in any location where unwanted reflections may be received, reducing the impact of the reflections, and move at a rate significantly slower than that of a vehicle. For this reason it is acceptable to assume that it will be safe for pedestrians to divert their vision in order to avoid glare.

The glass reflectance limits noted above will also serve to reduce potential glare reflections that may occasionally be produced towards other buildings.

[1] Hassall, D. N. H. (1991): *Reflectivity. Dealing with Rogue Solar Reflections*, Faculty of Architecture, University of New South Wales, ISBN 0 646 07086 X

1 Introduction

Arup has been commissioned by Sovereign Wynyard Centre Pty Limited to carry out a reflectivity study of the proposed development at One Carrington Street, Sydney.

This reflectivity study assesses the impact of solar reflections on pedestrians and road traffic participants in the area surrounding the site. It is intended to address the qualitative requirements of the Central Sydney DCP 2012 Provision 3.2.7.

The assessment in this report is performed following the methodology of David N.H. Hassall of the University of New South Wales, which contemplates potential rogue reflections giving more detailed consideration to geometry, viewing angles, and sun positions. It is described in more detail in section 3.

2 Project Description

2.1 General

The proposed development at One Carrington Street will create commercial space above a new station concourse and retail spaces. It comprises the historic Shell Building as well as a 27-storey new built component. This report focuses on the proposed new building.

Located in the Central Business District of Sydney, the building is situated between George St to the East and Carrington St and Wynyard Park to the West. The building rises above the neighbouring properties, such that all of its principal elevations can be seen from road level. It is however located in a densely built up area of the CBD, and view towards the building is restricted mostly to the streets that lead directly past the site.

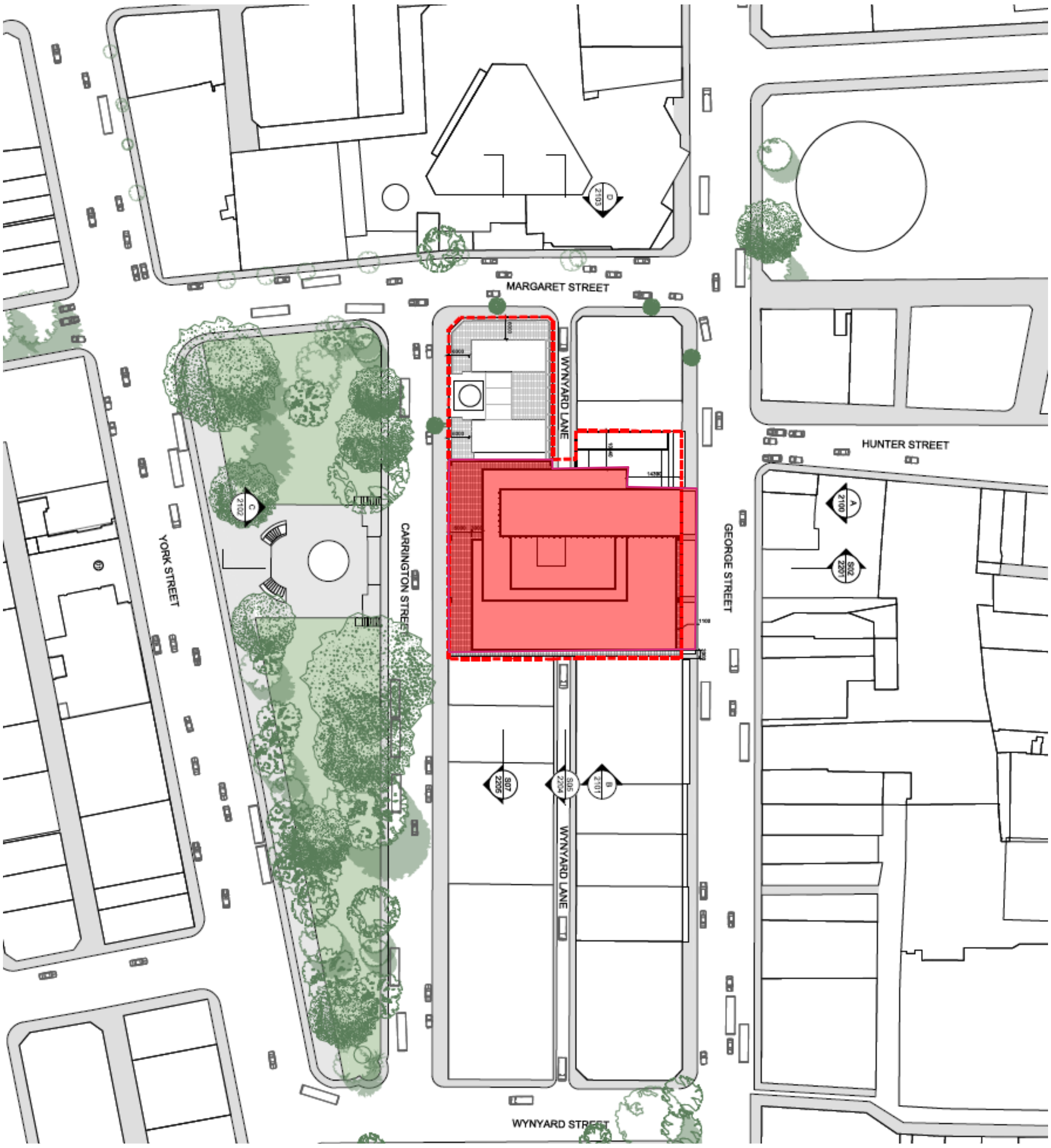


Figure 1: Site plan. New building highlighted in red (plan by Make + Architectus)

2.2 Facades

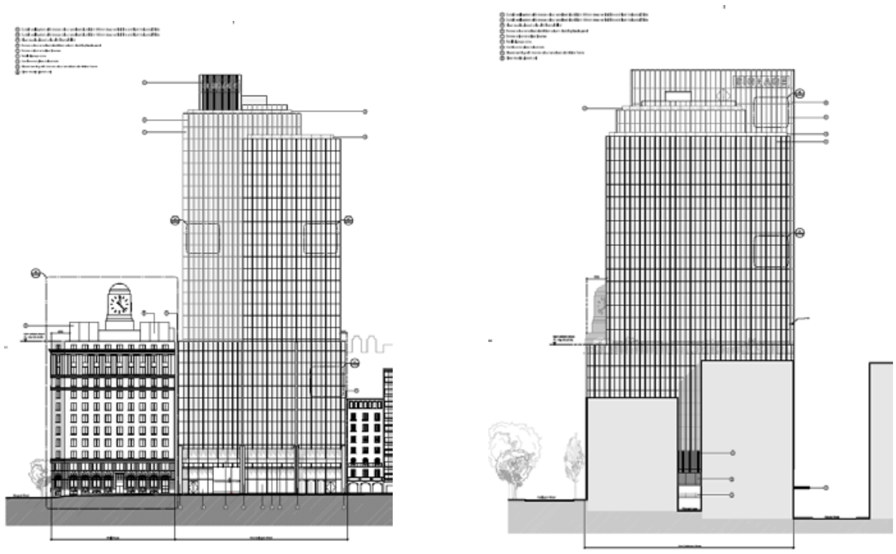


Figure 2: Carrington St (west) and south elevations (Make + Architectus)

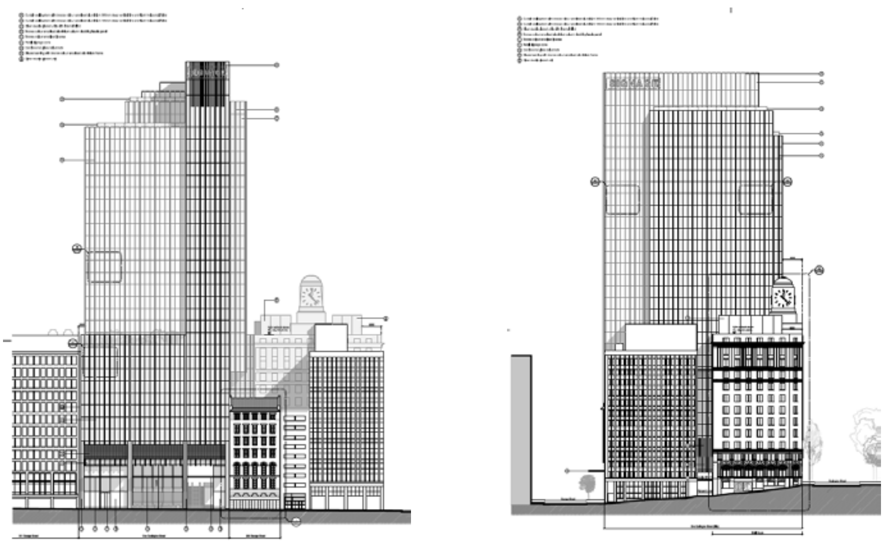


Figure 3: George St (east) and north elevations (Make + Architectus)

The building consists of a number of interlocking volumes, so that there are several different façade planes within each elevation. All of these planes are however aligned with the four principal project directions.

The intent for the facades is to be predominately full height glazing. All glazing will have a normal specular reflectivity no higher than 20% as per council requirements.

Several elevations feature projecting vertical fins at different spacing. Features such as projecting fins and spandrel areas that are not glazed are intended to be metal clad with anodised aluminium or a similar diffuse finish. The finish is to be selected to have a specular component of reflectivity no higher than 20%.

3 Assessment of Facade Reflections

3.1 Criteria for Assessment

The method for this study follows that of David N. H. Hassall of the University of New South Wales, which has been widely used to assess reflections off building projects in Sydney. This method quantifies reflections and classifies reflections using the terms disability glare and discomfort glare. These are defined in the Hassall methodology as follows:

- Disability glare – glare from reflections which impact the observer in a way that they are unable to perform a visual task, such as reading or driving, without taking evasive action (such as turning away or raising a hand to shield the eyes). It is critical that a driver's view is unaffected by disability glare as this has the potential to cause road accidents. Note that the term 'Disability' indicates temporary impact on the ability to perform visual tasks and does not imply that the glare effect leads to long-term disability in any form.
- Discomfort glare – glare from reflections causing the observer psychological annoyance.

Calculations following this method centre on equivalent veiling luminance in the eyes of observers due to solar reflections. The terms 'veiling luminance' and 'veiling glare' refer to the effect of multiple reflection and scattering within the eye of direct light from a bright source. This produces a perception similar to a thin veil being overlaid on the visual scene, and reduces the contrast in the scene, potentially impairing visual tasks.

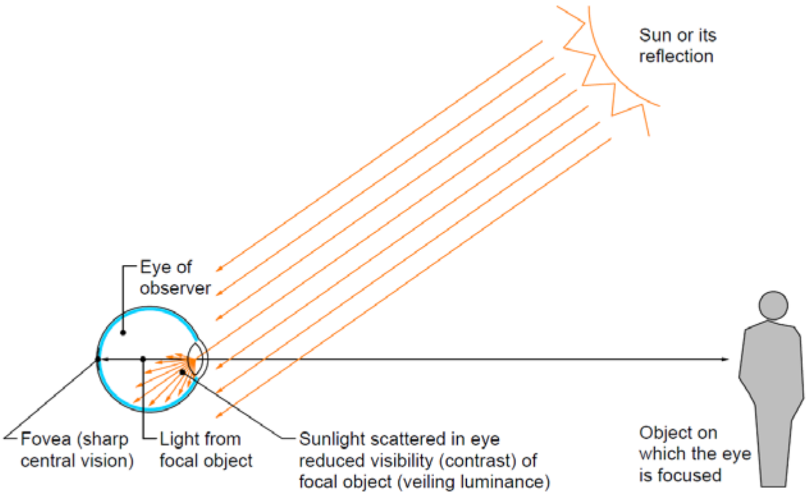


Figure 4: Bright sunlight falling into the eye reduces contrast and visibility of objects. This effect can be quantified by the equivalent veiling luminance measure.

A prerequisite for veiling glare is thus that reflections of the sun are visible relatively close to the direction of view of an observer.

3.2 Methodology

The assessment of undesirable solar reflections is based on the methodology described by Hassall. This involves several steps, as outlined below.

- The size, orientation and extent of reflective objects on each facade are determined by examination of drawings provided by the architect, the site and surrounds, and expected glazing materials.
- Several observer locations are chosen for critical facades, representing locations from which traffic participants may observe the facades.
- Times at which the sun is reflected off the facade are determined, as well as the directions in which it is reflected.
- If the sun is reflected towards any observer, the equivalent veiling luminance in the eye of the observer is calculated and evaluated against the maximum allowed level of 500 Cd/m² according to Hassall. This involves calculations of the strength of solar illumination, the position of the sun in front of the facade, the apparent position of the sun reflected in the facade, and the reflected solar illumination received by the observer. If the limit is exceeded, further assessment is carried out to evaluate if other factors such as facade shading make the situation acceptable or not.

3.3 Assumptions

- All glazed facades have been assumed to have a reflectivity of 20% as the worst case allowable value.
- It is assumed that to carry out the visual tasks required for traffic participation, drivers and pedestrians face parallel to the ground, and parallel to their direction of travel.

3.4 Modelling and Assessment Approach

This reflectivity study used a 3D model of the building and the surrounding topography. The 3D model was developed from the architectural 3D model as a simplified massing model, however retaining accurate orientations of façade surfaces. Relative road elevation information was taken from available 3D topography.

Facades have been analysed in true elevation angles as provided with 3D model information by Architectus architects. Small scale detail such as joints, any expressed framing profiles, downpipes, etc has been omitted from the model. They subtend insufficient angles in the visual field to reflect a large enough portion of the sun disk to cause unacceptable glare.

Being opaque and of diffuse finish, the external vertical fins included in the design on a number of the façade elevations would effectively reduce the potential of glare by blocking reflections off the vision glass in between at shallow angles of incidence. They have not been included in the analysis model. This is considered conservative and allows for a 'worst case' assessment of the façade reflections regardless of potential future adjustments to the fin spacing.

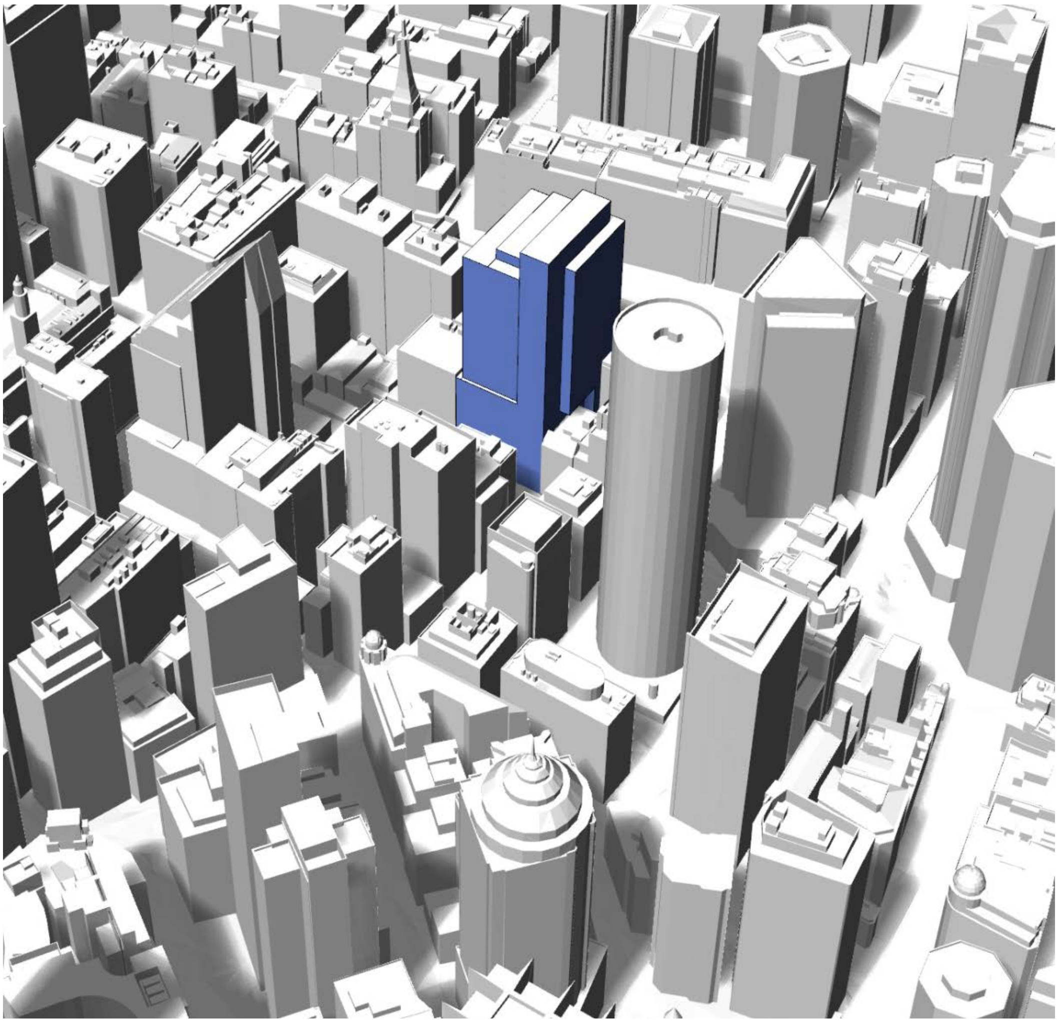


Figure 5: Image of the 3D building and context model. Surfaces shown in blue have been assumed as reflective.

This model was used to interrogate the view of the building and solar reflections originating from it along the paths shown in Figure 6.

Ref.	Road	Dir.
A	George St	S
B	George St	N
C	Hunter St	W
D	Margaret St	E
E	Carrington St	N
F	York St	S
G	Western Distributor	S
H	Western Distributor	N

Figure 6: Site map showing observer paths from which glare has been assessed

3.5 Results for Analysed View Directions

Observed model analysis outcomes for each of the travel paths are summarised below. Indicative perspective views and reflected sun charts are shown for a single viewpoint on these paths. Note however the modelled paths have been reviewed along their entire lengths.

The sun charts indicate the times of the year when solar reflections are visible from each view location. The coloured region on each chart shows the projected façade. Where this region intersects the reflected sun path, the façade can reflect the sun's light towards the location.

The equivalent veiling luminance of these reflections is calculated with respect to a driver's heading direction, and is colour coded in projected facades in sun charts and in perspective views. Façade areas are shown orange to red where reflections exceed the Hassall limit of 500Cd/m². Reflections off projected façade area shown in blue to cyan are below this limit in intensity.

A. Traveling South on George Street

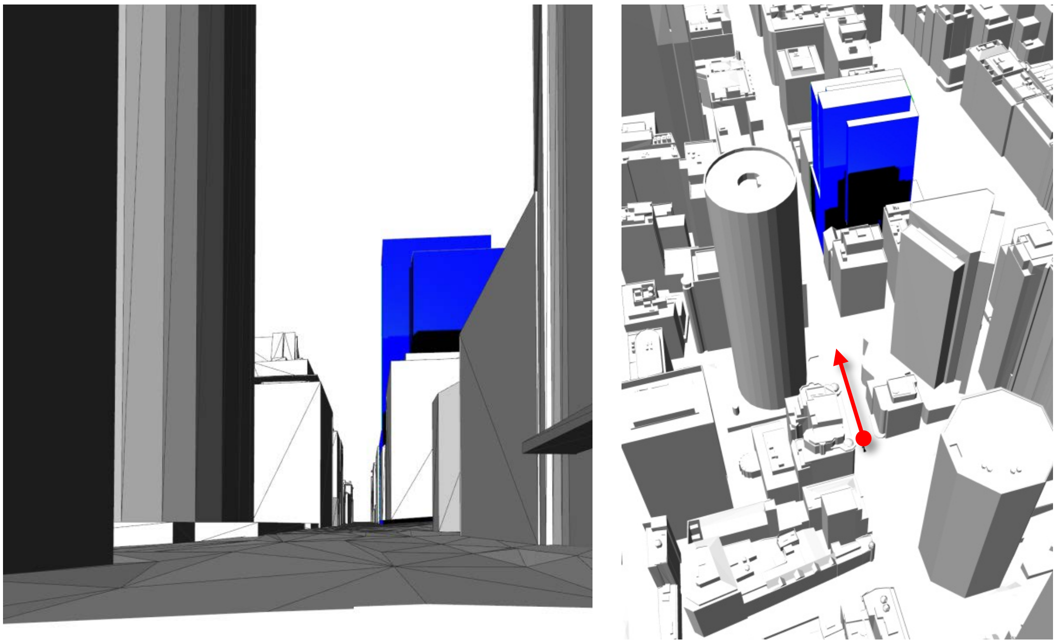


Figure 7: Perspective view from road and view of relative observer position

Viewed from locations along this stretch of road the upper reaches of the north facades of the building can reflect the sun towards drivers for up to approximately 1 hour around midday in winter months.

However, at 20% normal glass reflectivity the equivalent veiling luminance of reflection of up to approximately 180 Cd/m² lies well below the Hassall threshold.

Reflections from the facades towards this observer path have thus been found to pose minimal risk of glare.

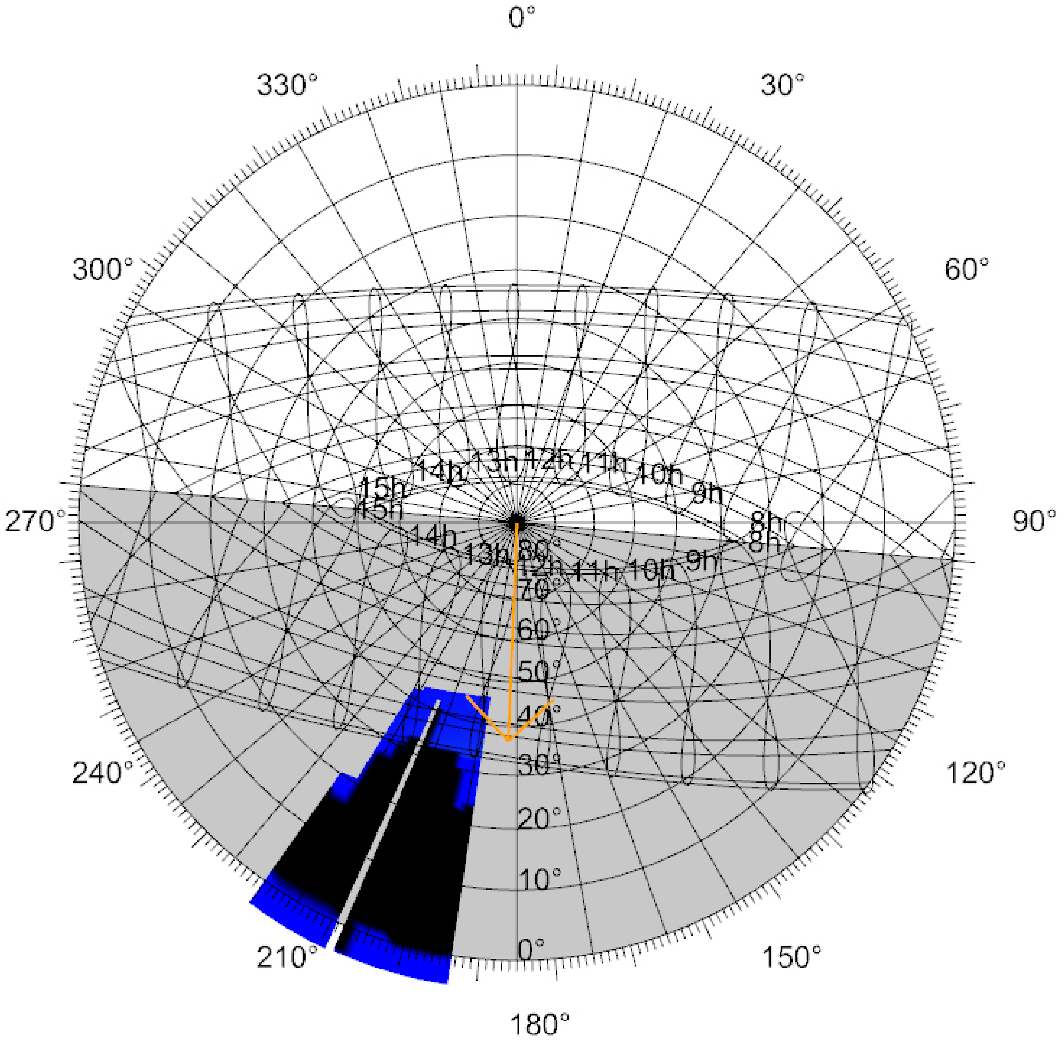


Figure 8: Stereographic sun chart of north facades

B. Traveling North on George Street

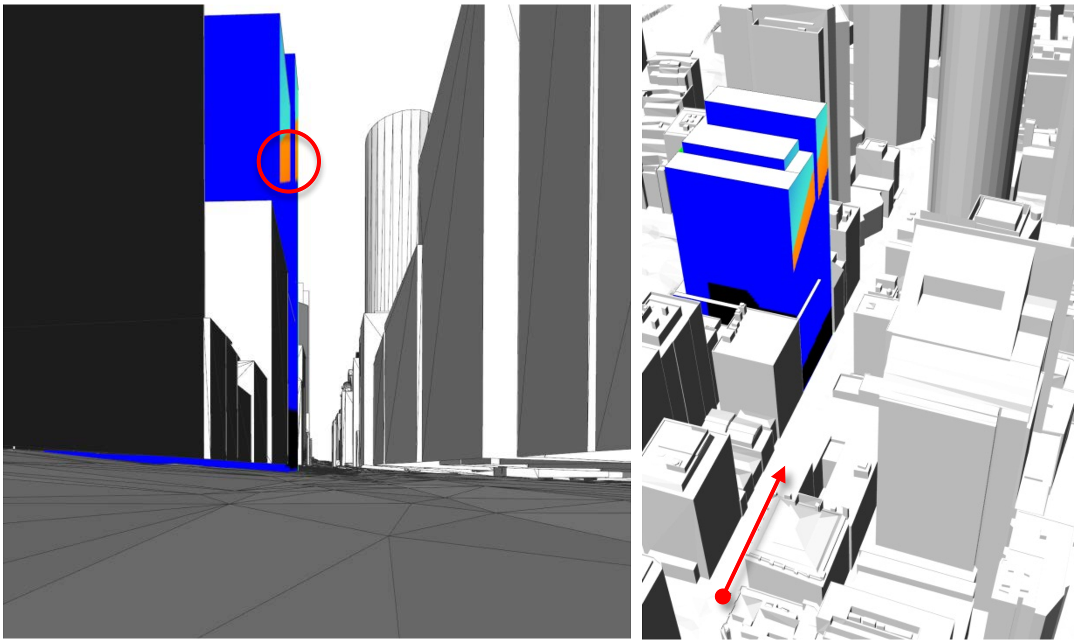


Figure 109: Perspective view from road and view of relative observer position

Viewed from locations along this stretch of road the east façade planes of the building can theoretically reflect the sun towards drivers for intervals of up to 5-10 minutes during late winter mornings.

The equivalent veiling luminance of reflections at 20% normal glass reflectivity would theoretically reach up to 650 Cd/m², exceeding the Hassall threshold.

However, these reflections only occur at shallow glancing angles of incidence (<7°). Such reflections are not considered problematic due to the following:

- As traffic participants are moving parallel to the façade, the direct sun would be visible at a similar angle from the view direction. The direct sun would thus be the primary source of glare, and the façade reflection arguable does not increase the likelihood of glare
- Reflections of the sun disk are distributed across a number of façade panels and are significantly scattered by minimal misalignments and distortions such as pillowing of double glazed units, effectively reducing the equivalent luminance
- Expressed vertical fin elements would block most or all of the sun reflection

Reflections from vertical facades towards this observer path have thus been found to pose minimal risk of glare.

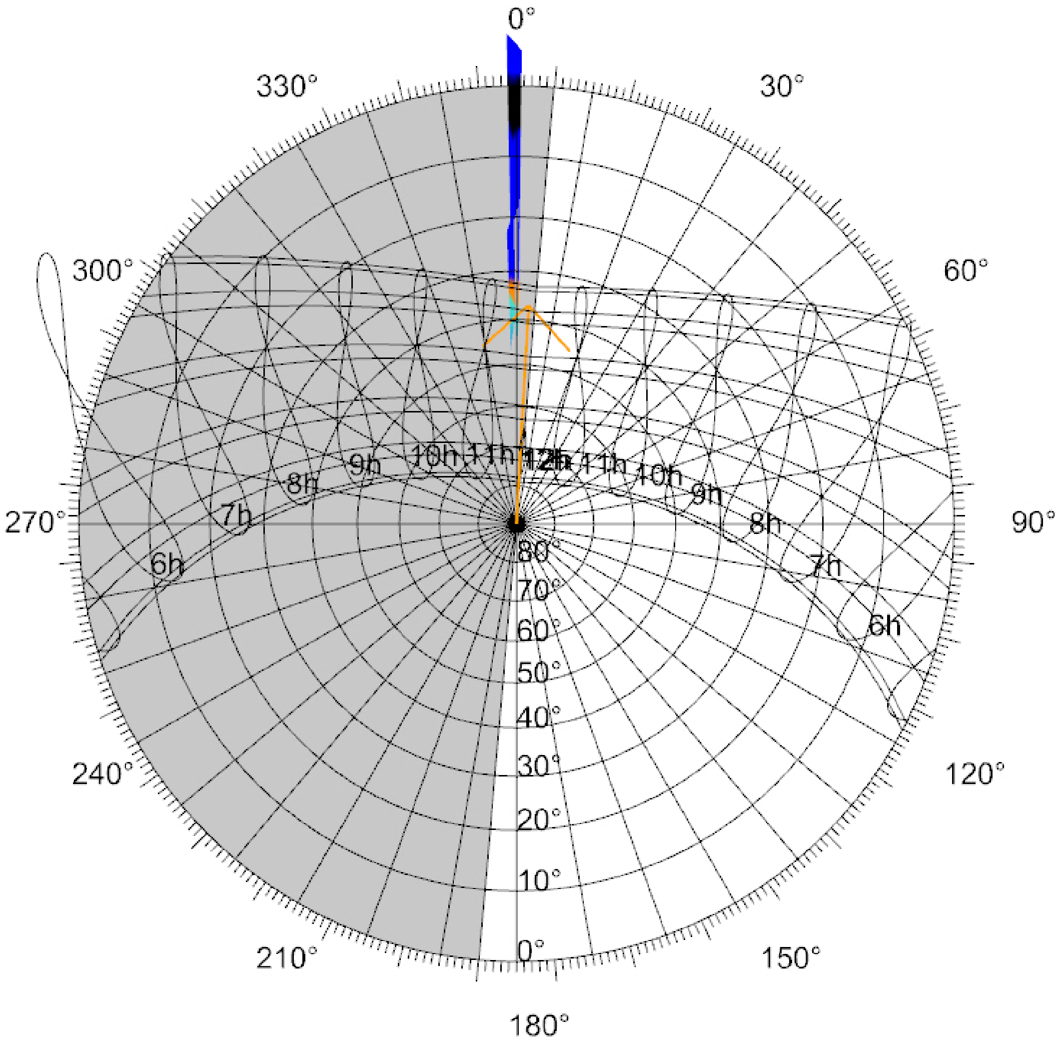


Figure 11: Stereographic sun chart of east facades

C. Traveling West on Hunter Street

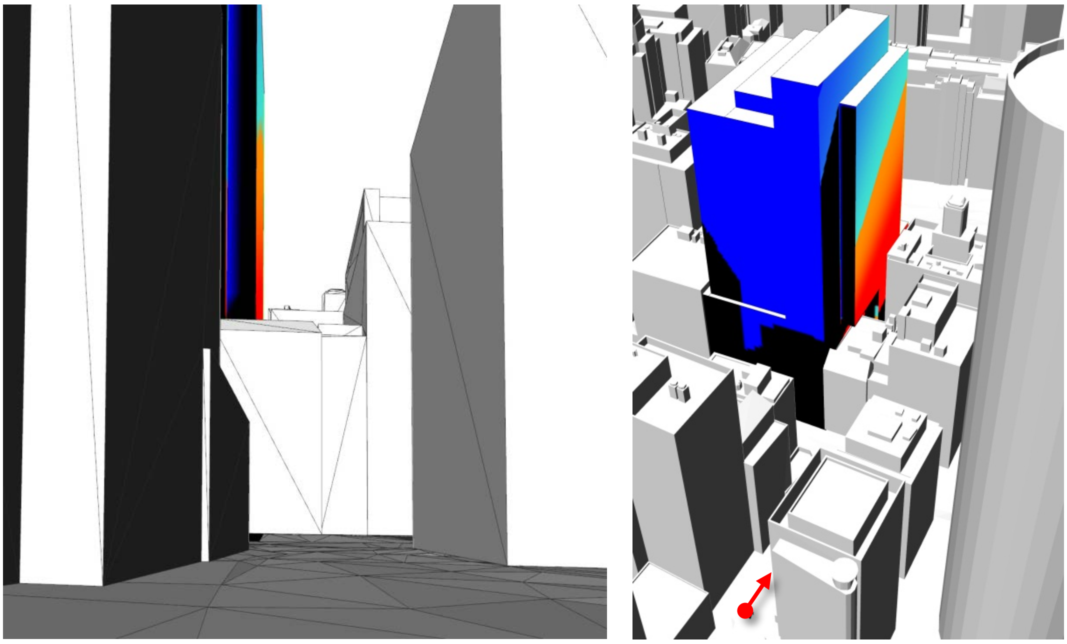


Figure 12: Perspective view from road and view of relative observer position

Viewed from locations along this stretch of road the north façade planes of the building can theoretically reflect the sun towards drivers for intervals of up to 5-10 minutes during late winter mornings.

The equivalent veiling luminance of reflections at 20% normal glass reflectivity would theoretically reach up to 2200 Cd/m², exceeding the Hassall threshold.

However, these reflections only occur at shallow glancing angles of incidence (<7°). Such reflections are not considered problematic due to the following:

- The angle subtended in the visual field by the north façades (0.25° approx.) is smaller than that of the sun disk. This would effectively reduce the equivalent luminance of partial sun reflections
- As traffic participants are moving parallel to the façade, the direct sun would be visible at a similar angle from the view direction. The direct sun would thus be the primary source of glare, and the façade reflection arguable does not increase the likelihood of glare
- Reflections of the sun disk are distributed across a number of façade panels and are significantly scattered by minimal misalignments and distortions such as pillowing of double glazed units, effectively reducing the equivalent luminance
- Expressed vertical fin elements would block most or all of the sun reflection

Reflections from vertical facades towards this observer path have thus been found to pose minimal risk of glare.

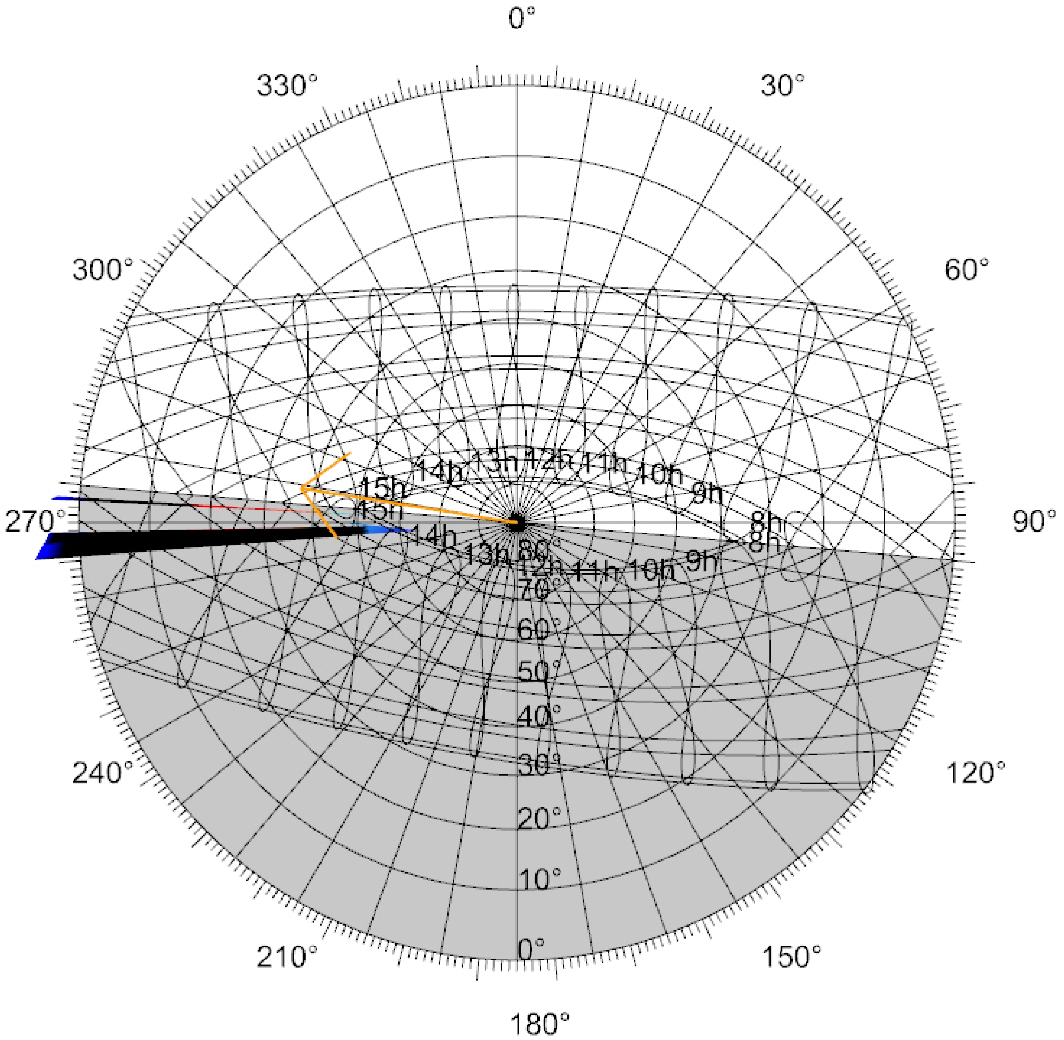


Figure 13: Stereographic sun chart of north facades

D. Traveling East on Margaret Street

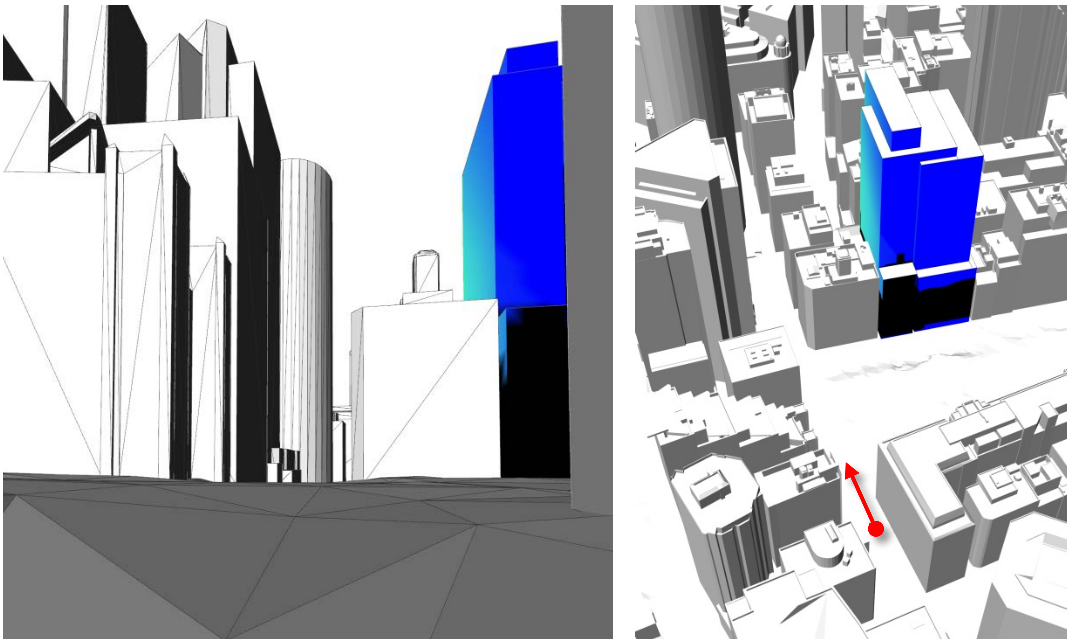


Figure 14: Perspective view from road and view of relative observer position

Viewed from locations along this stretch of road the north facades of the building can reflect the sun towards drivers for up to approximately 15 minutes during summer mornings.

However, at 20% normal glass reflectivity the equivalent veiling luminance of reflection of up to approximately 430 Cd/m² lies well below the Hassall threshold.

Reflections from the facades towards this observer path have thus been found to pose minimal risk of glare.

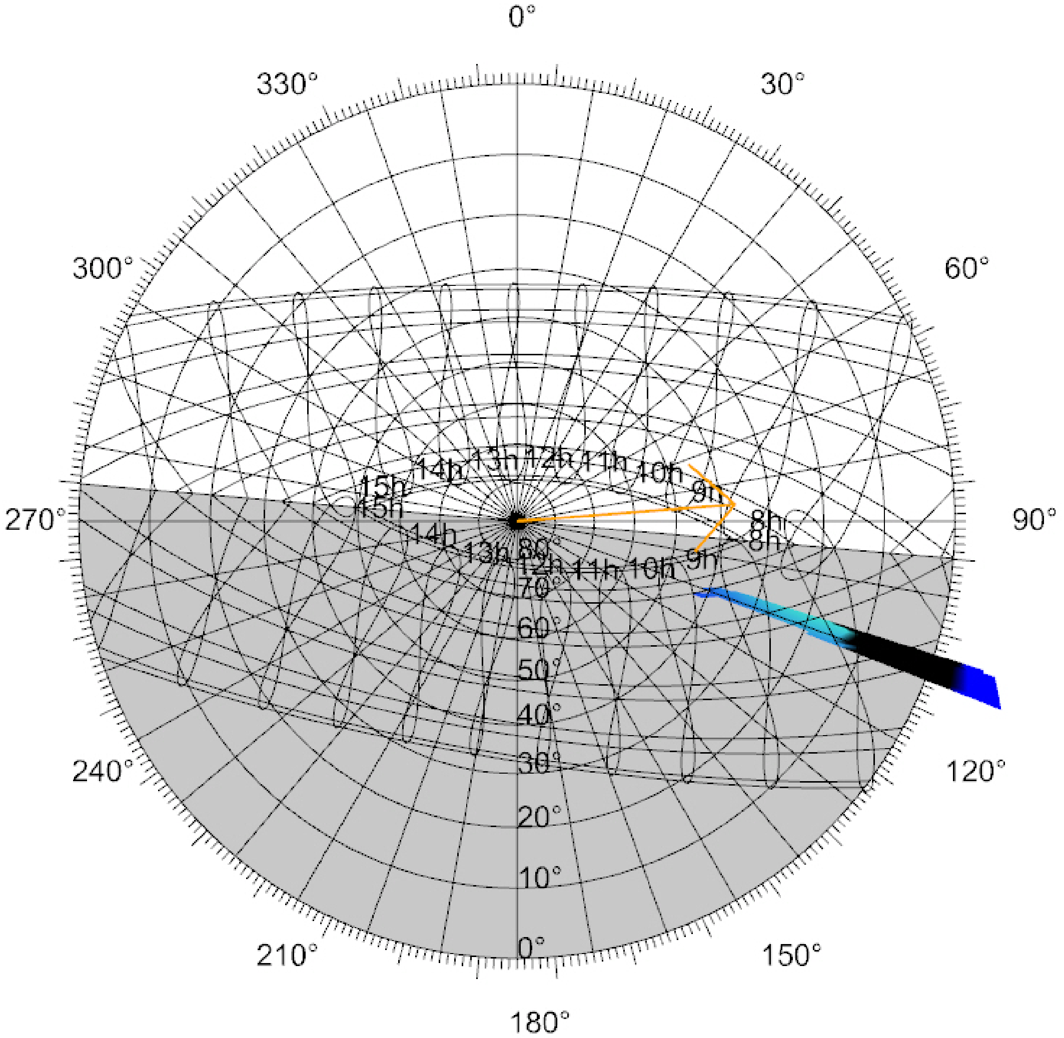


Figure 15: Stereographic sun chart of north facades

E. Traveling North on Carrington Street

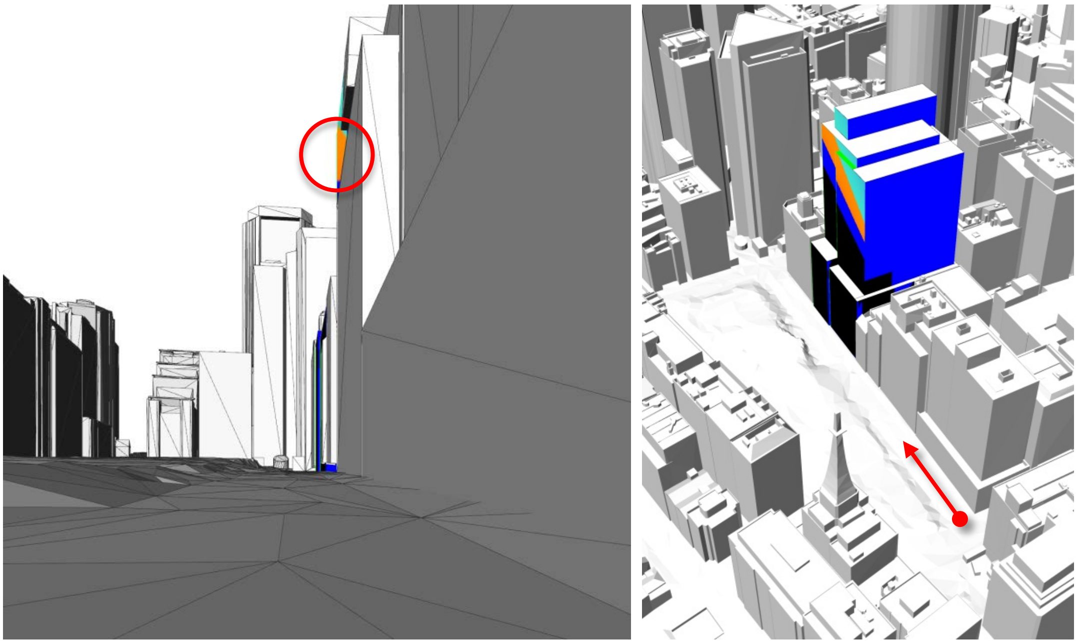


Figure 16: Perspective view from road and view of relative observer position

Viewed from locations at the southern end of this stretch of road the west façade planes of the building can theoretically reflect the sun towards drivers for intervals of up to 2-3 minutes around midday in winter.

The equivalent veiling luminance of reflections at 20% normal glass reflectivity would theoretically reach up to 610 Cd/m², exceeding the Hassall threshold.

However, these reflections only occur at shallow glancing angles of incidence (<7°). Such reflections are not considered problematic due to the following:

- As traffic participants are moving parallel to the façade, the direct sun would be visible at a similar angle from the view direction. The direct sun would thus be the primary source of glare, and the façade reflection arguable does not increase the likelihood of glare
- Reflections of the sun disk are distributed across a number of façade panels and are significantly scattered by minimal misalignments and distortions such as pillowing of double glazed units, effectively reducing the equivalent luminance
- Expressed vertical fin elements would block most or all of the sun reflection

Reflections from vertical facades towards this observer path have thus been found to pose minimal risk of glare.

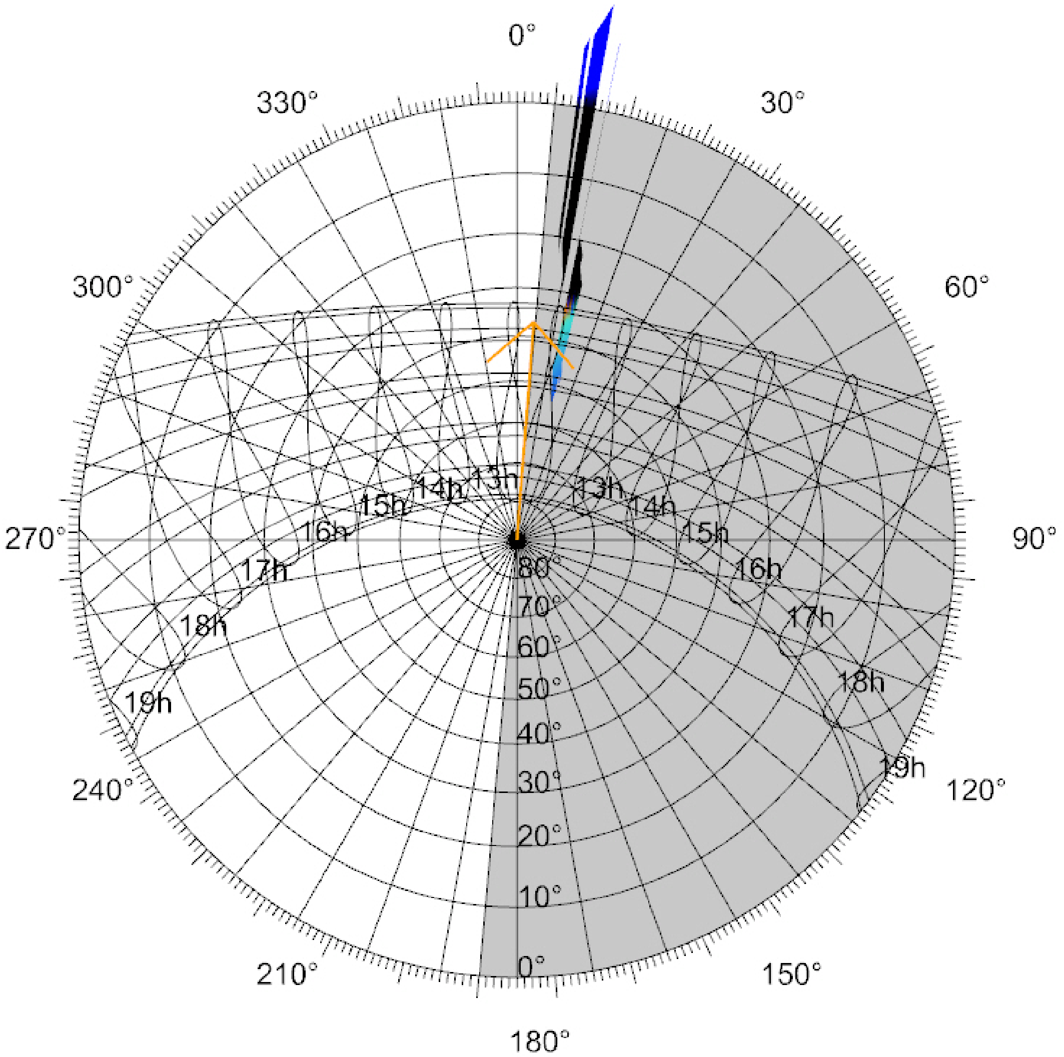


Figure 17: Stereographic sun chart of west facades

F. Traveling South on York St

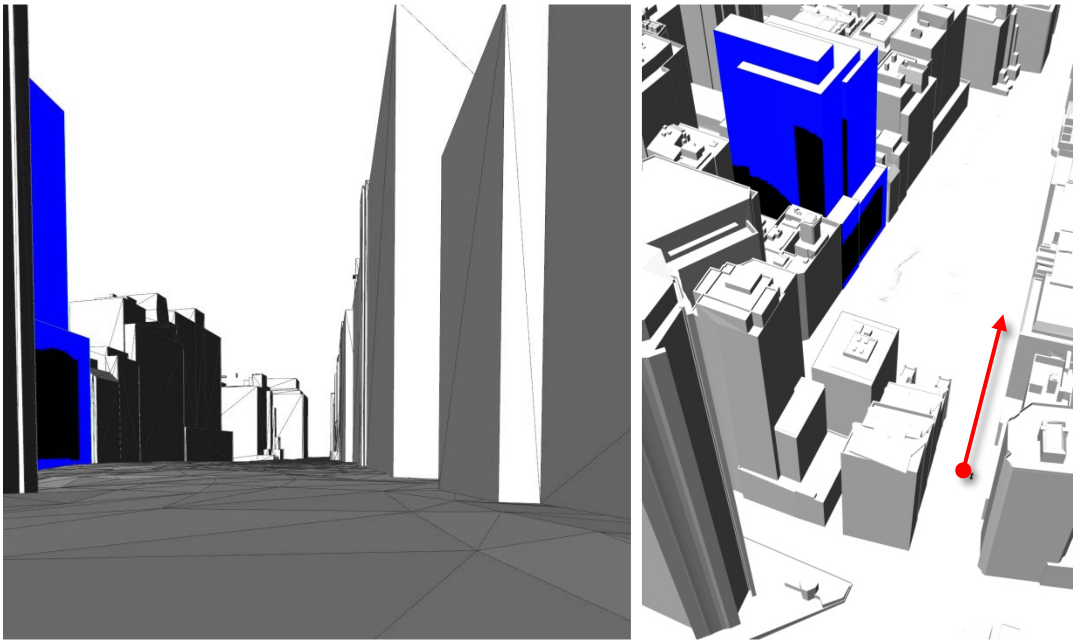


Figure 18: Perspective view from road and view of relative observer position

Viewed from locations along this stretch of road the upper west facades of the building can reflect low angle sun for up to approximately 1 hour during late summer afternoons.

However, the view towards the building lies well away from the principal view direction of traffic participants following York St, and at 20% normal glass reflectivity the equivalent veiling luminance of reflection of up to approximately 30 Cd/m² lies well below the Hassall threshold.

Reflections from the facades towards this observer path have thus been found to pose minimal risk of glare.

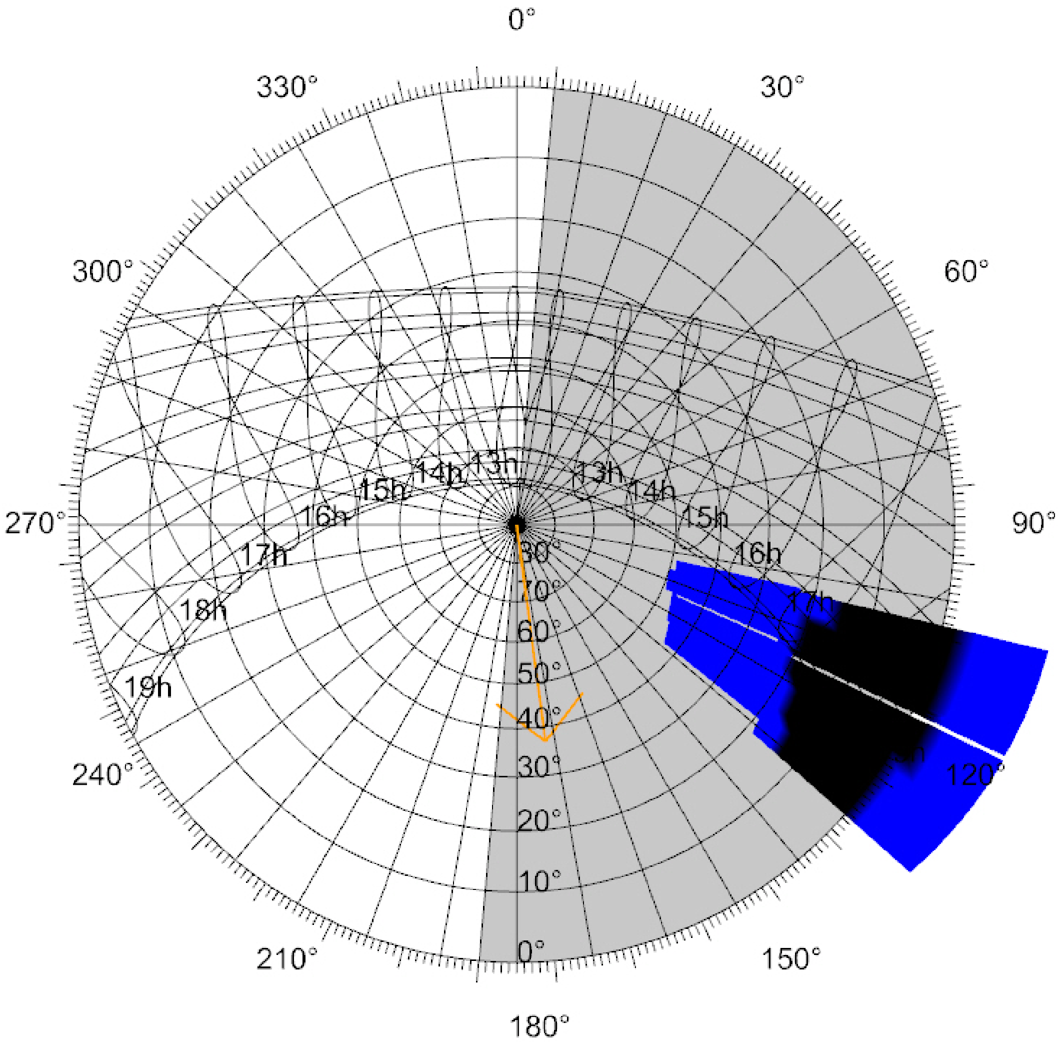


Figure 19: Stereographic sun chart of west facades

G. Traveling South on the Western Distributor

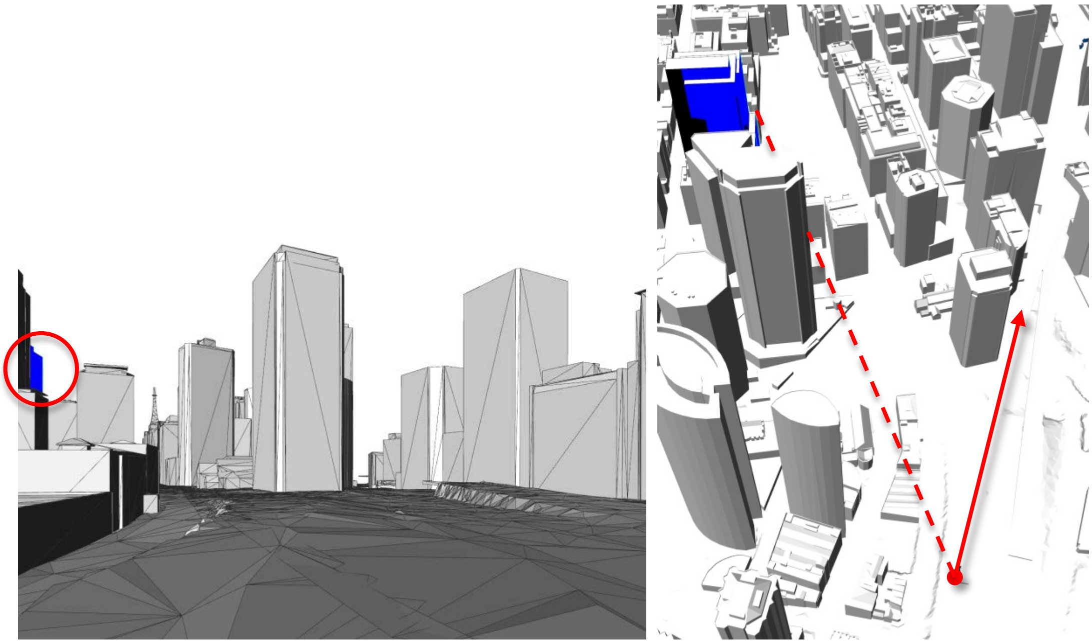


Figure 20: Perspective view from road and view of relative observer position

Viewed from locations along this stretch of road the upper north facades of the building can reflect low angle sun for up to approximately 30 minutes during winter mornings.

However, the view towards the building lies well away from the principal view direction of traffic participants, and at 20% normal glass reflectivity the equivalent veiling luminance of reflection of up to approximately 10 Cd/m² lies well below the Hassall threshold.

Reflections from the facades towards this observer path have thus been found to pose minimal risk of glare.

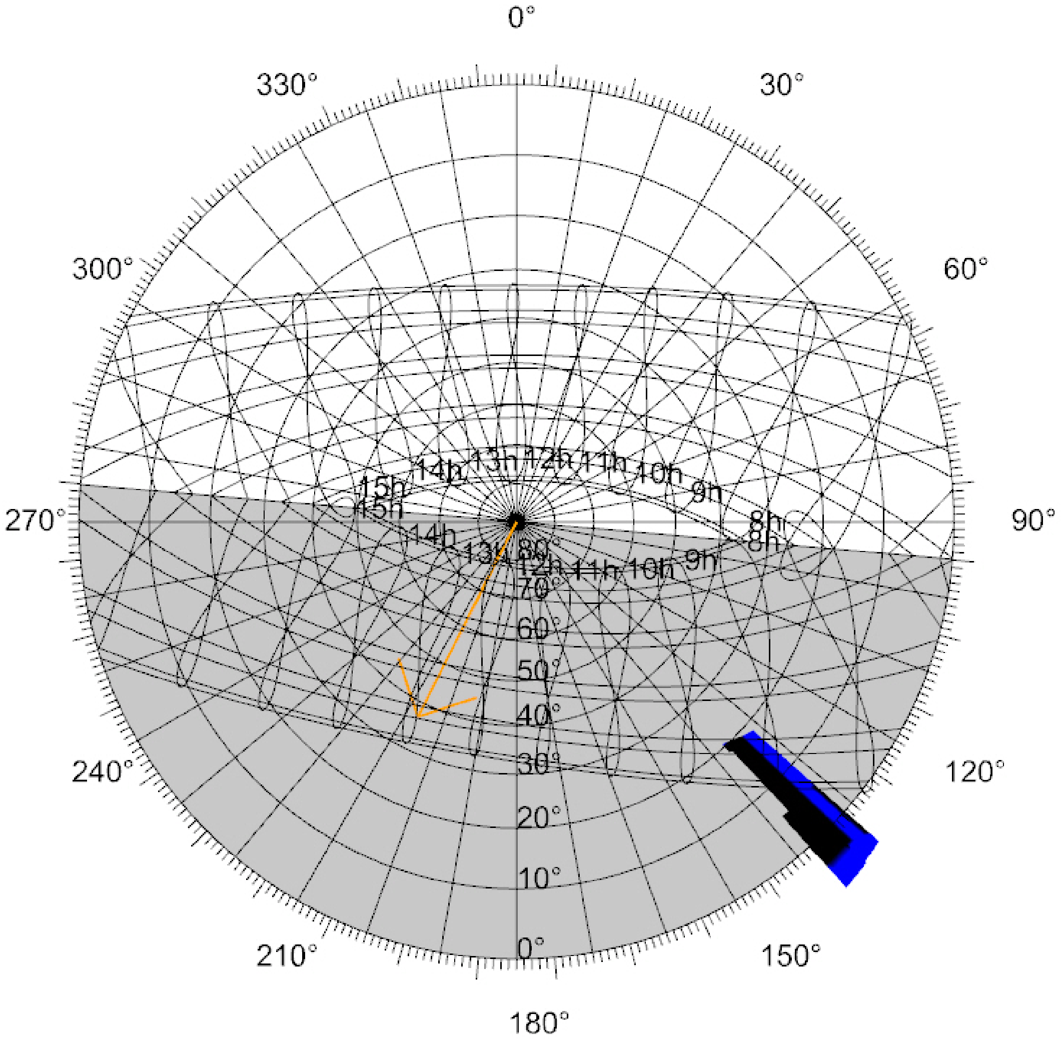
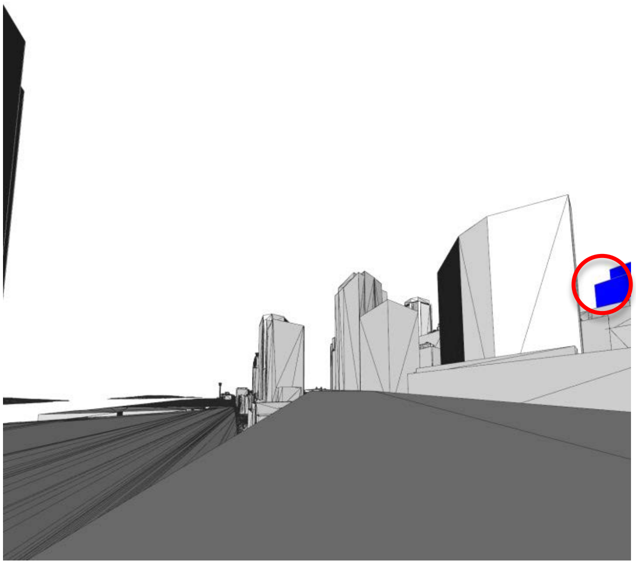


Figure 21: Stereographic sun chart of north facades

H. Traveling North on the Western Distributor



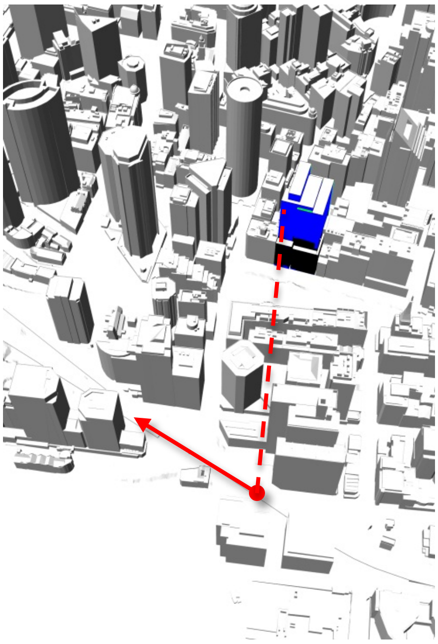


Figure 22: Perspective view from road and view of relative observer position

Viewed from locations along this stretch of road the upper north facades of the building can reflect low angle sun for up to approximately 40 minutes during mid-season afternoons.

However, the view towards the building lies well away from the principal view direction of traffic participants, and at 20% normal glass reflectivity the equivalent veiling luminance of reflection of up to approximately 50 Cd/m² lies well below the Hassall threshold.

Reflections from the facades towards this observer path have thus been found to pose minimal risk of glare.

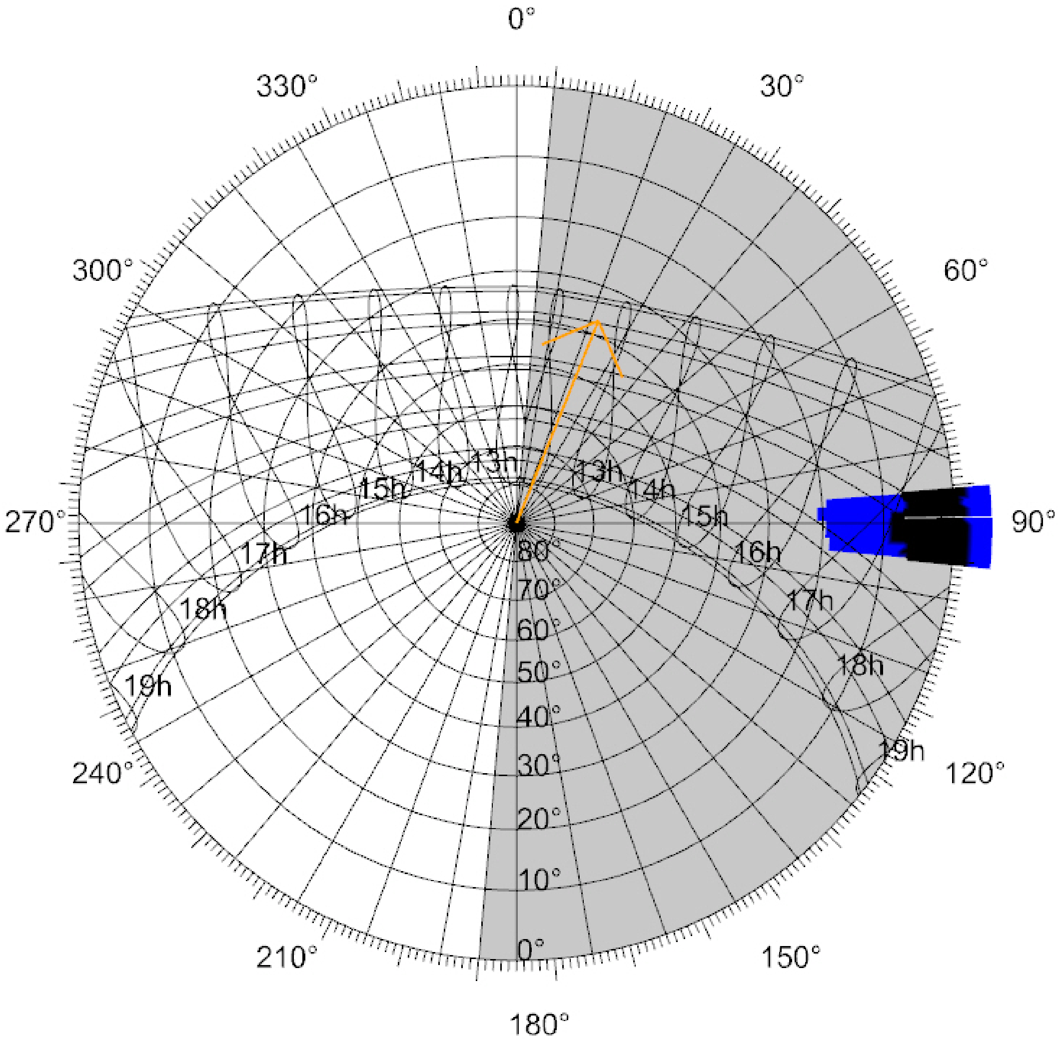


Figure 23: Stereographic sun chart of west facades

Summary

Reference	Road	Driving direction	Maximum Lv identified at 20% reflectivity	Allowable specular reflectivity for glazed surfaces to limit reflection to ≤ 500 Cd/m²
A	George St	S	180 Cd/m²	20%
B	George St	N	660 Cd/m²*	20%
C	Hunter St	W	2200 Cd/m²*	20%
D	Margaret St	E	430 Cd/m²	20%
E	Carrington St	N	610 Cd/m²*	20%
F	York St	S	30 Cd/m²	20%
G	Western Distributor	S	10 Cd/m²	20%
H	Western Distributor	N	50 Cd/m²	20%

* = theoretical values. Shallow angles of incidence in these cases mean that actual intensity of reflections will be significantly reduced. Additionally, external shading will effectively block reflections in these cases

Table 1: Summary of roads reviewed for sun reflections

3.6 Impact on Traffic in Other Locations

From further afield e.g. on hill areas in other suburbs it may be possible that locations exist where the building can be seen from road level. These would however be at a distance where typical glazing surfaces of the building would subtend angles significantly smaller than the sun disk, and scattering effects from small misalignments e.g. due to construction tolerances and climatic distortion of double glazing panels would reduce the observable intensity of reflections, so that it is not expected to be high enough to create unacceptable glare.

3.7 Impact on Pedestrians

From the perspective of pedestrians moving along roadways, the incidence of reflections from the building is generally similar to the examined road traffic locations. Glare from reflections is therefore expected in similar locations.

Furthermore, pedestrian observers are easily able to adjust their view and thus reduce the glare impact of reflections. They move at a rate significantly slower than that of a vehicle. For this reason it can be assumed that it will be safe for pedestrians to divert their vision in order to avoid glare.

3.8 Impact on Surrounding Buildings

Solar reflections off the facade may reach surrounding buildings in the CBD area. This may occur for limited time periods throughout the day, i.e. during the morning sun may be reflected off the east facades towards buildings further to the east, and afternoon sun may be reflected towards buildings further west.

In general, reflections from facades with external reflectance below 20% are much less likely to cause discomfort to occupants of surrounding buildings than facades with strongly reflective glazing. The proposed building is targeting a glass reflectance below 20% in accordance with the Central Sydney DCP, which will serve to reduce potential glare reflections that may occasionally be produced towards other buildings.

The limited visible light transmittance of glazing in surrounding office buildings (in existing buildings commonly below 50-60%) will further reduce the intensity of any reflections.

For the above reasons it is expected that the development will have little or no solar reflection impact on the occupants of surrounding buildings.

4 Conclusion

The proposed building at One Carrington St performs well in terms of solar reflectivity, and reflections have not been found to cause unacceptable glare according to the Hassall methodology under the below assumptions.

Reflected glare risk from facades visible to traffic participants could be discounted for either of the following reasons:

- Facades do not reflect any portion of the sun's path towards traffic participants; or
- Any reflections found were below the assumed limit of acceptability as set out by Hassall; or
- Reflections with intensities theoretically above the threshold occur at shallow angle of incidence, such that reflections of the sun disk are significantly scattered by minimal misalignments and unevenness of façade panels, and such that the direct sun is visible at the same time as the reflections and presents a higher risk of glare than the reflections

These findings are valid as long as glazing reflectivity is kept within the following limits:

- **All glazed facades: 20%**

This result is obtained in spite of worst case assumptions about the extent of reflective facade cladding, and not taking into account obscuring effects from smaller façade elements and surrounding vegetation.

Pedestrians are easily able to adjust their view in any location where unwanted reflections may be received, reducing the impact of the reflections, and move at a rate significantly slower than that of a vehicle. For this reason it is acceptable to assume that it will be safe for pedestrians to divert their vision in order to avoid glare.

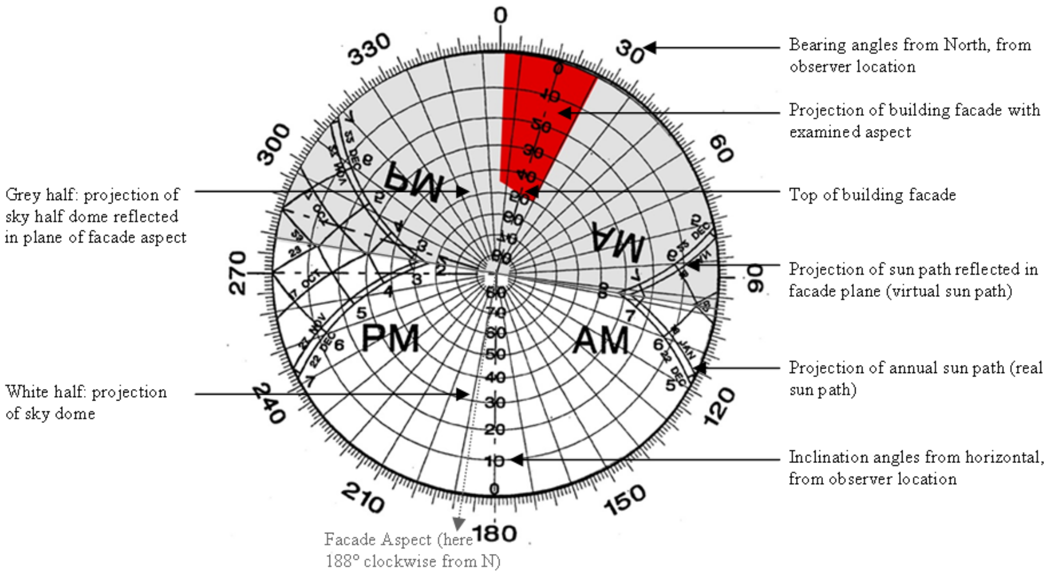
The glass reflectance limits noted above will also serve to reduce potential glare reflections that may occasionally be produced towards other buildings.

Appendix A

Notes on Diagrams

A1 Reading Virtual Sun Path Diagrams

These diagrams combine a projection of the sky dome with the sun's annual path across it with a projection of the sky and sun path as it would be reflected in an infinite plane with the aspect of the facade being examined. The building facade outline as seen from the observer location examined is then plotted onto the diagram. If the reflected sun path intersects the projection of the building facade, the sun would be reflected from this facade towards an observer at this location. The sun path marks indicating months and times of day provide an indication of the times at which reflections would be cast towards the observer.



Example virtual sun path diagram

Appendix B

Reference Information

B1 Architectural Drawings

The reflectivity study presented in this report was based on 3D model information provided by the architect Architectus in February 2014 and updated for the building geometry as per DA plans and elevations Rev. 00 by Make and Architectus architects issued 19th March 2014.

B2 References

Hassall, D. N. H. (1991): *Reflectivity. Dealing with Rogue Solar Reflections*, Faculty of Architecture, University of New South Wales, ISBN 0 646 07086 X