# Table of Contents

**EXECUTIVE SUMMARY**

1 INTRODUCTION

1.1 Purpose

1.2 Wind and the urban microclimate

1.3 Local planning context

1.4 Information Sources

1.5 Revision history

2 METHODOLOGY

2.1 Local wind conditions

2.2 Comfort assessment criteria

2.3 Computational wind engineering

3 MICROCLIMATE ANALYSIS

3.1 Areas of focus

3.2 Winds from the north west (300° heading)

3.3 Winds from the south east (140° heading)

3.4 Winds from the west (270° heading)

3.5 Winds from the south west (230° heading)

4 RECOMMENDATIONS
EXECUTIVE SUMMARY

The Stage 1 DA submitted for the larger Macquarie Centre master plan stated the requirement for a wind microclimate assessment to be undertaken during the next phase of design and application, following the high level qualitative study undertaken by CPP. This analysis and report has been commissioned in response to that request, with reference to Condition 18 of the Concept Consent LDA2015/0655. The analysis and report has been updated further to assess conditions for the current architectural design.

At the early stages of design, getting building layout and massing correct is crucial to the success of providing a comfortable thermal environment for users of the development. If done incorrectly, wind flows through the streets can become limited, resulting in stagnant air pockets and excessive heat build-up, known as the urban heat island effect. Conversely, accelerating winds through streets and via down draft on taller buildings, equally, if not more unpleasant conditions can be created, and potentially define the success of particular areas in the public realm.

This study has been undertaken to assess the impact that the development is likely to have on the local wind microclimate, and the comfort of pedestrian and occupants using the public realm. Computational fluid dynamics, or CFD, has been used to simulate wind flows and estimate the likelihood of elevated wind speeds that can cause discomfort.

Prevailing winds come from the north west, however several other wind directions have also been assessed to provide confidence that adverse conditions can be minimised. The following features are recommended to be maintained as the design of the centre continues to develop to ensure comfortable conditions are experienced throughout the public realm and are considered acceptable for their intended use:

1. Incorporate trees and other landscape features throughout the Station Plaza
2. Maintain the awning along the Herring Road elevation
3. Use trees with evergreen foliage along Herring Road
4. Apply texture to facades to minimise downwash and wind acceleration

These measures have been incorporated into the design, and so it is likely that conditions will be comfortable for pedestrians and occupants for the majority of the year. The wind microclimate model is has been updated throughout the design process to ensure that adverse impacts are not introduced. Specifically, assessment of internal as well as external conditions has been assessed as the mall is naturally ventilated, with acceptable conditions likely to be achieved for the majority of the year.
1 INTRODUCTION

1.1 Purpose
This report has been prepared for AMP Capital to provide design advice on the impact to the local pedestrian wind environment and thermal comfort occurring as a result of the Macquarie Centre redevelopment, located in Macquarie Park, NSW. It is intended to provide information for consideration as part of the Development Application for the redevelopment of the Herring Road Podium and influence future design development.

1.2 Wind and the urban microclimate
With a focus on creating a comfortable urban realm and enhanced shopping experience, the redevelopment of Macquarie Centre needs to give consideration to the outdoor wind microclimate in relation to Sydney’s local conditions.

At the early stages of design, getting building layout and massing correct is crucial to the success of providing a comfortable thermal environment for users of the development. If done incorrectly, wind flows through the streets can become limited, resulting in stagnant air pockets and excessive heat build-up, known as the urban heat island effect. Conversely, accelerating winds through streets and via down-draft on taller buildings, equally, if not more unpleasant conditions can be created, and potentially define the success of particular areas in the public realm.

1.3 Local planning context
The Stage 1 DA submitted for the larger Macquarie Centre master plan stated the requirement for a wind microclimate assessment to be undertaken during the next phase of design and application, following the high level qualitative study undertaken by CPP. This analysis and report has been commissioned in response to that request, with reference to Condition 18 of the Concept Consent LDA2015/0655. The analysis and report has been updated further to assess conditions for the current architectural design.

1.4 Information Sources
The following information sources have been referenced in preparing this report:
- Architecture:
  - Various 3D models and renders from Hames Sharley and NH Architecture
- Bureau of Meteorology:
  - 6 year history of wind speed and wind direction recorded at half-hourly intervals at weather station located at Olympic Park (station reference number 066212) (August 2011 to October 2017);
- Google Maps and Streetview

1.5 Revision history

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date Issued</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draft</td>
<td>0.1 13 August 2018</td>
<td>Draft For Project Team Review</td>
</tr>
<tr>
<td>Final</td>
<td>1.0 16 November 2018</td>
<td>Updated images for DA Submission</td>
</tr>
<tr>
<td>Final</td>
<td>2.1 12 August 2020</td>
<td>Updated based on amended DA Submission</td>
</tr>
</tbody>
</table>
2 METHODOLOGY

2.1 Local wind conditions

To assess the likely impact that the new development will have on the existing site, historical wind observations from a local meteorological station have been analysed. Sydney Olympic Park lies approximately 5km to the south west, and has hourly wind speed, direction and air temperature observations since August 2011. It is acknowledged that the Stage 1 Concept DA report undertaken by CPP uses Bankstown wind data, which is slightly further away than the Olympic Park weather station, however there are unlikely to be significant differences in observations.

The impacts of wind tend to affect pedestrians in different ways, dependent on the season, or more realistically, by the temperature of the air. Higher speed winds are more likely to be tolerated in warmer conditions as they will provide a cooling effect, however during winter, cooler months, high speed winds can deter pedestrians from using outdoor spaces.

During daylight hours (assumed to be 7am – 9pm), predominant winds are from the north west, however there is also a frequent easterly occurrence based on historical data, as shown in Figure 1 below. Average wind speeds are around 3.4m/s at 10m above ground level.

During colder conditions (less than 15°C outdoor temperature), winds mostly come from the north west, and during warmer conditions (more than 30°C), winds come from both the east and the north west. Winds are generally stronger at warmer temperatures.

For this study, we are focussing on mitigating high speed winds around the redevelopment. When only the higher speed wind observations are selected in the historical data, winds are predominantly from the north west and south east, with Figure 2 showing the relative frequency of occurrence above 6m/s (measured at 10m above ground level). This further confirms that north westerly winds are likely to be the cause of excessive winds if any are shown to occur around the redeveloped corner of the mall.

Figure 1 - Frequency of winds for all temperatures, as well as during hotter and colder periods

Figure 2 - Wind direction frequency at higher wind speeds
2.2 Comfort assessment criteria

Extensive research has been conducted in the field of pedestrian comfort in external wind environments. This study uses the Lawson Comfort Criteria as a “standard” against which the wind simulation results have been compared. The Lawson Comfort Criteria have been developed over the last thirty years and are well established and used internationally. The Criteria reflect the fact that leisurely activities, such as sitting, require low wind speeds in order for the pedestrian undertaking the activity to be “comfortable”. However, for more transient activities such as walking, pedestrians can tolerate stronger wind conditions.

Table 1 shows the threshold of wind conditions for each of the stated pedestrian activities as proposed by Lawson for wind comfort. For each pedestrian activity, an upper threshold of wind speed is defined, beyond which conditions are considered unacceptable for the stated activity. Beneath the threshold the wind conditions are described as “tolerable” (or “suitable”) for the stated pedestrian activity. The threshold wind speeds assume conditions are not exceeded for more than 5% of the time, with wind speeds based on mean wind speeds, rather than gust wind speeds.

<table>
<thead>
<tr>
<th>Threshold mean wind speed (m/s)</th>
<th>Activity</th>
<th>Impacts at threshold speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Uncomfortable for pedestrians in the vicinity of entrance doors or sitting outside for long periods of time.</td>
<td>Wind felt on face; leaves rustle; wind vane moved by wind</td>
</tr>
<tr>
<td>6</td>
<td>Uncomfortable for pedestrians standing or sitting for shorter periods of time.</td>
<td>Leaves and small twigs in constant motion; light flags extended</td>
</tr>
<tr>
<td>8</td>
<td>Uncomfortable for pedestrians 'leisure walking' e.g. strolling and sightseeing.</td>
<td>Raises dust and loose paper; small branches moved</td>
</tr>
<tr>
<td>10</td>
<td>Uncomfortable for pedestrians walking quickly e.g. walking to a destination, and cycling.</td>
<td>Small trees in leaf begin to sway; crested wavelets form on inland water</td>
</tr>
</tbody>
</table>

2.3 Computational wind engineering

2.3.1 The process

There are two main methods by which wind flows around a development can be assessed:

1. physical wind tunnel testing, and
2. computational fluid dynamics, or CFD modelling.

CFD is a computer-aided engineering tool for the analysis of the complex physical phenomena of fluid flow and heat transfer. It provides an indication of airflow patterns, and in this application, is used to visualise likely wind flow patterns around the proposed development.

The analysis used here represents a snapshot in time for the wind conditions simulated. As such, the simulation is steady-state and does not capture transient effects such as gusting wind. The effect of air temperature on the flow (such as thermal storage effects) has not been modelled, and the “comfort” discussed in this report is related purely to air movement.

2.3.2 Software

This wind assessment study has been carried out by using the ANSYS Workbench v18.2 software package utilising the CFX simulation engine. CFX is a world-recognised CFD software code which offers the ability to analyse and assess the speed, temperature and indoor air quality (IAQ) behaviour in a given spatial domain.

2.3.3 Simulation model

A 3D CFD model of the proposed development was created from the architectural model using the Rhino CAD package. Figure 3 shows the geometrical model of the proposed development used for the CFD simulation, including the surrounding buildings. A number of simplifications were required in order to produce results in a reasonable time frame. Any impacts that are likely to be improved or worsened by the simplifications are noted in the corresponding analysis sections. The 3D model is then placed in a virtual wind tunnel to allow multiple wind conditions to be simulated.

Figure 3 - Geometrical model used in the CFD analysis

2.3.4 Boundary Conditions

The following boundary conditions are applied in the simulation:

- Wind direction: Four wind directions have been simulated depending on the frequency of occurrence and likelihood of creating elevated wind speeds in the public realm (Section 2.1) – degrees clockwise from true north (in order of frequency for all temperatures) 300° (just off north west), 140° (south east), 270° (west), and 230° (south west)
- Wind speed: 6.1m/s at 10m above ground level with a logarithmic profile (Section 2.1).
- Surface roughness: 0.3m as larger objects are included as physical obstructions.
- Turbulence model: A k-epsilon model has been used, and applied at all boundaries.

2.3.5 Limitations

This simulation analysis is based on a simplified range of environmental factors and a steady-state solution only. Actual environmental conditions will be dynamically and continuously varying, and the conditions simulated here represent only a potential snapshot of real conditions under a worst-case scenario. Variations of wind speed, direction and its subsequent effect in particular have not been considered and will further affect the local wind environment.
3 MICROCLIMATE ANALYSIS

This section summarises the analysis undertaken to assess the likelihood of discomfort occurring due to elevated wind speeds. As this study has been undertaken sufficiently early in the design stage, the master plan and built form is likely to be able to adapt and incorporate features that can sufficiently address any adverse conditions. These recommendations and architectural responses are provided in Section 4.

The following analysis is focussed on the likely winds speeds experienced around the entrances to Macquarie Centre to the west of the redevelopment on the north west façade along Herring Road, as well as the public realm area on the corner of Herring Road and Waterloo Road around the entrance to Macquarie University station. Wind speeds are compared with particular activities occurring in that region. Analysis presented in this section focuses on the public pedestrian realm at 1.75m above ground (assumed head height). The colours in the contour plots correspond to the associated activity categories in the Lawson Comfort Criteria, shown again below for reference. The order of discussion is based on frequency of occurrence.

<table>
<thead>
<tr>
<th>Threshold mean wind speed (m/s)</th>
<th>Activity</th>
<th>Impacts at threshold speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Uncomfortable for pedestrians in the vicinity of entrance doors or sitting outside for long periods of time.</td>
<td>Wind felt on face; leaves rustle; wind vane moved by wind</td>
</tr>
<tr>
<td>6</td>
<td>Uncomfortable for pedestrians standing or sitting for shorter periods of time.</td>
<td>Leaves and small twigs in constant motion; light flags extended</td>
</tr>
<tr>
<td>8</td>
<td>Uncomfortable for pedestrians ‘leisure walking’ e.g. strolling and sightseeing.</td>
<td>Raises dust and loose paper; small branches moved</td>
</tr>
<tr>
<td>10</td>
<td>Uncomfortable for pedestrians walking quickly e.g. walking to a destination, and cycling.</td>
<td>Small trees in leaf begin to sway; crested wavelets form on inland water</td>
</tr>
</tbody>
</table>

Table 2 - Lawson comfort criteria (coloured scale)

3.1 Areas of focus

The wind microclimate analysis will focus on a number of key areas around the redevelopment, particular where pedestrians are most likely to congregate:

1. Relocated bus shelters on Herring Road
2. Macquarie University train station south eastern entrance
3. Station Plaza
4. The Laneway
5. Herring Road Entry

A separate internal analysis has also been undertaken to consider internal environment conditions, with the architectural design refined to incorporate beneficial features. The internal environment is therefore not discussed further within this report.
3.2 Winds from the north west (300° heading)

Figure 5 shows likely wind speeds under a 95th percentile wind condition in plan view for north westerly winds. Coloured contours correspond to the activity category shown in Table 2. The majority of the public realm and surrounding areas are likely to be suitable for long periods of sitting or standing, with only a smaller number of regions experiencing wind speeds of up to 6m/s, which is suitable for shorter periods of sitting and standing.

Winds from the north west have the potential to result in the most uncomfortable conditions across all focus areas, however the CFD analysis indicates that wind speeds around the bus shelters and train station entry are likely to be deemed acceptable. Wind speeds in the Station Plaza and in the vicinity of the Laneway and Herring Road entries may be deemed uncomfortable for a small proportion of the year, however the use of trees as wind breaks will improve conditions. This has been incorporated into the landscape plan, therefore this occurrence is likely to be low risk.
3.3 Winds from the south east (140° heading)

Figure 8 shows likely wind speeds under a 95th percentile wind condition in plan view for south easterly winds. Coloured contours correspond to the activity category shown in Table 2. The conditions simulated show that wind speeds in all focus areas are likely to remain below 4m/s, suggesting that all areas are suitable for long periods of sitting or standing. No additional wind mitigation measures are therefore proposed given that the structure of the centre itself (Figure 9) is likely to produce sufficient shelter for all activities likely to be undertaken.

Figure 8 - Wind speed categories for winds from a 140° heading

Figure 9 – Building structure shelters the public realm from south easterly winds
3.4 Winds from the west (270° heading)

Figure 10 shows likely wind speeds under a 95th percentile wind condition in plan view for westerly winds. Coloured contours correspond to the activity category shown in Table 2. The majority of the public realm around the development is likely to be suitable for long periods of sitting or standing, with some small areas suitable for shorter periods of sitting and standing.

Winds from a westerly direction are likely to present the largest risk of discomfort at the station entrance, through the plaza, and along Herring Road. Based on the wind speeds simulated, the wind speeds in these areas are likely to be comfortable for their intended use, and will be further improved with the trees detailed in the landscape plans. Therefore, no additional wind mitigation measures are proposed.

3.5 Winds from the south west (230° heading)

Figure 11 shows likely wind speeds under a 95th percentile wind condition in plan view for south westerly winds. Coloured contours correspond to the activity category shown in Table 2. Whilst this wind direction does not occur often, it is mostly unobstructed and would likely have the most adverse impacts on the public realm. It can be seen in Figure 11 that the majority of the public realm between the station entrance and proposed extension has wind speeds below 4m/s, however there is likely to be a region that experiences winds of up to 6m/s as winds separate of the most western corner. This can be seen more clearly in Figure 12. In the current landscape plan, planting through the Station Plaza has been incorporated, which is recommended to be maintained to reduce the impacts of these winds. With the inclusion of this planting, conditions are likely to be deemed as acceptable for the intended use of the space external to the proposed development.

Figure 10 - Wind speed categories for winds from a 270° heading

Figure 11 - Wind speed categories for winds from a 230° heading

Figure 12 - South westerly winds separating off the western corner of the development
4 RECOMMENDATIONS

This report has presented the analysis undertaken to simulate winds around the proposed extension to Macquarie Centre. Based on the wind conditions assessed in this study, the majority of the public realm and pedestrian areas are likely to be for sitting and standing for short periods of time as a minimum. Initial analysis indicated that there was a risk that westerly winds may get sucked in to the centre through entrances on Herring Road, however the development of the design, including awnings and tree planting, is highly likely to ameliorate the issue.

The following features are recommended to be maintained as the design of the centre continues to develop to ensure comfortable conditions are experienced throughout the public realm and are considered acceptable for their intended use:

5. Incorporate trees and other landscape features throughout the Station Plaza (image top right)
6. Maintain the awning along the Herring Road elevation
7. Use trees with evergreen foliage along Herring Road (image below)
8. Apply texture to facades to minimise downwash and wind acceleration (image bottom right)

These measures have been incorporated into the design, and so it is likely that conditions will be comfortable for pedestrians and occupants for the majority of the year. The wind microclimate model has been updated throughout the design process to ensure that adverse impacts are not introduced. Specifically, assessment of internal as well as external conditions has been assessed as the mall is naturally ventilated, with acceptable conditions likely to be achieved for the majority of the year.

Figure 13 - Planting along Herring Road combined with an awning will provide shelter from uncomfortable conditions

Figure 14 - Landscaping and textured facades to dissipate infrequent high speed winds