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Cockle Bay Park Redevelopment

State Significant Development, Development Application (SSD DA) Appendix Z - Reflectivity Report

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1 Introduction

This report has been prepared to accompany a detailed State Significant Development (SSD) Development Application (DA) (Stage 2) for a commercial mixed-use development, Cockle Bay Park, which is submitted to the Minister for Planning and Public Spaces pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The development is being conducted in stages comprising the following planning applications:

- Stage 1 – Concept Proposal setting the overall 'vision' for the redevelopment of the site including the building envelope and land uses, as well as development consent for the carrying out of early works including demolition of the existing buildings and structures. This stage was determined on 13 May 2019, and is proposed to be modified to align with the Stage 2 SSD DA.
- Stage 2 – Detailed design, construction, and operation of Cockle Bay Park pursuant to the Concept Proposal.

2 The Site

The site is located at 241-249 Wheat Road, Sydney to the immediate south of Pyrmont Bridge, within the Sydney CBD, on the eastern side of the Darling Harbour precinct. The site encompasses the Cockle Bay Wharf development, parts of the Eastern Distributor and Wheat Road, Darling Park and Pyrmont Bridge.

The Darling Harbour Precinct is undergoing significant redevelopment as part of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) including Darling Square and the W Hotel. More broadly, the western edge of the Sydney CBD has been subject to significant change following the development of the Barangaroo precinct.

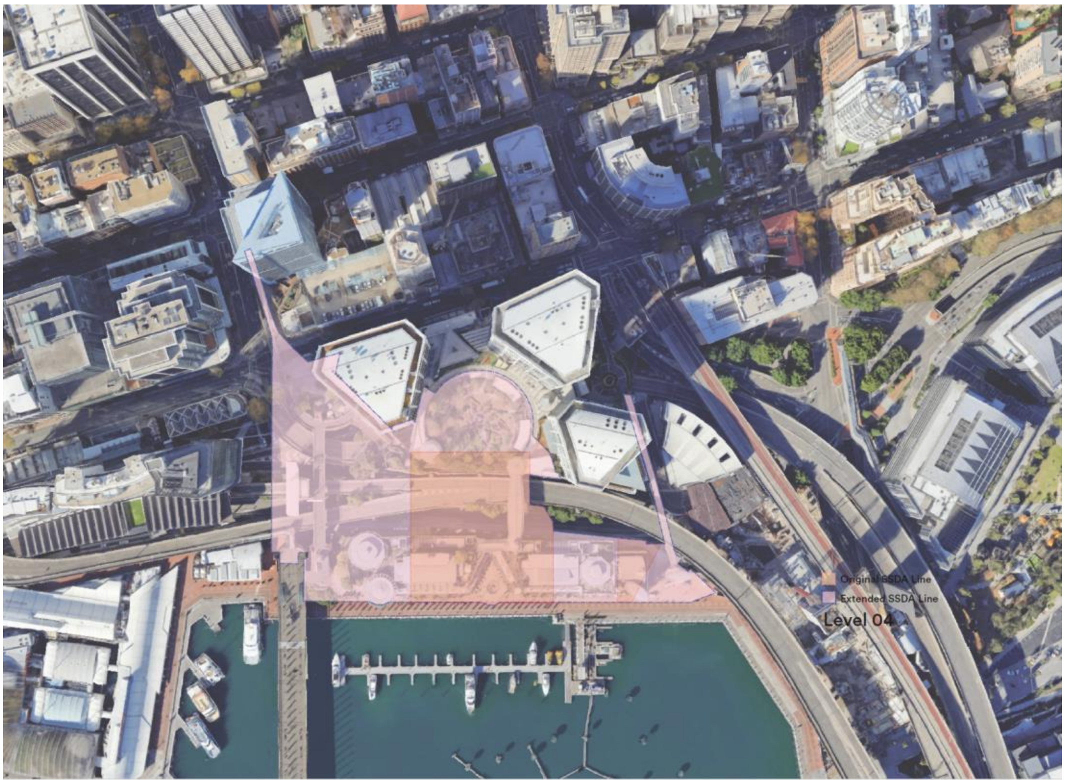

Figure 1: Location Plan

This report has been prepared in response to the Secretary's Environmental Assessment Requirements (SEARS) dated 12 November 2020 for SSD-9978934. Specifically, this report has been prepared to respond to those SEARS summarised in Table 1.

Table 1: SEARS requirements

Item	Description of Requirement	Section Reference (this report)
7	**Amenity** The EIS must: […] • detail the reflectivity levels of chosen materials of the façade and the inclusion of various passive solar design measures within the development	7

This report has also been prepared in response to the following Stage 1 (SSD 7684) conditions of consent summarised in Table 2.

Table 2: Concept approval of Conditions of Consent

Item	Description of Requirement	Section Reference (this report)
C2	**Building Design** Future Development Application(s) shall include a Reflectivity Analysis demonstrating that the external treatments, materials and finishes of the development do not cause adverse or excessive glare.	6, 7

3 Assessment locations

The Reflectivity Assessment is concerned with roads from which the proposed development is prominently visible, in particular where its glazed facades are visible at low angle above the plane of view and close to the dominant direction of travel. In addition to the streets immediately surrounding and leading up to the site, the assessment includes roads in Pyrmont and the Western Distributor.

Table 3 summarises the main roads and travel directions in proximity of the site.

Table 3: Roads and travel directions for assessment

Reference	Road	Direction
1	Union St / Darling St	East
2	Western Distributor	East / North
3	Pier St	East
4	Harbour St	North
5	Park St / Druitt St	West
6	Market St	West
7	Western Distributor	South
8	Sussex St / Shelley St / Lime St	South

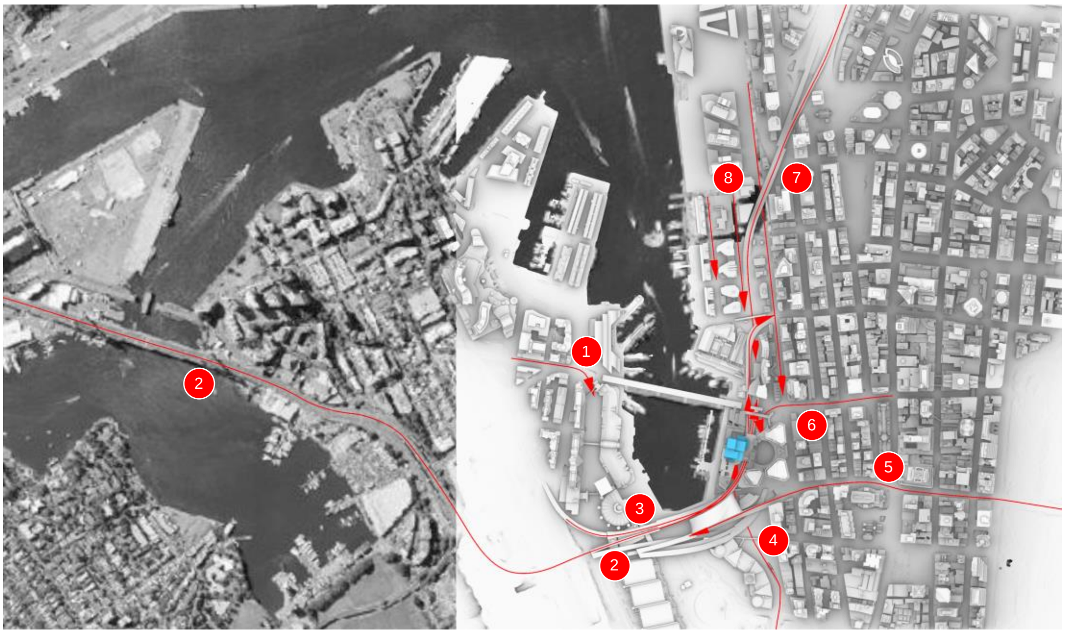

Figure 2: Map of assessed roads. Locations are taken into account at closely spaced intervals along indicated lines

4 Façade description

Tower

The building has a rectilinear floor plate with the elevations aligned close to cardinal directions.

The tower façade consists of curtain wall modules of which some are faceted. Spandrels at the edge of floor slabs are proposed to have 'shadow box' arrangements with cladding of glass that is the same as the vision glass.

There are three main types of façade panels:

- Flat glazed panels with horizontal and vertical shading blades
- Panels with diagonal split in the vision glazing, with the upper half tilted outwards
- Panels with a diagonal split, with the upper half as spandrel with solid non-specular reflective cladding

This design approach has two effects on the façade reflectivity:

- In addition to reflection from the main vertical plane of façade, the sun incident on one elevation is reflected into two other directions (from the tilted halves of one type of glazing panel, which may be pointed either left or right)
- The percentage of façade surface that reflects specularly into a single direction is reduced, both by the solid cladding triangles and the tilted glazing reflecting sunlight into a different direction

In addition, the tower façade features external horizontal and vertical shading elements and protrusions of the tilted elements shading adjacent panels. These would have a small reducing effect on reflections but have not been taken into account in the analysis.

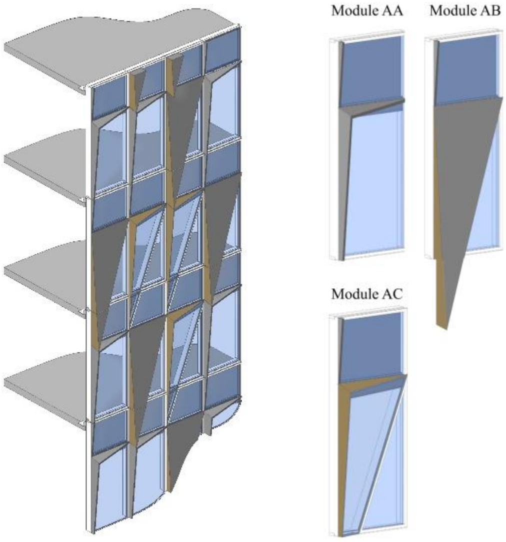

Figure 3: Tower facade with three main panel types

Podium

The podium is articulated in a series of volumes mostly visible from the west of the site, with solid wall towards the Western Distributor passing underneath the site, with a smaller group of buildings with wellness facilities oriented towards Darling Park on the east.

Facades consist of operable facades to retail tenancies mostly set back under overhangs behind external terraces, and fixed facades with glazing supported by expressed mullions and non-specular reflective solid cladding to opaque sections.

5 Methodology

5.1 Controls

This study responds to the Concept approval of Conditions of Consent C2 requiring a reflectivity analysis demonstrating that the external treatments, materials and finishes of the development do not cause adverse or excessive glare, and to the SEARS Requirements Item 7 requiring detail on the reflectivity level of façade materials.

An explicit limit for the reflectivity of glazing and finishes is not provided in the Conditions of Consent or the SEARS; the 20% limit found in the Sydney DCP 2012 and development controls from other Sydney Councils is assumed as a starting point maximum value for this assessment. The assessment seeks to establish whether this reflectivity level can be applied without causing glare, or whether it is required to restrict reflectivity levels further.

5.2 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. It has been specifically developed for the purpose of reviewing the potential glare impact of solar reflections from facades on traffic in detail, beyond a nominal facade material reflectivity limit.

The term “glare” describes adverse visual effects caused by large ratios of luminance in the visual field. Glare can generally be defined in two ways by its impact on observers (these may coincide):

- Discomfort glare – resulting in psychological annoyance, desire to avert view
- Disability glare –impacting the ability to recognise objects in the visual field and thus ability to carry out visual tasks (such as reading or driving)

It is critical that a driver’s view is unaffected by disability glare as this has the potential to cause road accidents, thus the Hassall methodology focuses on prediction of this aspect of glare.

It further singles out veiling glare as the predominant mode of glare that can occur from façade reflections towards traffic. Veiling glare is defined in this context as glare due 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. A prerequisite for veiling glare is thus that reflections of the sun are visible relatively close to the direction of view of an observer.

Veiling glare is a form of perceptive effect of glare; whether it leads to discomfort or disability glare depends on the intensity of the effect.

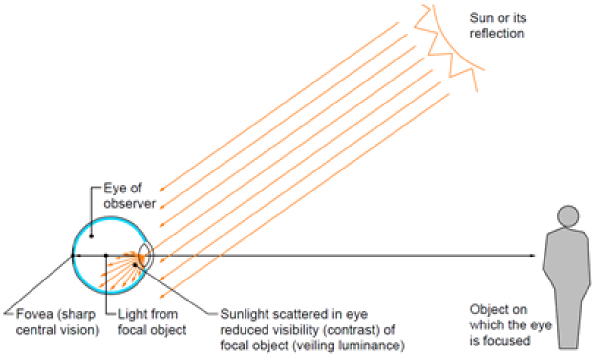

Figure 4: Bright sunlight falling into the eye reduces contrast and visibility of objects. This effect can be quantified by the equivalent veiling luminance measure.

Hassall proposes a workflow to track solar geometry, estimate sun intensity, establish actual façade reflectance, and numerically calculate a measure for the veiling effect. This measure, the equivalent veiling luminance, measured in cd/m² (candela per metre squared), is a representation of apparent brightness to the human eye corrected for the angular distance of the glare source from the focus of vision, which reduces the veiling effect.

The Hassall methodology further proposes a limit of acceptability of equivalent veiling luminance of façade reflections for traffic of **500 cd/m²**. Where this is exceeded, solar reflections are considered as potentially causing disability glare.

5.3 Workflow

Arup use in-house developed software to carry out the Hassall calculation based on 3D models, capable of checking for annual worst-case reflections anywhere off the façade towards locations along a stretch of road. We have applied this software to a simplified model of the glazed surfaces of the proposed development.

This involves several steps, as outlined below:

- The size, orientation and extent of reflective objects on each facade are determined by examination of drawings / 3D models 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. Within his methodology, Hassall discusses situations where an undesirable amount of

veiling glare is experienced but reflections fall outside the cone of sensitive vision and / or can be blocked by sun visor, hand or hat.

- On the multifaceted facades, the sun is only reflected by individual panels at a given time. Observed from a larger distance these do not reflect the full sun disk. In these cases, it is reasonable to assume that the intensity of reflections off a panel is proportionally diminished with the percentage of the sun disk solid angle that is reflected by the same panel.

5.4 Assumptions

- For the purposes of this assessment, all glazed facades are initially assumed to have a reflectivity of 20% (external specular reflectivity at normal incidence) as a maximum assumption based on typical council control limits in the Sydney region. Where glass reflectivity needs to be limited below this level in order to mitigate veiling glare, commentary is provided in the following sections.
- It is assumed that to carry out the visual tasks required for traffic participation, drivers and pedestrians face parallel to their direction of travel and view the road in front of them at 1° down relative to the plane of the road surface, as per view direction assumptions in AS4282:1997 5.4.2 which sets out similar considerations for the purposes of glare from night-time road lighting.

5.5 Modelling and Assessment Approach

This reflectivity study uses a digital 3D model of the proposed building and the surrounding context including buildings and topography. The model has been developed from the architectural 3D model and drawings. Relative road elevation information is taken from available context model 3D topography.

The model is used to interrogate the view of the building and solar reflections originating from it along the paths listed in Table 3.

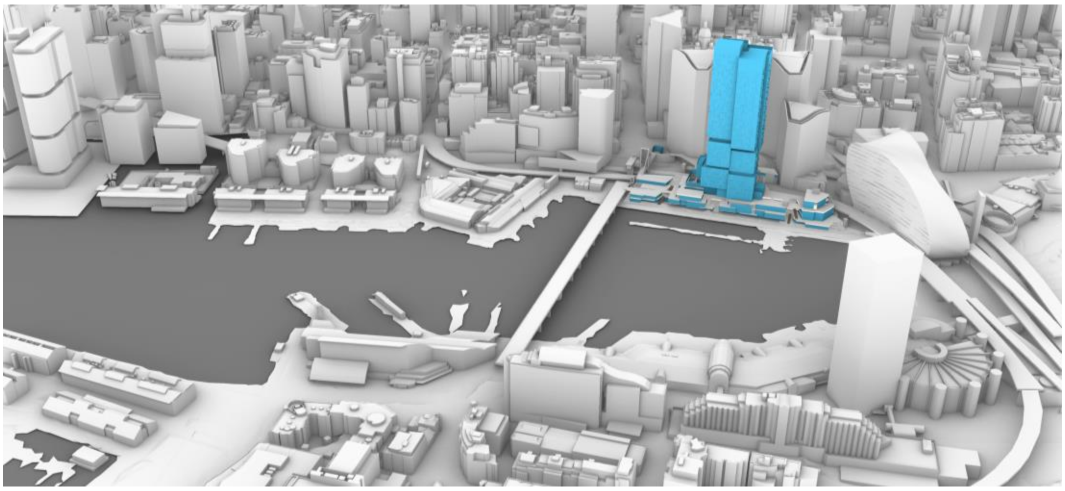

Figure 5: 3D model of proposed building and surrounding context

6 Assessment

6.1 Modelling results

The sections below will comment on the expected impact of reflected glare on traffic, for each observer path reviewed.

Where reflections from the development can exceed the limit of acceptability set out by Hassall (500 cd/m²), indicative perspective views are shown for a single viewpoint on these paths. Note however the modelled paths will be reviewed along their entire lengths.

The equivalent veiling luminance of reflections is colour coded in projected facades in perspective views. Façade areas are shown orange to red where reflections exceed the Hassall limit of 500cd/m² for prevention of disability glare. Reflections off projected façade area shown in blue to cyan are below this limit in intensity.

Calculations per the Hassall methodology are primarily aimed at road traffic but allow by extension reasoning about impact on pedestrians. See section 6.3 for further commentary.

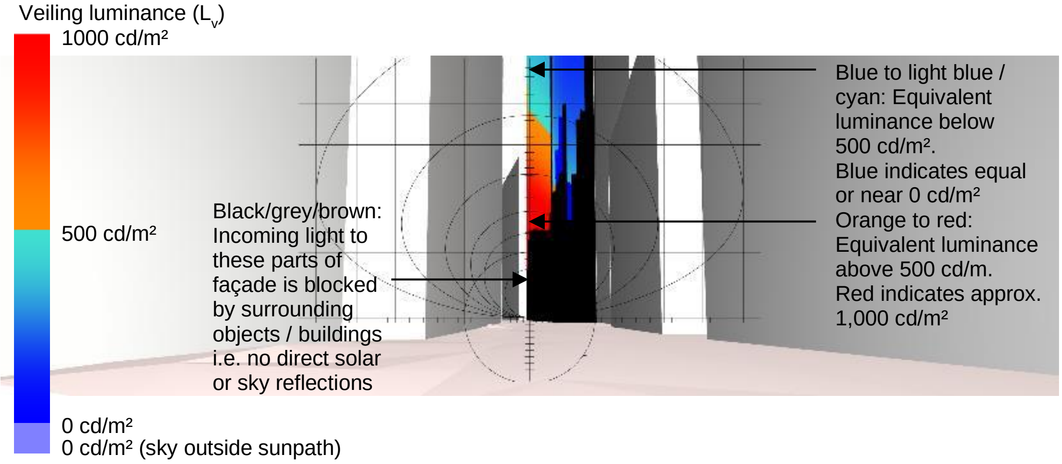

Figure 6: Key of colours indicating reflection intensity per Hassall calculation

6.1.1 Route 1 – Union St / Darling St heading east

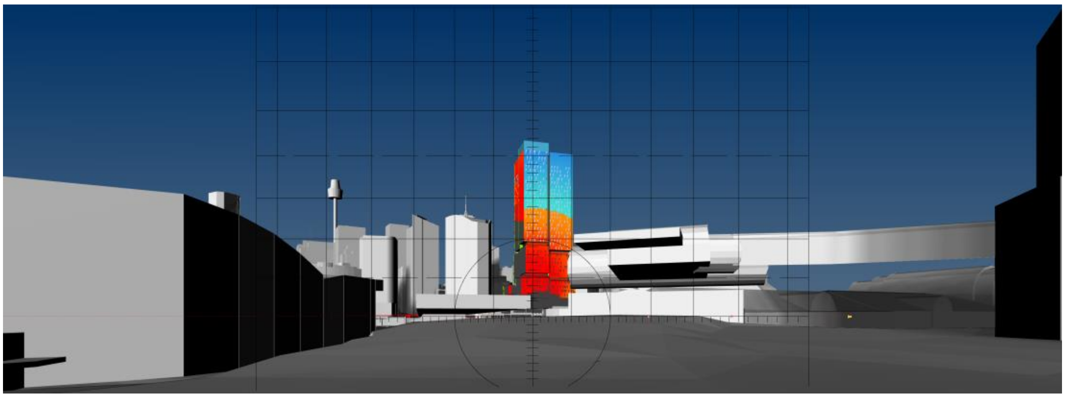

Figure 7: View from Union St / Darling St. Initial analysis assuming 20% reflectivity and full facade area reflecting

The west façades of the podium and tower are visible to drivers approaching from this direction and can reflect sun from the west during winter afternoons at the tower above Level 5.

Initial analysis carried out at 20% reflectivity and assuming fully reflecting flat façade had identified potential for solar reflections above the 500 cd/m² threshold (up to 1,620 cd/m² assuming 20% reflectivity of the glazing) occurring towards drivers on an approximately 20m length of road for the following approximate times:

- Up to 12 min per day between 5.35am and 6.20am in February/March and October

While reflections from the upper levels of the west façade occur above the 5° sun visor cut off angle per Hassall and can be controlled by drivers using the visor, reflections from levels 5-9 are visible below the 5° cut-off angle.

In order to reduce luminance of reflections to below the 500 cd/m² threshold, it is proposed that the nominal glass reflectivity of the tower west façade level 5-9 glazing is limited to <9.5% at normal incidence based on the current façade design.

In addition, the tower west façade has been designed to incorporate at least 37% tilted and non-reflecting elements by area between levels 5-9 which are visible below the 5° sun visor cut off angle. As the sun disk spreads out across several façade panels at this distance, part of the sun disk is not reflected towards drivers at the time that flat glazing reflects, and the resultant equivalent veiling luminance of the partial reflection can be considered proportionally reduced compared to the Hassall calculation value for the full sun disk reflection.

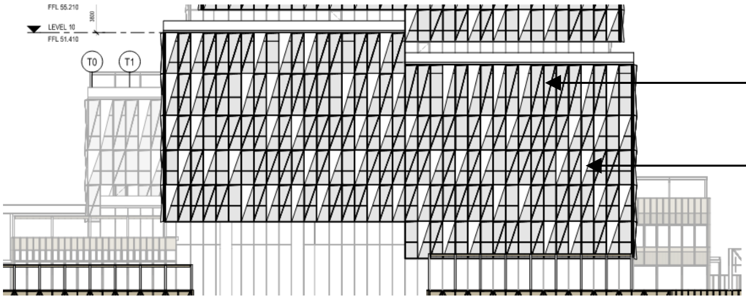

Figure 8: Partial west elevation

When considering the reduction of reflecting area in the proposed design of the tower façade and glazing reflectivity limit to 9.5%, the equivalent veiling luminance of sun reflections from the west façade remains below 495 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

Glancing angle reflections (<15° from façade surface) off the upper tower north facades can also occur during mid-season mornings, potentially exceeding the 500 cd/m² threshold (up to 1,600 cd/m² assuming 20% reflectivity of the glazing) for the following approximate times:

- Up to 8 min per day between 6.30am and 7.00am in February/March and October

However, from this viewing direction the excessive reflections on the north façade occur well above the 5° sun visor cut-off angle. Given that Union St / Darling St is not a high-speed road but within a 40km/h speed limit zone, it can be assumed based on Hassall (1991) 5.6 P5 that it is safe for drivers to adjust the sun visor to control glare from these reflections. Reflections would also be significantly reduced by the façade articulation and external shading elements.

With the mitigating effects of the façade articulation in the proposed design, reflections are thus not expected to result in unacceptable glare towards drivers in this location for west façade level 5-9 glazing reflectivity limited to **9.5%.**

An equivalent outcome may be developed with a higher percentage of tilted and solid panels, and glass with reflectivity up to 12%. This would need to demonstrate a similar veiling luminance outcome when developed.

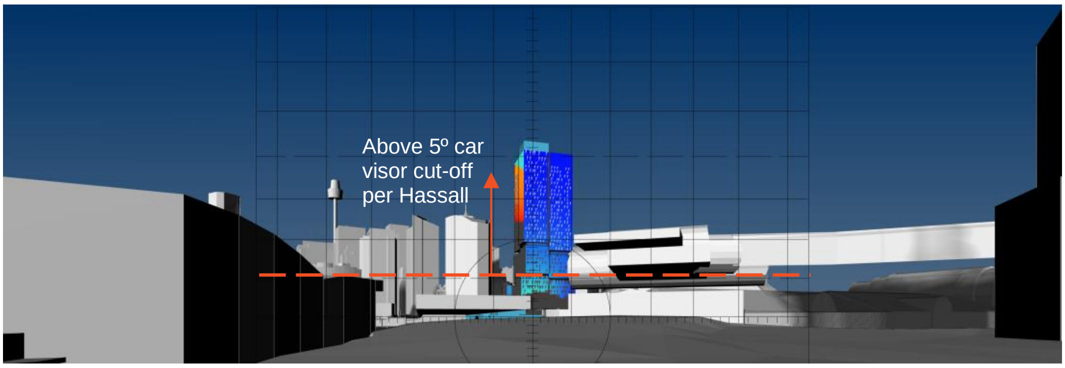

Figure 9: View from Union St / Darling St. Analysis for proposed design (assuming 9.5% reflectivity and factored for 63% facade area reflecting)

6.1.2 Route 2 – Western Distributor heading east / north

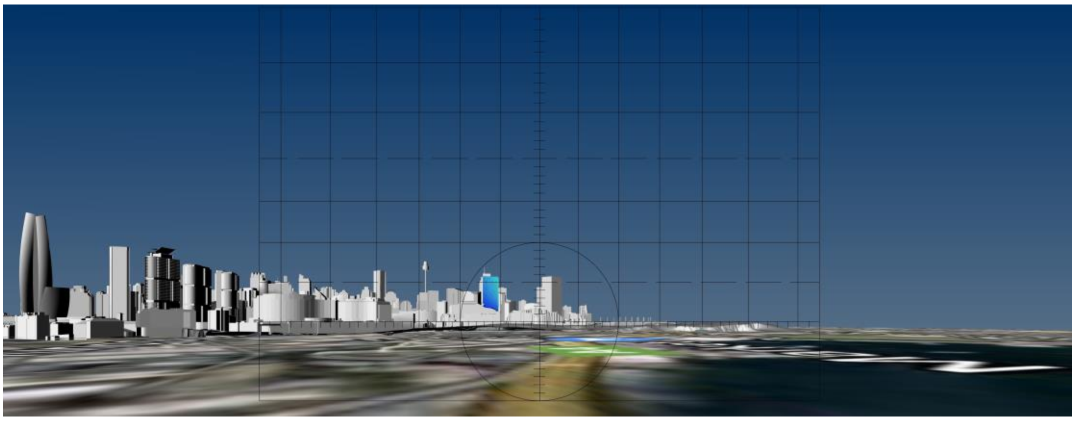

Figure 10: View from Anzac Bridge

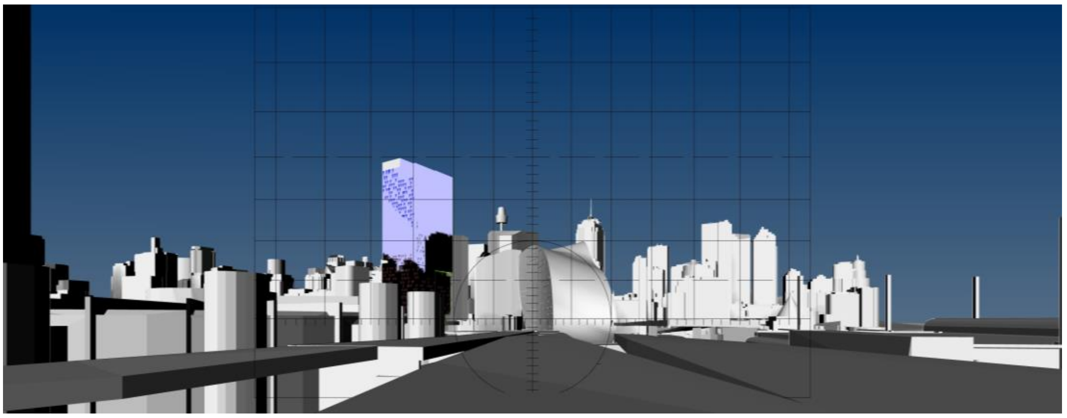

Figure 11: View from Western Distributor at Pyrmont, close to Darling Harbour

The west and south façades of the proposed tower are visible to drivers approaching from this direction, as well as podium facades once the Western Distributor passes the International Convention Centre close to the site.

The upper west tower facade can reflect sun towards Anzac Bridge at times during winter afternoons. However, the equivalent veiling luminance remains below 380 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

Tilted façade triangles on the upper west façade can reflect sun towards the section of the Western Distributor south of Darling Harbour at times during winter afternoons. However, the equivalent veiling luminance remains below 150 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

6.1.3 Route 3 – Pier St heading east

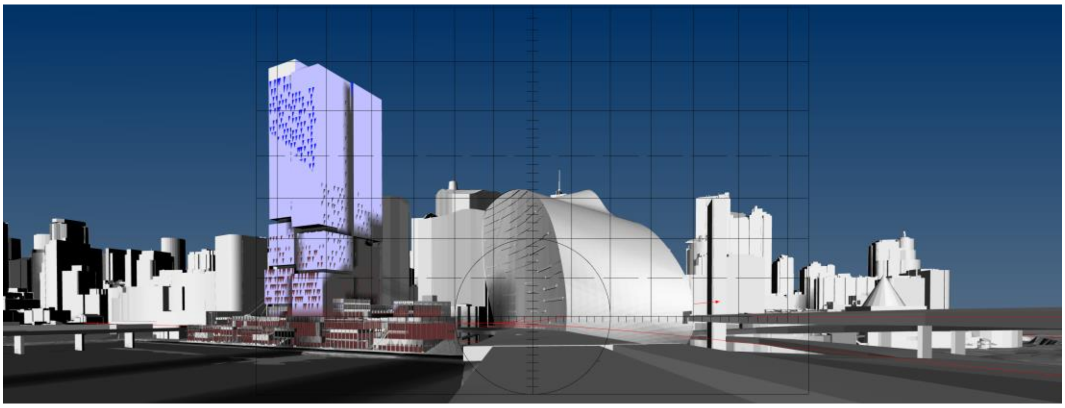

Figure 12: View from Pier St

The west and south façades of the proposed tower and west and south facing podium facades are visible to drivers approaching from this direction.

Tilted façade triangles on the upper west façade can reflect sun towards the section of the Western Distributor south of Darling Harbour at times during winter afternoons. However, the equivalent veiling luminance remains below 150 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

6.1.4 Route 4 – Harbour St / Wheat Rd heading north

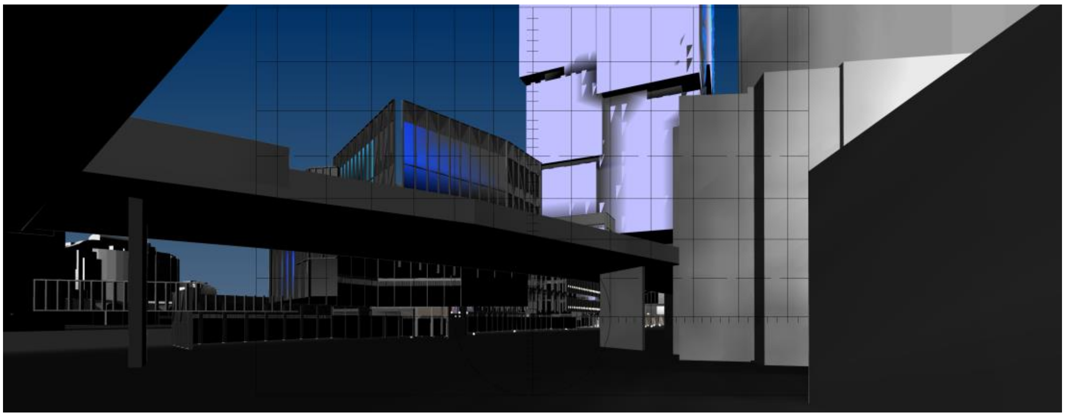

Figure 13: View from Harbour St

The south and east façades of the proposed tower and south west and south east podium facades are visible to drivers approaching from this direction.

The podium south west facades can reflect sun towards the section near the W Hotel building at times during mid-season afternoons, and the podium south east façade can reflect sun at times during mid-season mornings. However, the equivalent veiling luminance remains below 280 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

6.1.5 Route 5 – Park St / Druitt St heading west

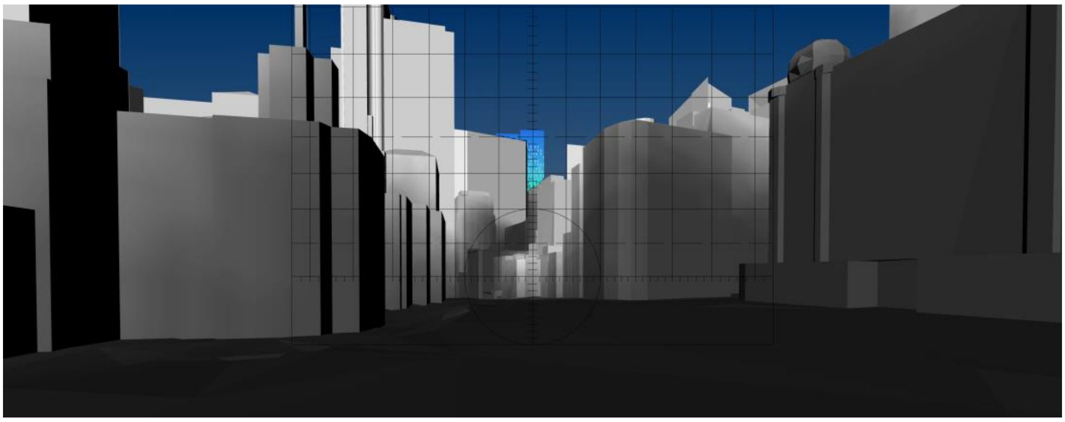

Figure 14: View from Park St leading into Druitt St

The east façades of the proposed tower are visible to drivers approaching from this direction and can at times reflect sun from the east during summer mornings. However, the equivalent veiling luminance remains below 480 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

For this reason, reflections are not expected to result in unacceptable glare towards drivers in this location.

6.1.6 Route 6 – Market St heading west

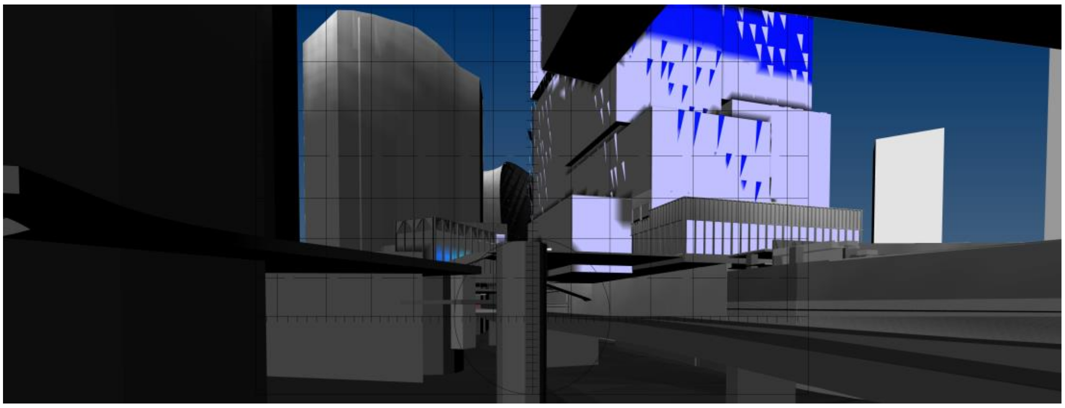

Figure 15: View from Market St

The north and west façades of the proposed building podium and tower become visible to drivers approaching from this direction as they turn onto the ramp towards the Western Distributor. The north facades of the upper tower, some tilted glazing on the tower north façade and part of the podium gym façade can at times reflect sun from the north west during winter afternoons. However, the equivalent veiling luminance remains below 270 cd/m², below the limit of acceptability set out by Hassall (500 cd/m²).

For this reason, reflections are not expected to result in unacceptable glare towards drivers in this location.

6.1.7 Route 7 – Western Distributor heading south

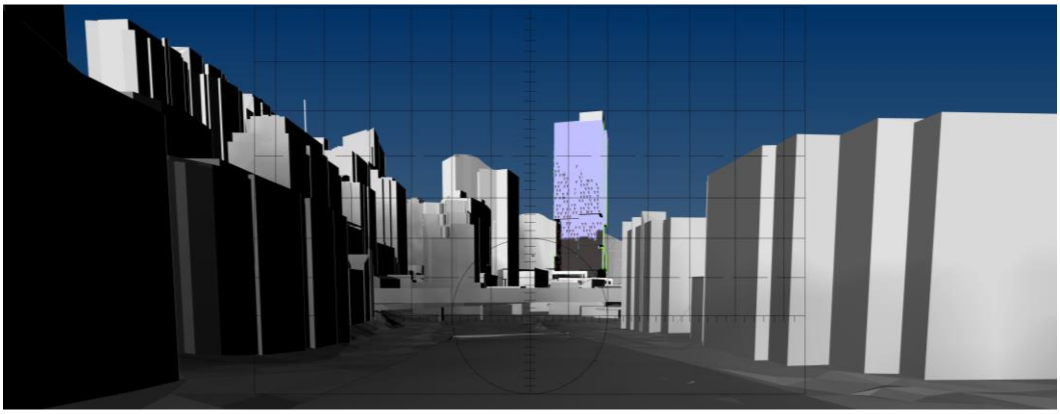

Figure 16: View from Western Distributor heading south

The proposed building facades do not reflect the sun towards drivers approaching from this direction.

6.1.8 Route 8 – Sussex St / Shelley St / Lime St heading south

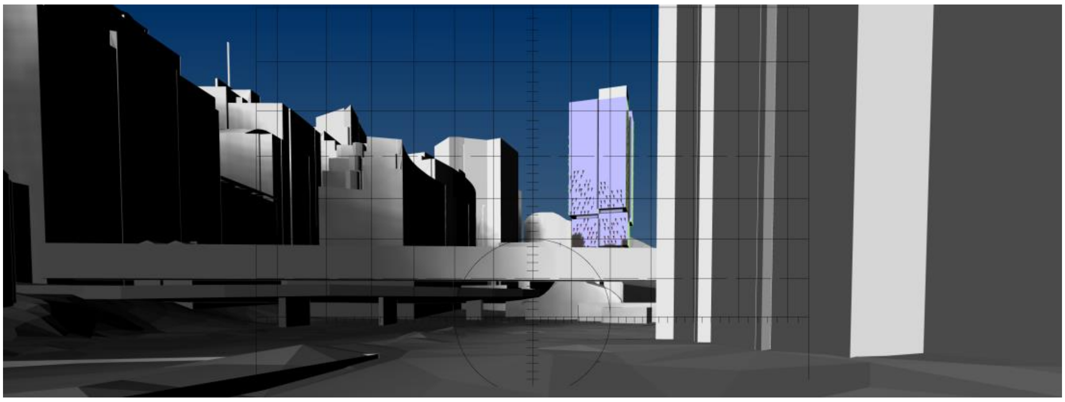

Figure 17: View from Sussex St

The proposed building facades do not reflect the sun towards drivers approaching from this direction in the noted streets.

6.2 Impact on Traffic in Other Locations

From further afield, it may be possible that other 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) would reduce the observable intensity of reflections, so that it is not expected to be high enough to create unacceptable glare.

6.3 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.

6.4 Impact on Surrounding Buildings

Solar reflections off the façade may reach surrounding buildings in the CBD area, as would be expected for any glazed façade in a dense urban context that can be reached by sunlight.

In general, reflections from façades with normal 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%, which will serve to reduce any potential glare reflections that may occasionally be produced towards pedestrians and other buildings.

7 Conclusion

The following table summarises the outcome of the reflectivity assessment for individual roads reviewed:

Ref.	Road	Dir.	Max Lv identified [cd/m²]	Note
1	Union St / Darling St	East	West façade: 495 (at 9.5%) North façade: 1,600	West façade reflections Within acceptable limit with faceted facade and limiting tower west façade glazing reflectivity to 9.5%. North façade reflections can be controlled using sun visor which is deemed acceptable by Hassall for comparable situations (Hassall, 1991).
2	Western Distributor	East / North	380	Within acceptable limit
3	Pier St	East	150	Within acceptable limit
4	Harbour St	North	280	Within acceptable limit
5	Park St / Druitt St	West	480	Within acceptable limit
6	Market St	West	270	Within acceptable limit
7	Western Distributor	South	0	No sun reflection
8	Sussex St / Shelley St / Lime St	South	0	No sun reflection

Reflected glare risk to traffic participants in all analysed locations could be discounted for all visible facades for either of the following reasons:

- The intensity of any reflections will be below the limit of acceptability set out by Hassall (500 cd/m²);
- Surrounding buildings and topology or other parts of the building itself will be blocking reflections that could cause glare to drivers; or
- The position of reflections within the visual field is not critical and would allow traffic participants blocking with sun visor.

These findings are valid, and Condition of Consent C2 hence satisfied by this report, as long as glazing reflectivity is kept within the following limits:

- **Tower west façade glazing levels 5-9: 9.5%**, with design configuration of solid spandrel and tilted glazing as per SSDA elevations. An equivalent outcome may be developed with a higher percentage of tilted and solid panels, and glass with reflectivity up to 12%; this would need to demonstrate a similar veiling luminance outcome when developed.
- **All other glazed facades: 20%**

These limits set upper bounds for reflectivity relevant to SSDA Requirement 7.

The result is obtained despite conservative assumptions about the extent of reflective facade glazing and does not take into account obscuring effects such as from smaller façade elements (small shading overhangs, joints, local plantroom louvres etc) and surrounding vegetation.

Appendix A

Reference Information

A1 Architectural Drawings

The reflectivity study presented in this report is based on the DA drawings A-DA1000 through A-DA2570 by Henning Larsen Architects and on 3D context model information from the architectural project model.

A2 Glossary and Abbreviations

Reference	Description
AS	Australian Standard
cd/m²	Candela per square meter (equivalent veiling luminance measure)
DA	Development Application

A3 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